Construction Approaches to Enhance Sustainability in Affordable Housing in Developing Countries

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Abstract— **The responsiveness of the construction industry to the preservation of natural resources for the benefits of future generation has been very poor in developing countries. This is unconnected to the demand for sustainable shelters to house the growing population and meeting the demand for supporting infrastructure to provide better living standards for the people. Building energy efficient houses does not only contribute to better living conditions, but also a better environment thereby culminating into creating sustainable communities. The existing literatures reveal the existence of much discussion about sustainable development, but this is not matched with much action. This paper aims to provide a new approach upon which housing development for low and middle income population in developing countries could be constructed to enhance sustainability. The study employs the use of quantitative methods for data gathering and construction professionals within South African construction industry were the research participants. The data were analysed using descriptive statistical techniques. The research highlights four construction methods and factors which affect the construction methods that enhance sustainability in housing. Eliminating material wastage and complexities in housing processes are the core factors which when achieved will reduce construction cost to a minimum, reduce negative impact of construction on the environment while maintaining high quality in the housing constructed.**

Keywords; Construction industry, enhance sustainability, housing development, human settlement, innovative technologies, lean construction, modular construction, sustainable housing

I. INTRODUCTION

One of the greatest challenges facing developing nations is the provision of infrastructure to enhance construction of sustainable shelters in line with the sustainable agenda of the United Nations (UN). Housing contributes significantly to the relationships between society and the environment. This is evident as its construction and operation consume large amounts of natural resources on the one hand and on the other, housing itself is exposed to a variety of environmental impacts [14]. It is the responsibility of government at all levels in a country to make available the much needed resources while the construction industry is saddled with the implementation of construction projects to enable the achievement of sustainable development. It is however to be noted that the tension between urban growth, poverty alleviation, affordable housing provision, access to quality shelters and environmental conditions can be mitigated through the adoption of appropriate construction approaches in housing development and programmes [14].

Reference [4] stressed that South Africa is experiencing immense pressure on landfill sites, due to high volume of waste generated during construction and demolition activities. The percentage wastes generated from these activities account for 10-20% of landfill space and recycling of this waste have not been given the attention it deserves [4]. Therefore, there is varied and significant political, social and environmental pressure to reduce green-house gas emission and waste generated in construction of low-income housing. It is on this not that, the South Africa housing sector embraced the use of alternative building materials such as; moladi panels, interlocking blocks and sand-bag as walling material for construction of affordable housing for the low income sector over the years. Affordable housing experts notably reference [5] noted that, these building materials have helped to provide housing at relatively cheap cost. Although, acceptable in terms of cost but occupation of buildings constructed with the alternative building materials have always been met with stiff resistance by the targeted users.

Sustainable housing is often believed to mean resource-saving buildings. This paper views ‘’sustainable housing as socially-enhancing and environmentally friendly residential practices integrated into the wider urban settlement system” [14]. It is against this backdrop that this paper aims to provide a new approach upon which housing development for the middle-income class in developing countries could be constructed under the tenet of sustainability learning from the South African affordable housing sector experience.

A. Housing challenges in South Africa

The challenges to provide sustainable affordable housing is prevalent in both developed and developing countries, the need for decent affordable housing is acute in developing nations and for South Africa it is no different. This trend is driven by rapid urbanisation due to rapid population

growth, rural–urban migration and for South Africa; the inequalities of the past. The United Nation (UNFPA, 2007:9) estimated that about 5 billion people in the world will be living in urban areas by the year 2030. This figure is very alarming and one critical decision that must be made is how the population will be housed. Human beings have strived to make habitat as comfortable as possible to enhance their social wellbeing and to ensure their mental and family development. Thus, it is important for a nation that intends to guarantee wholesome development and maximum productivity of the population to pay optimum attention to the housing needs of their citizens [10]. The housing challenge in South Africa is multi-dimensional; there is the challenge of poor quality delivery and delay in project completion in some cases. Reference [6] ascribes poor quality delivery and delay in project completion to a lack of capacity and expertise on the part of contractors.

