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Explaining the lower usage rate of indigenous construction materials in Ghanaian public buildings using bounded rationality

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ABSTRACT

Judicious use of Indigenous Construction Materials (ICM) contributes to sustainability of a local construction industry. Why has the use of ICMs not contributed to the sustainability of the Ghanaian Construction Industry (GCI), and how can the use of ICMs engender the sustainability of GCI and that of similar developing countries? This paper uses bounded rationality and mixed-method strategy to explain the ICM usage rate in the GCI, and describes measures for improving the sustainability of the local construction industry through ICMs use. Relatively high ICM cost and non-availability of alternatives have been found as factors largely responsible for constrained ICMs usage. This paper is one of the first to draw on a synergy of the bounded rationality theory and empirical findings to give advanced insight into factors constraining the use of ICMs, as well as provide a measured usage rate of local building materials using real building projects cases. The research has carved a path for nurturing sustainable construction industry in developing countries through indigenous resources.

1. Introduction

Indigenous Construction Material (ICM) is known as a native or vernacular material sourced within a given locality for construction purposes [1]. According to Cunningham and Cunningham [2], ICM is any material that is locally produced and manufactured, naturally occurring, and abundant in a country. Thus, ICMs naturally occur and/or are produced locally within a given geographical area or country as opposed to Foreign Construction Materials (FCMs), which are imported. The world over, the use of ICMs tend to lead to more cost-effective and sustainable buildings [3]. It is also important to note that the ‘Agenda 21 for Sustainable Construction in Developing Countries’ (A21_SCDC) clearly advocates for the use of ICMs to achieve the larger goal of sustainable development within the sub-Saharan region and other developing countries [4]. Beyond A21_SCDC, studies relating to sustainable/green construction in developing countries have advanced [5]. To realize Sustainable Construction (SC), in developing countries, the use of ICMs plays key role. Salgin et al. [1] have buttressed this assertion by arguing that indigenous buildings/architecture/construction methods bear features that characterize present days’ green construction. Subsequently, Asman et al. [6] and Agyekum et al. [7] have emphasized that, ICMs form critical components of sustainable buildings, and drive the green building agenda. ICMs are used for production of building elements such as timber-framed structure, sun-dried brick walling/Adobe, and rammed earth or Atakpame walling, which form major input for producing sustainable buildings [7]. Hence, ICMs, which are naturally more abundant and accessible, should be promoted in any local construction industry to improve the ability of indigenes to afford built environment products in tropical African

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countries and other developing countries with similar economic conditions such as Ghana. Therefore, this research is undertaken to improve understanding of factors influencing choices of materials for buildings, drive the green building agenda, and promote cost-effective and sustainable buildings through the use of ICMs.

In this research, the indigenous location is Ghana. In Ghana, buildings are generally constructed with a mix of ICMs and FCMs. The indigenous materials that are mostly used for construction in Ghana are stone, sand and timber [7–9]. Other indigenous materials such as bamboo, thatch, laterite, and clay also exist for construction purposes [10,11] but are not widely used. FCMs mostly used in Ghana include steel, glass, plastic, porcelain, and copper. For some FCMs, there are no ICM substitutes and so the dependence on such FCMs is likely to continue in the Ghanaian Construction Industry (GCI). For other FCMs, there are locally available ICMs. However, there continues to be preference for such FCMs in Ghana [12]. One of the strengths of the GCI is that most of the indigenous materials suitable for construction purposes are in abundance [1,13]. Despite this reported ICMs abundance there is heavy dependence on FCMs for building [12,14]. Similarly, Jegede and Taki [15] have reported that there is low patronization of indigenous building materials in Nigeria. To achieve a sustainable local construction industry through sustainable construction practices, this research empirically determines the ICM-FCM usage mix in selected cases of buildings, and identifies measures for promoting the use of ICMs locally. Further, it is known that continued dependence on FCMs will not foster a sustainable local construction industry [16]. Meanwhile, there is lack of rich data to explain how the local construction industry can depend more on ICMs to ensure industry sustainability [17]. Therefore, the first objective of this research is to empirically ascertain the extent of usage of ICMs vis-à-vis FCMs in buildings. The second objective is to identify factors that account for the ICM-FCM usage mix in Ghana. The third objective is to explore how ICMs usage can be improved to sustain the local construction industry. Cases of public buildings have been used to determine the extent of usage of ICMs. The Bounded Rationality (BR) theory and BEPs perspectives have been integrated to explain the factors that account for ICM-FCM usage mix and how ICMs can be improved for sustenance of the local construction industry. The paper contains the following subsequent sections: previous research on ICMs use in Ghana; elucidations from the BR; the research methodology; data analysis, results and discussions; and conclusion, including the way forward.

