The following publication Adabre, M.A. and Chan, A.P.C. (2020), "Towards a sustainability assessment model for affordable housing projects: the perspective of professionals in Ghana", Engineering, Construction and Architectural Management, Vol. 27 No. 9, pp. 2523-2551 is published by Emerald and is available at https://doi.org/10.1108/ECAM-08-2019-0432.

Towards a Sustainability Assessment Model for Affordable Housing Projects: The Ghanaian Perspective

Abstract

Purpose - This paper presents a sustainability assessment model to holistically guide sustainable construction and green retrofitting of affordable housing from the Ghanaian perspective.

Design / methodology / approach - A comprehensive review was carried out, which yielded 16 sustainability indicators. Then, a questionnaire survey was conducted among respondents in the Ghanaian housing sector. Forty-seven (47) valid responses were received and analyzed using fuzzy synthetic evaluation (FSE) technique.

Findings - A four-index model was developed that includes: Housing and Transportation (H + T) index, household-satisfaction index, efficient stakeholder-management index and quality-related index. These indices account for 25.3%, 26.3%, 23.6% and 24.9% of sustainability attainment in affordable housing, respectively. Accordingly, household-satisfaction has the greatest contribution to sustainability attainment in affordable housing.

Research limitations / implications - Due to challenges in obtaining responses to the questionnaire, the study was conducted with relatively small number of responses.

Originally / value - The model serves as a tool that could be used to objectively and comprehensively assess sustainability performance in affordable housing. Besides, it could be used as a baseline to calibrate future projects and for benchmarking success levels of comparable housing projects. Finally, the estimated indices are applicable in decision making for optimum resource allocation for sustainable low-cost housing in the Ghanaian perspective.

Keywords: Affordable housing; Low-cost housing; Public housing; Sustainable housing; Criteria; Success Index; Assessment criteria; Indicators

1. Introduction

The role of the construction sector in delivering infrastructure facilities to the society is indispensable. However, in achieving this role, a prodigious amount of unrenewable resources is consumed. Besides, large amount of carbon dioxide is consequently emitted. It has been estimated that the total amount of carbon dioxide emission from the global construction industry in 2009 was 5.7 billion tons. This contributed to about 23% of the total carbon dioxide emissions from the global economic activities (Huang et al., 2018). Moreover, the operation of most of the constructed facilities further contributes to the depletion of non-renewable energy and carbon dioxide emission. Among the facilities, housing facilities require much attention.

The housing sector is a major consumer of the global energy and a contributor to CO_2 emissions. Heating and hot water provision among private households in Europe account for 40% of the total energy consumption and 25% of greenhouse gas emissions (Lechtenböhmer & Schüring, 2011). Similarly, Asumadu-Sarkodie & Owusu (2016) estimated that about 54% of electricity is used to run homes in Ghana. Based on these problems, sustainable housing is the hypothetical solution. However, study shows that the poverty level recorded in both urban and rural areas were 43% and 59%, respectively, among African countries (Obeng-Odoom, 2010). These statistics partly show the high number of low-income earners in Ghana, who cannot procure sustainable technologies for their housing or cannot afford sustainable housing. Therefore, to curb the detrimental impact of the housing sector, sustainability attainment in affordable housing for low and middle-income earners is essential (Sullivan & Ward, 2012; Adabre & Chan, 2019).

Affordable housing facilities could be termed as social housing, public housing or cooperative housing based on the country and income level of the target household (Zeng et al., 2019). For instance, social housing in the case of England, are houses that are allocated based on income of households or housing needs of the households while affordable housing facilities are provided as facilities below market rent / price but above the rent or price level of social housing. However, social housing is mostly termed as affordable housing in the case of Italy (Czischke & van Bortel, 2018). Cooperative housing facilities are owned by a corporation or a cooperative that seeks to provide low-cost housing to its members. In the case of Ghana, the distinction among these forms of housing is not clear. However, affordable housing, which is often termed as public housing, serves as shelter to civil servants who may be low- or middle-income earners. Additionally, affordable housing could yield optimum benefits when they are made sustainable. Sustainable affordable housing (SAH) is "housing that meets the needs and demands of the present generation without compromising the ability of future generations to meet their housing needs and demand" (Pullen et al., 2010 p. 13). SAH ensures optimum economic, social and environmental benefits of housing for a low or middle-income household.