South Africa has been very active in addressing housing issues, ranging from acute shortage of housing stock to low quality of many existing shelters in urban communities. Policy issues such as the 1994 white paper on housing, People Housing programme (PHP) and Breaking New Ground (BNG) Housing Programme, Upgrading of informal Settlement programme (UISP) among others were introduced as well as the installation of water and sanitation services and construction of basic shelters. These initiatives according to the National Department of Human Settlements (NDoHS) Reports have resulted in 1.6 million housing units and provided 500,000 families with secure titles from 1994 to 2004. By 2007 government spending on housing showed that 2.4 million houses had been constructed or sites were allocated While financial housing subsidies continue to be on the rise, actual houses delivered appears to be on the decline as at 2009. Notwithstanding the success of these laudable programmes, South Africa continues to face a substantial housing deficit with the backlog in housing provision estimated at 2.3 million [13, 15 & 12].

B. Sustainability in housing construction

Sustainable housing is housing designed, built and managed to promote economic development of occupants, environmental stewardship, quality of life and social equity and affordable to all spectrum of income, while still confronting the challenges of urbanisation, poverty eradication, lack of access to sustainable energy and economic uncertainty [14]. Housing provides an important means for addressing local and global environmental concerns in relation to public health, energy and water and material efficiency.

Construction processes often create massive environmental problems such as noise pollution, air and dust, harmful contamination through toxic waste and waste from construction and demolition activities. Extraction of raw materials often results in degradation of land and ecosystems, and deforestation. These often result in the destruction of economic activities in rural communities where natural resources are extracted for building materials. To achieve sustainability in construction process, [14] discourages the use of harmful building materials and finishes. The UN-Habitat policy documents further suggest that those construction technologies which are in harmony with local conditions, affordable and durable, reliable and functional for modern life are important for sustainable housing development. However, [5] study on the comparative analysis of innovative technologies, describes sustainable building as houses constructed with innovative technologies from a green and sustainability point of view, which could attract some additional cost over conventional buildings.

Reference [8] advocated re-engineering of construction processes to curb resource wastefulness during construction of buildings. Reference [14] suggests that low cost sustainable building methods be combined with modern methods to deliver affordable and durable homes. Though shifts from conventional to sustainable approach takes time, as it requires changes from different facets of the industry, it is however essential to identify the current practice in the industry and establish new courses to improve the practice, bearing in mind what the future priority should be.

II. Research Methods

This study was designed to assess the relative factors that influence construction professionals' choices of identified construction concepts. The perception of professionals in the building construction industry on the level of influence of the construction concepts on cost and sustainability of affordable housing were examined. Respondents for the study were drawn from the 3 largest provinces in South Africa (Gauteng, KwaZulu Natal and Western Cape), since affordable housing which is the focus of the study is constructed in all of these provinces as well as the entire country based on the template provided by South Africa National government. The 3 largest provinces were considered because most of the construction firms in South Africa operate in these provinces due to large volume of housing construction projects that are taking place in these provinces. The sampling frame consists of the General Building Contractors who are registered with the Construction Industry Development Board (cidb). The probability sampling technique was used in the selection of the sampled population for the study.

The proportional stratified random sampling technique was used to determine the survey sampled population from the entire population of registered General Building contractors. Table I shows the population of general Building contractors on the cidb register in the targeted provinces. To determine suitable representatives and ensure fair representation, a formula developed by Czaja and Blair cited in reference [1] was applied: $ss = z^2 \, x \, \frac{p(1-p)}{c^2}$

Where; ss = sample size, z = standardised variable, p = percentage picking a choice, expressed as a decimal, c = confidence interval, expressed as a decimal

The application of the sample size formula resulted in the surveyed sample population as shown in Table II.

TABLE I. POPULATION OF GENERAL BUILDING CONTRACTORS ON CIDB REGISTER

Province	cidb Grade							**Total**
	3	4	5	6	7	8	9	
Gauteng	153	202	163	209	118	59	32	936
KwaZulu Natal	170	217	142	142	56	17	0	744
Western Cape	38	73	38	51	31	12	10	253
TOTAL	**361**	**492**	**343**	**402**	**205**	**88**	**42**	**1933**

Source: cidb official website March 2015

TABLE II. POPULATION OF GENERAL BUILDING CONTRACTORS SURVEYED FOR THE STUD

Province	cidb Grade						**Total**	
	3	4	5	6	7	8	9	
Gauteng	7	10	8	10	6	3	2	46
KwaZulu Natal	8	10	7	7	3	1	0	36
Western Cape	2	4	2	2	1	1	1	13
TOTAL	**17**	**24**	**17**	**19**	**10**	**5**	**3**	**95**