2. Literature review

2.1. *Using ICMs for promotion of sustainable construction in Ghana*

ICMs are important for creating sustainable buildings [7] to ensure a sustainable local construction industry. Previous works done to promote SC in Ghana have not focussed on finding out how ICMs can be improved to sustain the GCI. For instance, Darko et al. [18] focussed on driving forces of green building technology adoption without incorporating ICMs. Subsequently, Darko and Chan [19], who looked at how green building technologies can be adopted in the GCI, did not clearly integrate ICMs, which is a significant component for driving the SC agenda and ensuring sustainable construction industry. Further, understanding the factors accounting for the current ICM-FCM usage mix in the GCI is necessary for understanding the factors that account for the low patronage of ICMs. However, the work of Ahmad et al. [17] reveals that there is lack of empirical studies, especially qualitative studies, in previous works, on the factors responsible for improving the use of ICMs for SC and sustainable local construction industry in Ghana. The few quantitative studies on ICMs in Ghana are unable to provide a deeper and clear understanding of the subject. The work of Chan and Adabre [20], which aimed at bridging the gap between sustainable housing and affordable housing, did not focus on explaining how ICMs can boost the achievement of a sustainable GCI. In contributing to the SC agenda, Sadick et al. [21] examined the relationship between building occupants' productivity and indoor environmental quality. Sumanasekara and Jayasinghe [22] had shown that ICMs are important for creating indoor environmental quality. However, the work of Sadick et al. [21] did not address the role that ICMs play in engendering indoor environmental quality, which is an important feature of SC. Obeng-Ahenkora and Danso's [23] work identified the lack of indigenous technology as one of the factors influencing pricing decisions of construction materials. However, their study did not focus on the factors that influence the pricing and choosing of ICMs as against FCMs in Ghana.

Few recent works such as Hatsu et al. [24] and Afriyie et al. [25] that have focused on indigenous materials usage in Ghana did not aim at engendering a sustainable GCI. A content analysis of green building studies reviewed by Debrah et al. [26] shows that most of the works done on green building adoption and financing focus on developed countries with little attention paid to promotion of the concept in developing countries such as Ghana. This observation is confirmed in a systematic literature review of critical success factors for promotion of green building by Chen et al. [27]. There is sufficient evidence in literature that little attention is paid to investigating the factors that account for the current ICM-FCM usage mix in buildings, and how ICMs can be improved. This shortcoming in previous research on ICMs and FCMs impedes the discourse relating to achieving SC in developing countries. Therefore, this research contributes to making good this identified dent in previous literature to accelerate achievement of the global sustainable development goals.

2.2. *ICMs used in Ghana*

Table I shows the ICMs available for use in Ghana and their literature sources. This is to bring specificity into the kind of ICMs that fall within the scope of this paper. Table 1 lists the building elements made up of the ICMs. The table also catalogues the alternate FCMs that produce the respective building elements.

The review in Table 1 reveals that, from previous research works, sand, stone, timber, bamboo, thatch, laterite, and clay are the indigenous materials useable for construction purposes. Therefore, in this paper, ICMs refer to these specific materials. Studies have

Table 1
Specific Indigenous Construction Materials and alternate Foreign Construction Materials used in the Ghanaian Construction Industry.

Common ICMs in Ghana	Building element output	Alternate FCMs	Previous work(s) done on ICM
Sand	➢Structural frame	o Steel	[28]
	➢Walling	o glass, steel	
	➢Finishes	o porcelain, plastic	
Rock	➢Structural frame	o Steel	[8]
	➢Walling	o Steel, glass	
	➢Finishes	o porcelain, plastic	
Timber	➢Structural frame	o steel, glass,	[7]
	➢Doors and windows	o aluminum, glass	
	➢Walling	o steel, glass	
	➢Roofing	o aluminum,	
	➢Finishes	o porcelain, plastic, aluminum	
Bamboo	➢Structural frame	o Steel	[10,29]
	➢Walling	o steel, glass	
Grass (thatch)	➢Roofing	o Aluminum	[7]
Laterite	➢Walling	o steel, glass	[13,30]
	➢Finishes	o porcelain, plastic	
Clay	➢Walling	o steel, glass	[11]
	➢Roofing	o aluminum	[7]
	➢Finishes	o porcelain, plastic	

shown that, Ghanaian slags are not suitable as clinker material for production of cement [31]. Thus, Ghana continues to rely on imported clinker for production of cement [32]. Therefore, in this paper, cement is not an ICM.

2.3. Elucidations from the bounded rationality theory

Simon [33] carved bounded Rationality (BR) theory as a new way of modelling decision-making in economics and political science fields. In the 21st century, BR has been applied in other non-economics disciplines such as: sports [34] and health [35]. However, studies and research work in the construction industry have benefited little from the BR discourse. BR theory has become very useful in explaining how economic beings make choices to meet a need. Therefore, the research leverages on this strength of BR to explain the factors that account for ICMs-FCMs usage mix in the GCI.

In the BR discourse, the argument of Simon [33] is that the economic man can be rational in part of their actions but remain not rational in other parts of their actions before arriving at a choice. Thus, such choices would not be the optimal. BR takes a position that is contrary to what pertains in the mainstream economics theory, where it is assumed that individuals/economic agents are rational and have the computational capacities for making all necessary evaluations to arrive at the optimum decision. In the eyes of BR, criteria for making decisions vary according to these constraints: the level of the information that has been searched and obtained so far [36]; the characteristics of the job to be performed [37]; the environmental features in which the decision maker finds themselves [38]; and the level of expertise of the decision maker, sometimes referred to as 'Naïve Allocation' [39]. In the context of this research, the expert is the BEP. From the position of BR, the decisions of BEPs, as economic agents, cannot be perfect.

In the complex situation of how to use ICMs judiciously to promote SC, coupled with BEPs' limited knowledge and experience in using ICMs, it becomes impossible to make an optimum decision, especially when faced with the presence of competing FCMs. This falls in line with Simon's [33] proposal that individuals do not maximize or optimize, instead they "satisfice." Here, the implication is that BEPs would focus on a criterion that is adequate for them to decide between ICMs and FCMs. Once an alternative fulfils that criterion, a choice is made without conducting a full evaluation and cost-benefit analysis of all the available options. This is the point where "satisficing" comes in Ref. [40]. In satisficing, the BEP would choose the option that is good enough and not necessarily the best option.

Discourse on BR suggests that in making decision, economic agents adopt heuristics rather than a strict rigid set of rules that will lead to optimized outcome [41]. The discourse further argues that such individuals apply heuristics because of the complex situation they face. The elements that make situations complex for the individuals and limits their rationality include cognitive limitation, information imperfection and time constraints [42]. Individuals apply heuristics to make quicker decision amidst inadequate information. Within the context of this study, an example of where a BEP's behaviour repressed by heuristics can be seen when contrasting a two design scenarios. The first is a simple situation involving employing the intellectual or professional ability (cognitive strategies) in designing multi-storey building with steel and glass (FCMs). The second is a difficult situation involving using professional ability for designing a multi-storey building using timber (an ICM). Both design scenarios, are finite scenarios with perfect information. Therefore, according to Bendor [43], they are equivalent. However, in the latter situation, which is more difficult or complex, Bendor [43] argues that mental capacities and abilities become binding constraints. Therefore, the individual BEP, who is a designer/engineer, would not be able to make optimal decisions to achieve SC. Thus, to understand the mental limits of the designer/engineer in such complex situations, this study aims at interrogating how Ghanaian BEPs work around their cognitive limits, and what behaviours or heuristics appear in the decision-making process to arrive at a good-enough decision. Fig. 1 summarizes the constructs of BR that form the foundation for empirical investigation in this research.

According to Agyekum et al. [7], Ghanaian BEPs view ICMs as important for SC. However, there continues to be reliance on

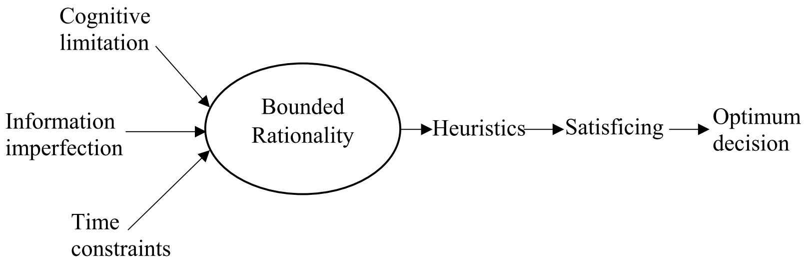

Fig. 1. Constructs of bounded rationality.

imported materials (FCMs) in the GCI [12,32]). Factors accounting for these unsustainable choices can be explained in the light of the BR theory. The BR posits that there are cognitive limitations that prevent individuals from making decisions that will lead to the optimal choice [44]. The cognitive system of BEPs that make the decision includes their previous knowledge or expertise they hold in the use of ICMs. Additionally, the theory of bounded rationality states that, with the availability of some amount of information, which may not be complete, humans can make good decisions, since it is almost impossible to analyze all available alternatives and perform all calculations, before making a choice [45]. This can theoretically explain why most BEPs would specify FCMs for public building projects in Ghana instead of increasing the usage level of ICMs to promote SC. Notwithstanding, empirical data is needed to find out the information or criterion that influences FCMs and ICMs choices in the GCI. This is important and falls in line with the discourse on BR, that, "human decisions should not be assumed *a priori* to follow logical, statistical or any other formal models; rather, they should be investigated empirically" [41]. Therefore, this research integrates Ghanaian BEPs and the BR perspectives to explain what influences the ICMs-FCMs usage mix in Ghana.

3. Research methodology

To effectively achieve the research objectives, theory and evidence-based information from humans were necessary. Thus, this research took the social constructivists' stance. The BR Theory is employed to complement empirical findings to explain factors responsible for ICMs and FCMs usage rates in buildings. Applying the theory in this manner necessitated the use of the abductive research approach [46]. Answering the research question required determination of the usage rate of ICMs in public buildings. Hence, as applied by Brunet et al. [47] in built environment research, there was performance of document analysis on bills of quantities (BQs) of three cases of common public building typologies. Using basic statistical descriptive analysis facilitated determination of the ICMs usage rates for the individual building typologies and the overall average usage rate. Further, there was the need to ascertain the extent of general knowledge of GCI practitioners on the factors that account for the ICM-FCM usage mix. This required conducting a survey on 104 practitioners using questionnaires. The respondents were sampled on the basis of purposive sampling method with the objective of obtaining data from built environment practitioners who have not less than five years of post-qualification working experience in designing and supervision of public building projects. Furthermore, to have deeper understanding of the constraining factors, and elicit measures for improving ICM use towards sustaining the local construction industry, the next stage of the research covered selection of experts through purposive sampling and snowball sampling [48] for the conduct of interviews. This led to semi-structured interviews of 60 BEPs who are designers and engineers with not less than 10 years of post-qualification working experience. Through this third stage of the research process, rich data were obtained from relatively more experienced BEPs. Therefore, the research applied the mixed method strategy (triangulating qualitative method over quantitative method) [49]. This strategy allowed for leveraging on the strengths of each method to achieve the research objectives. The thematic template analysis technique, as applied by Salvo et al. [50], was employed to analyze the qualitative data obtained from the interviews. Fig. 2 summarizes the research design.