A simple random sampling technique was used for the selection of general building contracting firms included in the survey from the entire population within the strata. A total of 95 respondents form the sample size for the study. Close ended quantitative questionnaire was sent to the research participant through an online mediated platform (survey monkey). The merits of online internet surveys are well documented in the literature by a host of authors notably [3 & 2]. A five point Likert scale was used to measure the perception of the study respondents on the identified construction concepts and their uniqueness in enhancing sustainability in affordable housing. It is worth stating that the response rate was quite impressive, a total of 38 responses were received out of which 33 responses were found suitable for analysis. In total, an approximately 40% response rate was recorded. Reference [9] and [11] considered survey responses within the range of 20% - 30% to be adequate for researches that involve the construction industry.

III. DATA ANALYSIS AND DISCUSSION

A. Data Analysis

Data collected through the questionnaires survey were analysed using descriptive statistics and mean scores. Four construction concepts namely; traditional construction method, concurrent engineering, modular construction and lean construction were identified and respondents were asked to rate the extent to which the construction concepts influence sustainable housing construction, using the factors listed as benchmark for rating. In addition, their perceptions on the significance of the concepts related to sustainable housing delivery were sought.

1) Extent to which ''Traditional construction" supports sustainability enhancement in building construction

Table III and Table IV present the summary of the descriptive analysis on the extent to which the ''traditional construction concept" influences sustainable housing construction. To put the results in perspective, the results in Table III shows the perception of the respondents as follows; 88% of the respondents viewed; simplicity of construction, minimise materials wastages, flexibility in construction and construction cost minimisation as important and extremely important, though ''simplicity of construction" had the highest mean score value of 4.30, thereby making this factor to be ranked 1st while material wastage minimisation, flexibility in construction and construction cost minimisation were ranked 2nd and ease of building adaptation was ranked 3rd. To accurately interpret the respondents' perception on these factors, their opinion on level of preference to usage of traditional construction method using the factors as a basis was sought.

The results in Table IV shows that approximately 52%, 49% and 46% of the respondents decidedly prefer the traditional method due to simplicity of construction, flexibility in construction and construction cost minimisation respectively. Respondents' perception on other factors reveals that the traditional construction method is somewhat preferred as evident from the results. The value placed on these factors is evident in the mean score value of 2.48, 2.45 and 2.39 ranking them 1st, 2nd and 3rd The results of the analysis of factors that influence the respondents' preference of the traditional construction method further corroborate the results of influence of traditional method on sustainability. It can however be inferred that, the ability of general building contractors to execute building projects with less complexities in-terms of construction machinery usage and perceived reduction in cost of construction, prompted the use of traditional construction methods despite their perception that the method appears not promoting construction materials waste reduction.

TABLE III. RESULTS OF PERCEIVED INFLUENCE OF TRADITIONAL CONSTRUCTION ON SUSTAINABILITY

Factors	**Rating scale**					**Mean score**	**Ranking**
	Extremely not important	**Not important**	**Indifferent**	**Important**	**Extremely important**		
Simplicity of construction	3%	0%	9.1%	39.4%	48.5%	4.3	1
Minimise materials wastage	0%	0%	12.1%	54.5%	33.3%	4.21	2

Contribute to depletion of natural environment	0%	3%	27.3%	54.5%	15.2%	3.81	4
Flexibility in construction	0%	0%	12.1%	54.5%	33.3%	4.21	2
Require more space for construction activities	0%	15.2%	15.2%	54.5%	15.2%	3.76	5
Minimise cost of construction	0%	0%	12.1%	54.5%	33.3%	4.21	2
Ease of adaptation	0%	3%	15.2%	45.5%	36.4%	4.15	3

TABLE IV. ANALYSIS ON FACTORS DETERMINING LEVEL OF REFERENCE FOR TRADITIONAL CONSTRUCTION

Factors	Level of preference			Mean score	Ranking
	Less preferred	Somewhat preferred	Highly preferred		
Simplicity of construction	3%	45.5%	51.5%	2.48	1
Minimise materials wastage	30.3%	27.3%	42.4%	2.12	6
Contribute to depletion of natural environment	15.2%	51.5%	33.3%	2.18	5
Flexibility in construction	3%	48.5%	48.5%	2.45	2
Require more space for construction	21.2%	57.6%	21.2%	2	7
Minimise cost of construction	6.1%	48.5%	45.5%	2.39	3
Ease of adaptation	12.1%	51.5%	36.4%	2.24	4