4. Results and discussions

4.1. Usage rate of ICMs in public buildings

Results of the document analysis gave a picture of the extent to which public buildings in Ghana consume ICMs. The three building typologies used in the document analysis are 'residential', 'educational' and 'health'. The residential building is a three-storey staff flats block built in the northern part of Ghana. The educational building is a four-storey block of classrooms, laboratories, and offices for a secondary school in the mid-northern part of Ghana. The health building is a single two-storey accident and emergency centre in the south-eastern part of Ghana. Table 2 provides the various elemental costs, percentages and ICMs mix as specified for use in the three public buildings.

First step of the document analysis involved extracting the elemental costs from the Bills of Quantities (BQs) to determine the element that bears most heavily on the total construction cost of each building. The overall average elemental costs and percentages were then subsequently obtained. Further examination of the BQs led to identification of the specific building elements constructed with ICMs. In the document analysis results presented in Table 2, the digit '1' indicates the use of an ICM for the construction of the respective element under consideration. Insertion of the digit '0' indicates the non-usage of an ICM. The symbol ('n/a'), which means

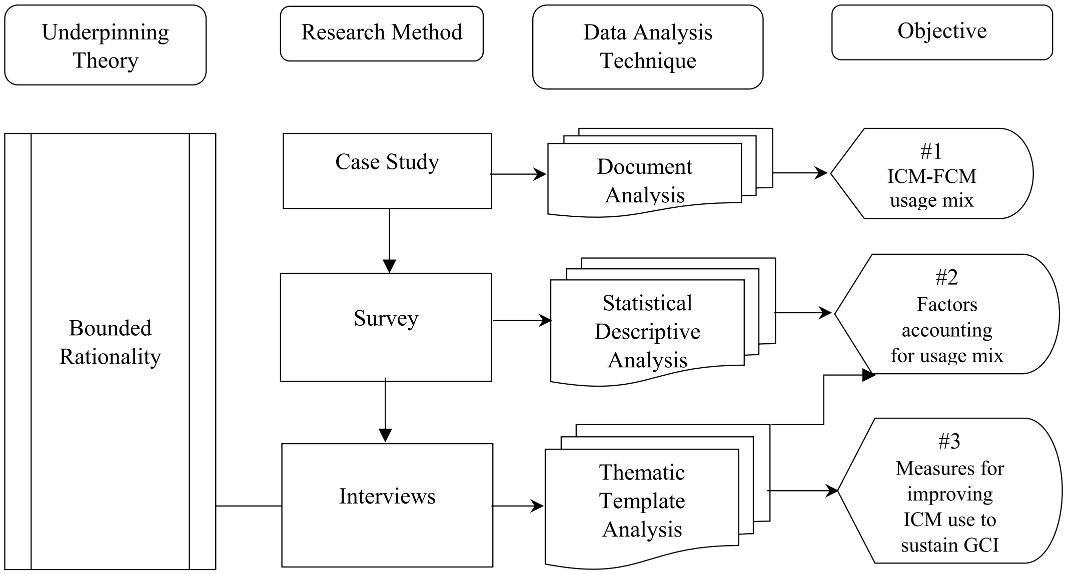

Fig. 2. Research design.

'not applicable', appears under the 'preliminaries & general items' and 'external works' building elements where it was not possible to extract the cost of ICMs. Hence, the 'preliminary & general items' and 'external works' elemental costs did not form part of the total construction costs used in determining the ICM usage rates for each of the building typologies. For the remaining elemental outputs, ICMs usage rates were determined by extracting them from the hundreds of BQ items.

The result of the document analysis of the three public building typologies has provided a framework for determining the usage rate of ICMs in a public building. This framework shows that, averagely, 14%, 30% and 12% of the total construction cost of buildings emanate from the 'structural frame', 'electrical, plumbing and mechanical installations', and 'finishes' building elements, respectively. These are the elements that bear heavily on the construction cost of the public buildings examined. The document analysis further revealed the ICMs usage rates for each of the building typologies as well as the overall average ICMs usage rate. It was found that 25%, 36% and 26% of construction cost of the residential, educational and health building typologies emanate from use of the ICMs. Thus, based on this framework, an average of 28% of the construction cost of public building is attributable to the use of ICMs. Invariably, this framework provides an ICM to FCM usage rate ratio of 3:7. However, the use of three cases of public buildings to determine the ICMs usage rate does not make the ratio generalizable but rather provides a replicable framework. Further, the ICM: FCM usage rate ratio derived assumes that the cost estimates provided in the BQs were not erroneous. It is worthy to note these limitations.

The ICM: FCM usage ratio resulting from the analysis indicates that, in public buildings, the usage rate of ICMs is relatively low. Although international standards do not specify the ICM: FCM ratios required for buildings in tropical African Countries such as Ghana, the ratio determined in this study compares to previous studies by Botchway and Masoperh [12] and Osabutey et al. [14], and Okpala [3]. In the study by Osabutey et al. [14], an interviewee made an anecdotal comment that foreign materials make up 67% of buildings in Ghana. Further, Okpala [3] also stated that, by value, over 70% of materials used for buildings in Nigeria are imported. These previous works were not based on specific empirical findings. However, this study has confirmed, through document analysis of three cases of public buildings, that, 72% of that value of buildings in a tropical country such as Ghana is made up of FCMs. Further observation of the ICMs usage trend in Table 2 shows that no ICM was used in the production of the 'electrical, plumbing, and mechanical installations' element, which is the highest cost centre among all the three building typologies studied. This is a trend that sets back the ability of GCI to be sustainable. Therefore, it became imperative to conduct further inquiries to unearth the factors that constrain the lower usage rate of ICMs and explain how ICMs usage rate can be improved to foster a more sustainable local industry.

The resulting ICM: FCM usage ratio is based on the specifications provided by BEPs. This is an empirical confirmation of statements made by Acheampong et al. [51] and Obeng-Ahenkora and Danso [23]. Most BEPs are of the view that ICMs will lead to a more sustainable construction industry [7]. However, the material specifications given by BEPs for the construction of public buildings indicate a contrary trend. It is essential to obtain empirical data to confirm whether this behaviour of the BEPs in Ghana emanate from the constraints related to professional inexperience, precedence, limited information, the market (client) demands constraints, or lack of indigenous technology. Hence, subsequent stages of this paper bring clarity to this choice behaviour in the light of BR.

4.2. ICMs usage and sustainable construction in Ghana

Before the interviews, a survey was conducted to obtain general awareness level of GCI practitioners of the characteristics of ICMs that make them useful for SC. Table 3 presents the results of the survey. Majority of the survey respondents were of the view that using ICMs for buildings will reduce Ghana's carbon footprint [7]. Ironically, while majority of the respondents were of the view that greater

Table 2
Framework for determining Indigenous Construction Materials usage rate in public buildings

				Bills of quantities element outputs												
				Preliminaries & general items	Substructure	Structural Frame	Walling	Roofing and roof structure	Doors, windows, fittings, and fixtures	Burglar proofing and Balustrade	Electrical and Mechanical Installations	Floor, wall, and ceiling finishes	Painting and Decorating	External Works	TOTAL	
		Overall average percentage		**3%**	**10%**	**14%**	**5%**	**6%**	**7%**	**4%**	**30%**	**12%**	**2%**	**6%**	**100%**	
Public Building Project Typologies	**Residential**	Elemental cost (Ghana Cedis)		100,000.00	222,841.70	423,150.20	100,990.00	109,412.00	186,168.00	334,371.40	866,462.88	299,689.00	102,008.00	300,000.00	3,045,093.18	
		Elemental Percentage		3%	7%	14%	3%	4%	6%	11%	28%	10%	3%	10%	100%	
		ICM usage	Rock	n/a	1	1	0	0	0	0	0	0	0	n/a	3%	**25%**
			Sand	n/a	1	1	1	0	0	0	0	1	0	n/a	11%	
			Timber	n/a	1	1	0	1	1	0	0	0	0	n/a	10%	
			Bamboo	n/a	0	0	0	0	0	0	0	0	0	n/a	0%	
			Thatch	n/a	0	0	0	0	0	0	0	0	0	n/a	0%	
			Laterite	n/a	1	0	0	0	0	0	0	0	0	n/a	1%	
			Clay	n/a	0	0	0	0	0	0	0	0	0	n/a	0%	
	Educational	Elemental cost (Ghana Cedis)		270,000.00	640,755.00	2,109,741.00	545,395.00	201,004.00	866,828.00	80,000.00	2,961,467.99	1,049,002.00	186,613.00	200,000.00	9,110,805.99	
		Elemental Percentage		3%	7%	23%	6%	2%	10%	1%	33%	12%	2%	2%	100%	
		ICM usage	Rock	n/a	1	1	0	0	0	0	0	0	0	n/a	5%	**34%**
			Sand	n/a	1	1	1	0	0	0	0	1	0	n/a	15%	
			Timber	n/a	1	1	0	1	1	0	0	0	0	n/a	13%	
			Bamboo	n/a	0	0	0	0	0	0	0	0	0	n/a	0%	
			Thatch	n/a	0	0	0	0	0	0	0	0	0	n/a	0%	
			Laterite	n/a	1	0	0	0	0	0	0	0	0	n/a	1%	
			Clay	n/a	0	0	0	0	0	0	0	0	0	n/a	0%	
	Health	Elemental cost (US Dollars)		12,105.78	51,267.98	21,189.27	16,596.80	35,657.54	20,920.94	–	98,497.20	46,566.85	4,765.76	24,592.91	332,161.03	
		Elemental Percentage		4%	15%	6%	5%	11%	6%	0%	30%	14%	1%	7%	100%	
		ICM usage	Rock	n/a	1	1	0	0	0	0	0	0	0	n/a	3%	**26%**
			Sand	n/a	1	1	1	0	0	0	0	1	0	n/a	13%	
			Timber	n/a	1	1	0	0	1	0	0	0	0	n/a	7%	
			Bamboo	n/a	0	0	0	0	0	0	0	0	0	n/a	0%	
			Thatch	n/a	0	0	0	0	0	0	0	0	0	n/a	0%	
			Laterite	n/a	1	0	1	0	0	0	0	0	0	n/a	3%	
			Clay	n/a	0	0	0	0	0	0	0	0	0	n/a	0%	
			Overall average of ICM usage rate =													**28%**