2) Extent to which ''Concurrent Engineering" supports Sustainability enhancement in building construction

Perceptions of General Building contractors in South Africa were sought on the use of concurrent engineering construction methods for housing projects. Table V presents the summary of descriptive statistical analysis on the extent to which the "concurrent engineering" influences sustainable housing construction.

The results in Table V shows that approximately 94% of the respondents (with a mean score value of 4.48) ranked reduction in cost of construction as the most important factor for using concurrent engineering methods in construction of affordable housing.

TABLE V. SA GENERAL BUILDING CONTRACTORS' PERCEPTION OF CONCURRENT ENGINEERING CONSTRUCTION METHOD ON SUSTAINABILITY IN HOUSING DELIVERY

Factors	Rating scale					Mean score	Ranking
	Extremely not important	Not important	Indifferent	Important	Extremely important		
Promote integration of two or more construction methods	3%	3%	15.2%	33.3%	45.5%	4.15	3
Eliminate materials wastages	3%	3%	6%	48.5%	39.4%	4.18	2
Enhance construction speed	6.1%	0%	6.1%	57.6%	30.3%	4.06	5
Flexibility in construction	3%	3%	9.1%	69.7%	15.2%	3.90	6
Increase quality	0%	0%	21.2%	45.5%	33.3%	4.12	4
Minimise use of space for construction	3%	3%	24.2%	45.5%	24.2%	3.84	7
Minimise construction expenses	3%	0%	3%	33.3%	60.6%	4.48	1

Similarly, 88% of the respondents perceived elimination of materials wastages as the 2nd most important factor, having a mean score of 4.18 and integration of two or more construction method was ranked 3rd based on the results of analysis; 79% of respondents rate the variable as important with mean score of 4.15. Other factors were perceived by over 50% of the respondents as equally important in chosen concurrent engineering for housing projects. The results in Table VI shows that approximately 73% of respondents prefer using concurrent engineering as housing construction method due to the high level affinity of the method to eliminate materials wastage during construction (mean score of 2.66). This factor was ranked 1st and 61% and 58% of the respondents prefer concurrent engineering due to integration of two or more construction methods into the construction process and construction cost minimisation respectively. These two factors have the same mean score value of 2.54 hence they were both ranked 2nd while ''increase in quality" of housing product ranked 3rd with a mean score of 2.51.

It is worth noting that the results of the analysis have clearly shown that ensuring sustainability in the housing construction process is greatly enhanced through the use of concurrent engineering as method of construction which is evident from its ability to minimise cost, eliminate material wastage and the integration of two or more construction methods among other factors that were rated to have strong influence as shown in Table V and Table VI.

TABLE VI. ANALYSIS ON FACTORS DETERMINING LEVEL OF REFERENCE FOR CONCURRENT ENGINEERING

Factors	Level of preference			Mean score	Ranking
	Less preferred	Somewhat preferred	Highly preferred		
Promote integration of two or more construction methods	6.1%	33.3%	60.6%	2.54	2
Eliminate materials wastages	6.1%	21.2%	72.7%	2.66	1
Enhance construction speed	3%	45.5%	51.5%	2.48	4
Flexibility in construction	3%	63.6%	33.3%	2.30	5
Increase quality	0%	48.5%	51.5%	2.51	3
Minimise use of space for construction	15.2%	45.5%	39.4%	2.24	6
Minimise construction expenses	3%	39.4%	57.6%	2.54	2

3) Extent to which ''Modular Construction" supports sustainability enhancement in building construction

Perceptions of General Building contractors in South Africa were sought on the use of Modular construction methods for housing projects. Table VII presents a summary of the descriptive statistical analysis on the extent to which 'Modular construction" influences sustainable housing construction. The results in Table VII show that approximately 94% of the respondents with a mean score value of 4.60 rated reductions in duration for construction as the most important factors upon which modular construction is used for affordable housing construction. Conversely, 88% of the respondents perceived elimination of material wastages as the 2nd most important factor, having a mean score of 4.45 and minimizing construction cost was ranked 3rd based on the results of analysis which shows an overwhelming support by 94% of respondents and a mean score of 4.39.