Table 3
Built Environment professionals views on Sustainable Construction characteristics of Indigenous Construction Materials

SC Characteristics of ICMs	BE Professional's view			
	Yes	No	Not Sure	Total
	(%)	(%)	(%)	(%)
Use of ICMs will reduce Ghana's future CO_2 emissions	87.5	8.7	3.8	100.0
Use of ICMs will result in reduced capital costs	78.9	11.5	9.6	100.0
Greater capital cost is a challenge to use of ICMs	86.5	9.6	3.9	100.0
ICMs use will reduce quality of buildings	31.7	60.6	7.7	100.0
There are government regulatory and policy drive to boom ICMs use	74.0	12.5	13.5	100.0
There are governmental incentive schemes to drive ICMs use	14.4	79.8	5.8	100.0
Building designers/engineers specify ICMs for SC	17.3	69.2	13.5	100.0
Sustainable Public Procurement requirements promote ICMs use	32.7	57.7	9.6	100.0
Government collaborates with local communities to promote ICMs sourcing and production	10.6	76.9	12.5	100.0
Average percentages	48.2	42.9	8.9	100.0

capital cost is a challenge associated with the use of ICMs, there was still a wider view that using ICMs will lead to reduced capital costs. This trend does not present a consistent view across majority of the respondents about the relation between ICMs cost and SC in general. This opinion inconsistency is attributable to the cognitive limitation of the BEP [43] and has the potential to affect BEPs ICM choices.

More than 75% of the respondents hold the view that there are no incentives from government, and that government does not collaborate with other bodies to promote the use of ICMs. This indicates inadequacy in the performance of government's role to boost the use of ICMs for SC [52,53]. Further, the survey results show that 69% of these 104 GCI practitioners are of the view that BEPs do not specify ICMs for use in public building projects. This confirms the document analysis results.

Obtaining the general knowledge of GCI practitioners about the relationship between SC and ICMs from the survey was not adequate to explain the factors accounting for the determined ICM: FCM usage mix as well as how ICMs can be improved for sustenance of the local industry. Moreover, traces of inconsistent views, coupled with about 9% of the survey respondents not being sure about the ICM questions presented, made the use of the mixed method, triangulating qualitative over the quantitative data, more imperative.

4.3. Explaining the limited use of ICMs in public buildings in Ghana

Through purposive and snowball sampling techniques, 60 BEPs with: not less than 10 years of working experience in the GCI; knowledge in ICMs and green building; and specific experience in designing and supervising public buildings construction, were interviewed. The purpose of the interviews was to obtain rich and deeper explanations on why there is more dependence on FCMs for constructing public buildings, The interviews also paved way for interrogating how ICMs usage can be improved to sustain the local construction industry. Using template analysis, an analytical technique that allows for coding the qualitative data through initial and final templates, the final template containing theory-driven codes, data-driven codes and emerging themes was obtained as shown in Table 4.

The theory-driven codes were predetermined based on review of the BR theory. This informed the interview questions. Subsequently, due to the use of semi-structured interview method, data-driven codes emerged from the analysis of the interview data. A combination of the theory-driven and data-driven codes led to the emergence of themes that formed the basis for explaining the limited use of ICMs. Representative interview extracts have been inserted into the final template in Table 4 to show the relations between the interview data, the codes, and the emerging themes.

The analysis revealed that no part of the interview data was found to have relation with one of the theory-driven codes – 'time-constraint'. Thus, from this study, the 'time-constraint' construct of the BR cannot be used to explain the limited use of ICMs. However, considerable portion of the interview data demonstrated connection with the BR constructs of 'cognitive limitation' and 'information imperfection' [42,43]. It was found from the interviews that there is inadequate information on the use of ICMs even among the BEPs. The call for sensitization (awareness creation), education, and training of public building project supervisors in the use of ICMs, was made by interviewees. This is important for bridging the information gap concerning ICMs use to achieve SC. If government, as the public building project client, adheres to the call for extensive ICMs awareness creation, then curing the information imperfection constraint will be triggered (*see interview extract BEP17*). The presence of cognitive limitation constraining BEPs' ICMs choices became evident in the interviews when an interviewee indicated that there is lack of skills in the country for adding value to ICMs for construction purposes (*see interview extract BEP44*). In buttressing this assertion, another BEP recommended for skills transfer from other countries where some of Ghana's indigenous materials have been improved for construction purposes (*see interview extract BEP43*).

Remaining portions of the interviews generated other themes that did not intersect with the BR. These themes are 'Cost and availability', 'Relative Standard and Quality', and 'Governmental regulatory and policy formulation role'. These themes are based on the data-driven codes. It was found that, sometimes, ICMs can be more costly than FCMs in Ghana due to prohibitive cost of Ghanaian utilities/services for production ICM end-products. There are also not enough manufacturers for the abundant naturally-occurring ICMs resulting in lack of economies of scale to produce related finished products such as clay bricks – (*see interview extract BEP60*). Thus, these ICM products do not become available in copious quantities on the market, where competitive FCM alternatives are present. Analysis of the interview data confirms the survey results that indicate that, government is not collaborating with other ICM

Table 4
Thematic template analysis of Indigenous Construction Materials use constraining factors

Theory-driven codes	Relevant interview extracts	Data-driven codes	Emerging Themes
Information imperfection	"*The concept of ICM, unfortunately is not even popular and therefore no effort is made to promote it*" – BEP01 "*The producers of ICM need to step up their games in promoting and demonstrate to the industry players to see the needs to use ICM in the Country*." – BEP16 "*Training on indigenous building materials awareness and building contractors' capacity would go a long way.*"- BEP17 "*It's as a result of inadequate knowledge in the use of local materials*" - BEP58	*ICM information education and training paucity * Inadequate ICM promotion by local producers *Low ICM awareness	Awareness creation and Information
Cognitive Limitation	"*There's need for education and transfer of knowledge in the use of local building materials in the country*" – BEP43 "*Lack of local skills in improving indigenous materials for construction*" – BEP44	*ICM expertise, knowledge, and skills shortage	Knowledge and skills
Time Constraints			
	"*The non-availability of the ICM in most areas of the country. E.g., pozzolana cement within the northern part of the country and burnt bricks production not established even in areas of high clay deposits.*" – BEP59 "*The reason is that those materials are not available at market, and even is there we can't get them at larger quantity*." – BEP08 "*Sometimes our ICM is more expensive than the imported materials*" – BEP48 "*The major factors limiting the use of ICMs in the local industry include Unreliable supply of services (i.e., Electricity, power etc.); High cost of locally produced due to high electricity cost and transportation; and lack of economies of scale/Economies of scale not working in favour of ICM* "– BEP60	*Scarcity of ICM finished products *Resource inadequacy	Cost and availability
	"*The durability of these indigenous building materials is being questioned and therefore no patronage for them.* – BEP50 "*Because there is a believe that foreign materials are better than local indigenous materials*" – BEP54 "*Because of the misconception that locally manufactured items do not last long*" – BEP53 "*Most of the ICM are yet to meet the required standard*." -BEP54	* Lower quality and standard perception *Lack of funding support to local producers *ICMs relative fragility	Relative Standard and Quality
	"*Ghana Government should therefore find ways of sensitizing the general public on the importance and use of these materials as a way of assuring quality and promoting the usage*." - BEP03 "*It's my opinion that the government should lead the* agenda *by mandating the use of ICMs in local government projects.*" – BEP29 "*There's lack of policy from government for the use of local building materials*" - BEP37 "*Model Local Government Service structures should be constructed with ICM this would build confidence in the citizens to use ICM*" – BEP39	*Inadequate governmental stakeholder Sensitization on ICM use *Absence of governmental policy, programmes, and incentives for ICM promotion	Governmental regulatory and policy formulation role

stakeholders, such as manufacturers/producers who use ICMs as production inputs, to promote patronization of ICMs in the local industry. This finding aligns with Botchway and Masoperh [12] and Frimpong et al. [54] regarding the low patronage of ICMs in the local industry. Interviewees were of the view that, governmental programmes and policies such as: embarking on green building programmes for selected government buildings and incentivizing manufacturers and contractors to produce and use ICMs respectively, will boost ICMs usage in Ghana. – (*see interview extracts BEP16, BEP29, BEP37, and BEP39*). Analysis of the interviews also revealed that there is a general perception that ICMs are of relatively low quality and standard. Referring to *interview extract BEP54*, the view about ICMs in Ghana is that they do not meet international standards thereby leading to limited specification by BEPs and low patronization among consumers. Inclusion of ICMs in building codes and International Standard Organization's (ISO) guidelines should therefore be exploited both local and international regulatory bodies.

The themes emerging from the thematic template analysis show where the BR intersects with empirical data to explain the limited use of ICMs. The emerging constraining factors that explain the limited use of ICMs in Ghana based on only empirical data relate to the thematic areas of 'cost and availability', 'standard and quality', and 'governmental regulatory and policy role'. The BR and BEPs' perspectives integrate in the emerging thematic areas of 'awareness creation and information' and 'Knowledge and skills (Cognitive ability)' to explain the ICM: FCM usage mix. This intersection of BR and the BEPs' perspectives is depicted in Fig. 3.