Other factors were perceived by over 50% of the respondents as important in chosen modular construction for housing projects, though approximately 15% - 30% of respondents choose ''indifferent" option. The results in Table VIII show that approximately 76% of respondents prefer to use modular construction method due to high level attraction to reduce production period, eliminate materials wastage during construction, reduction in cost of construction and prevention of pollution. These factors thus have mean score of 2.72, 2.57 and 2.54 respectively; hence the factors were ranked 1st, 2nd and 3rd. Conclusively, the results of analysis have clearly shown that ensuring sustainability in housing construction process is somewhat enhanced through the use of modular construction methods, as evident from its ability to eliminate material wastage, faster production rates and reduction in the use of non-renewable materials among other factors shown in Table VII and Table VIII.

TABLE VII. SA GENERAL BUILDING CONTRACTOR'S PERCEPTION OF MODULAR CONSTRUCTION ON SUSTAINABILITY IN HOUSING DELIVERY

Factors	Rating scale					Mean score	Ranking
	Extremely not important	Not important	Indifferent	Important	Extremely important		
Rigidity in construction	3%	3%	27.3%	24.2%	42.4%	4	7
Avoid materials wastages	0%	3.0%	9.1%	27.3%	60.6%	4.45	2
Reduce use of non-renewable materials	0%	0%	12.1%	54.5%	33.3%	4.21	4
Optimise building design	0%	3%	9.1%	57.6%	30.3%	4.15	5
Minimise use of space during	0%	9.1%	27.3%	48.5%	15.2%	3.69	9
Minimise cost of construction	0%	0%	6.1%	48.5%	45.5%	4.39	3
Improve quality of output	0%	0%	18.2%	54.5%	27.3%	4.09	6
Prevent pollution	0%	0%	27.3%	45.5%	27.3%	4	8
Reduce construction time	0%	0%	6.1%	27.3%	66.7%	4.60	1

TABLE VIII: ANALYSIS ON FACTORS DETERMINING LEVEL OF REFERENCE FOR MODULAR CONSTRUCTION

Factors	Level of preference			Mean score	Ranldng
	Less preferred	Somewhat preferred	Highly preferred		
Rigidity in construction	15.2%	24.2%	60.6%	2.45	4
Avoid materials wastages	9.1%	24.2%	66.7%	2.57	2
Reduce use of non-renewable materials	9.1%	51.5%	39.4%	2.30	7

Optimise building design	3%	48.5%	48.5%	2.45	5
Minimise use of space during construction	9.1%	60.6%	30.3%	2.21	8
Minimise cost of construction	9.1%	27.3%	63.6%	2.54	3
Improve quality of output	9.1%	42.4%	48.5%	2.39	6
Prevent pollution	9.1%	27.3%	63.6%	2.54	3
Reduce construction time	3%	21.2%	75.8%	2.72	1

4) Extent to which "Lean concept" support sustainability enhancement in building construction

Table IX and Table X present a summary of the descriptive analysis on the extent to which the "Lean construction concept" influences sustainable housing construction. The results in Table IX show the perception of the respondents as follows; 100%, 97% and 94% of the respondents viewed; elimination of materials wastages, construction cost minimisation and minimise negative impact of construction on the environment as important and extremely important. These factor have mean score value of 4.54, 4.51 and 4.45 respectively, thereby ranking them 1st, 2nd and 3rd. However, to ensure correct judgement on the perception of the respondents on these factors, opinion on the level of preference to usage of lean construction concepts using the factors as a basis was determined and the results in Table X shows that approximately 82%, 76% and 67% of the respondents highly prefer lean construction concept due to the elimination of materials wastages, construction cost minimisation and minimise negative impact of construction on the environment respectively.

Respondents' perception on other factors reveals that lean concept is somewhat preferred as evident in the results. The value placed on these factors is evident from the mean score values of 2.78, 2.75 and 2.6. Thus the variables were ranked 1st, 2nd and 3rd among the factors that influenced respondents' choice of lean construction concept for housing projects.

The results of the analysis of factors that influence respondents' preference of lean construction concept further confirms that lean concepts have a great influence on construction of sustainable housing development.

TABLE IX: FACTORS THAT INFLUENCE GENERAL BUILDING CONTRACTOR ON CHOICE OF LEAN CONSTRUCTION CONCEPT FOR HOUSING PROJECT

Factors	Rating scale					Mean score	Ranking
	Extremely not important	Not important	Indifferent	Important	Extremely important		
Minimise negative impact on the environment	0%	0%	6.1%	42.4%	51.5%	4.45	3
Avoid materials wastages	0%	0%	0%	45.5%	54.5%	4.54	1
Improve quality of output	0%	0%	9.1%	51.5%	39.4%	4.30	4
Enhance flexibility in construction	0%	3%	9.1%	42.4%	45.5%	4.30	5
Minimise use of space during construction	0%	9.1%	12.1%	51.5%	27.3%	3.96	7
Minimise cost of construction	0%	0%	3%	42.4%	54.5%	4.51	2
Ease of adaptation	0%	0%	18.2%	54.5%	27.3%	4.09	6

TABLE X: ANALYSIS OF PREFERENCE ON THE FACTORS TOWARDS USE OF LEAN CONCEPT

Factors	Level of preference			Mean score	Ranldng
	Less preferred	Somewhat preferred	Highly preferred		
Minimise negative impact on the environment	3%	30.3 %	66.7%	2.63	3
Avoid materials wastages	3%	15.2 %	81.8%	2.78	1
Improve quality of output	3%	36.4 %	60.6%	2.57	4
Enhance flexibility in construction	6.1%	36.4 %	57.6%	2.51	5
Minimise use of space during construction	3%	54.5 %	42.4%	2.39	6
Minimise cost of construction	0%	24.2 %	75.8%	2.75	2
Ease of adaptation	12.1%	42.4 %	48.5%	2.33	7

B. Discussions

Sustainable construction is conceived to restore and maintain harmony between the natural and built environment, while creating human settlements that affirms human dignity and encourage economic equity [7]. To achieve creating sustainable settlements, adequate attention has to be given to the utilisation of building material during housing construction.

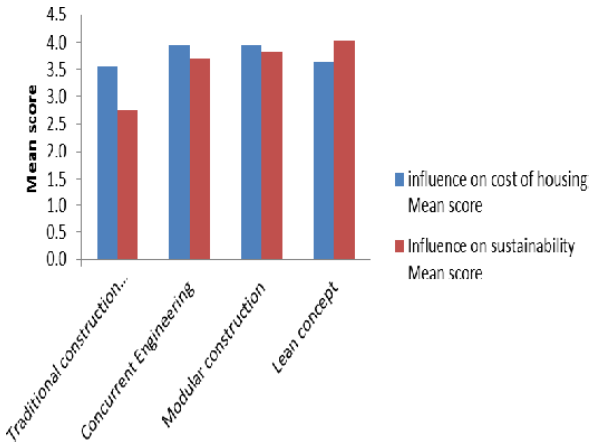

Figure 1. Overall influence of identified housing construction methods on sustainability enhancement

The results of this analysis have revealed that the construction methods examined have the potential to; eliminate complexities in the housing construction process, eliminate material wastage, produce good quality housing on the one hand and minimise cost of construction on the other. Furthermore, it will promote the efficient utilisation of building materials, which negatively impacts the natural environment.

The interplay of the factors revealed in the results of analysis among the construction methods shows that the mean scores for the overall influence of each of the methods on the cost of housing are above the threshold level of 3.0, while the mean score for aggregate influence of all the methods on sustainability enhancement in housing are above the threshold level of 2.5 (see Fig. 1).

IV. Conclusion

Sustainable construction is an opportunity to use world natural resources efficiently and effectively while creating settlements that affirms human dignity. In South Africa, the acceptance of sustainability is somewhat industry wide and acceptance of the housing produced using modular construction material and method have in most case been rejected by the target users. The paper thus suggests use of more than one construction methods for housing projects in developing countries since the merit of one method could overshadow the demerit of the second method.

Acknowledgement

The authors acknowledged the Cape Peninsula University of Technology (CPUT) Research Directorate for proving financial support through University Research Fund (URF) award to undertake this study.

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