5. Conclusion

Indigenous materials useable for construction purposes in Ghana include stones, sand, timber, bamboo, thatch, laterite, and clay. These ICMs play significant role in promoting the SC agenda in developing countries and fostering a sustainable local construction

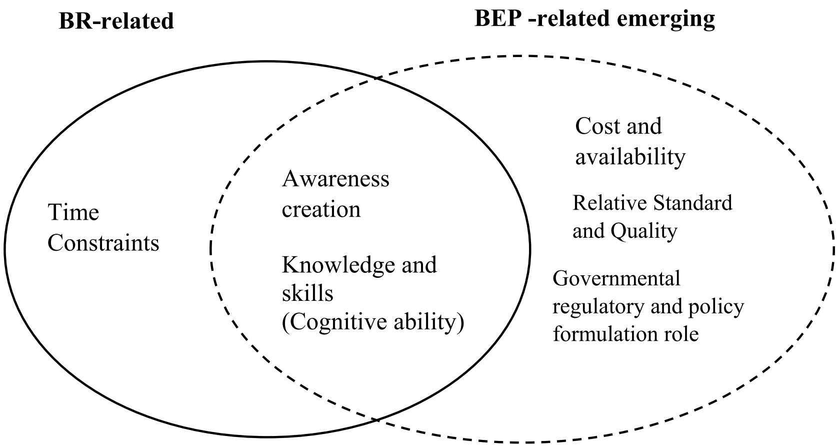

Fig. 3. Thematic integration of Bounded Rationality and Built Environment Professional's perspectives.

industry. However, through empirical observation in the case study of three public buildings, it has been determined that the ICM: FCM usage ratio is 3:7. This finding, though not generalizable, gives and empirical confirmation that there is low patronage of the ICMs locally. Further, this finding provides a framework for determining the material usage rate in buildings. The low patronage of ICMs confirms that there is a challenge militating against sustaining the GCI. The survey has confirmed that BEPs and government have crucial role to play in promoting ICMs usage in public building projects to sustain the local industry. However, it has been found that, although most BEPs believe depending more on FCMs will not promote a sustainable local industry, there is still lower ICMs usage rate in buildings supervised by these BEPs. The interviews conducted in the light of the BR theory have revealed that the BR's 'information imperfection' and 'cognitive limitations' partly explain the low specification rate of ICMs by BEPs. To cap the explanations provided by the BR, data-driven codes built from the interviews have shown that 'non-performance of the governmental regulatory and policy formulation role'; 'relatively higher ICMs cost and non-availability of ICM products on the market'; and 'perceived low standard and quality of ICMs' also constrain the specification and usage rate of ICMs. Thus, the BR and BEPs perspectives have been harnessed to explain the factors accounting for the ICM: FCM usage mix in Ghanaian public buildings. To cure this challenge that threatens the sustenance of the local construction industry, governmental policies and programmes should promote associations between local and international construction and manufacturing organizations, especially with organizations in developed countries that have advanced in producing materials locally. Such associations, which can be achieved through joint ventures and/or collaborations and professional training programmes, are avenues for curing the 'information imperfection' and 'cognitive limitations' of BEPs. Such professional relationships will capacitate the local construction and manufacturing industries to begin to produce construction materials locally towards building a sustainable local construction industry. This measure for capacitating the local construction industry is applicable in construction industries of tropical African developing countries with similar economic and social conditions as Ghana. In this manner, this paper contributes to achieving the goals of the Agenda 21 for sustainable construction in developing countries.

This research has employed the use of qualitative findings from mixed-methods, complemented by theory, to explain a phenomenon that has not been supported by empirical observation in previous research, to pursue SC in developing countries. This paper is one of the first to draw on a synergy of the bounded rationality theory and empirical findings to give advanced insight into factors constraining the use of ICMs, as well as provide a measured usage rate of local building materials using real building projects cases.

To be able to boost the use of ICMs for promotion of SC in developing countries, employing the benefits of 'economies of scale' in the production of the ICMs will facilitate circumvention of the 'relatively higher cost and non-availability' constraint. Governmental incentives will be needed to support local manufacturers to be able to produce the ICMs in massive quantities. Not only government, but local producers of ICMs need to also play crucial role in promoting ICMs patronization through sensitization programmes. This will contribute to diffusing the perception that ICMs are of lower quality and standards. Where this perception is real, it is recommended that government and local producers should embark on programmes that will enable transfer of relevant skills to workers and professionals in the local industry. This will lead to improvement and internationalization of the standard of ICMs in Ghana. Body (ies) that control the local construction industry should aim at having ICMs covered not only in local building codes but ISO guidelines to enable ICMs match FCMs' internationally accepted standards.

A limitation of this study appears in the use of Bills of Quantities of three cases of building projects, which constraints the generalization of the ICM: FCM usage mix ratio irrespective of the framework's replicability. Future work will be focussing on seeking the perception of BEPs, public and private construction projects clients, and contractors to measure the progress made by the local construction industry in using ICMs to foster a sustainable local industry. Also, larger quantities of BQs will be examined to expand the coverage of the framework for determining the ICM: FCM usage ratio.

Author contribution statement

Sarfo Mensah: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Samuel Laryea: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Data availability statement

The authors do not have permission to share data.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e17645.

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