Accordingly, studies have been conducted on various strategies for improving sustainability in affordable housing (Roufechaei et al., 2014; Casquero-Modrego & Goñi-Modrego, 2019; Adabre & Chan, 2019; Ansah et al., 2020). Considering the varied studies on measures for SAH, it is worth reiterating the two questions posed in Sustainable Cities International (2012) with regard to affordable housing: *(i) how to ascertain the current level of sustainability? and (ii) how to know whether we are on an acceptable path towards sustainable development?* In their rejoinder, Haider et al. (2018) affirmed that such questions could clearly be answered by employing a calculable approach or model for sustainability assessment.

A sustainability assessment model is an essential tool for guiding initiatives and for achieving sustainable development goals. Yet, there is noticeably inadequate coverage on a comprehensive model for assessing sustainability in affordable housing (Mulliner et al., 2013; Chan & Adabre, 2019). Studies on assessment model for affordable housing mostly focused on housing price / cost criterion (Stone, 2006). However, housing cost only reflects an aspect of economic sustainability, but does not evaluate the other sustainability aspects including environmental and social sustainability (Liu, 2014; Adabre & Chan, 2018). According to Mulliner et al. (2013) and Chan & Adabre (2019), in addition to the economic criterion, the non-economic criteria, namely, social and environmental criteria are equally crucial in evaluating sustainability attainment in such facilities. Subsequently, green building rating systems (GBRSs) have been established to improve general assessment for sustainable development in projects including housing. Yet, GBRSs have been criticized in many studies for some lacunae (Zuo & Zhao, 2014; Hamid et al., 2014; Awadh, 2017; Illankoon et al., 2017; Mattoni et al., 2018). Most GBRSs have broadly concentrated on assessment criteria for environmental sustainability with scant assessment criteria for social sustainability and economic sustainability (Hamid et al., 2014; Fenner & Ryce, 2017; Atanda, 2019).

Thus, while an affordable housing facility that is assessed using housing price / cost criterion could be economically sustainable on one hand, it might not be environmentally or socially sustainable on the other hand. Likewise, an affordable housing facility that is assessed by most of the GBRSs could be environmentally sustainable but not economically or socially sustainable. "Consequently, there is a possibility of acquiring a green certification that only accomplishes one particular criterion although all the other key assessment criteria are overlooked" (Illankoon et al., 2017 p. 218). Therefore, the sustainability – a holistic achievement of economic, environmental and social aspects – of most affordable housing facilities is open to question vis-à-vis some global housing problems such as poor-quality designs and high levels of residential turnovers or low take-up rate of affordable housing facilities (Winston, 2010; Teck-Hong, 2012; Mulliner et al., 2013; Adabre & Chan, 2018).

Appropriately, developing an assessment framework for an all-inclusive evaluation of sustainable development in affordable housing is crucial. This study seeks to do so from the Ghanaian perspective. The study's findings will aid policy makers and practitioners in defining performance targets for sustainable affordable housing. Besides, it could aid policy-makers and practitioners to comprehensively and objectively assess and compare sustainability performance of affordable housing facilities. This could facilitate efficient allocation of scarce resources during green retrofitting for attaining sustainable development goals in affordable housing. The remaining of the study is organized as follows: An extensive literature review was conducted in Section Two. Then, in Section Three, the research methodology is presented. Furthermore, statistical analysis of the survey responses and results are presented in the penultimate section, Section Four. Finally, Section Five presents the conclusion and recommendation.

2. Literature Review

Success is the ultimate goal of every project. It is the realization of some externally observed set of goals (Ashley et al., 1987). To appropriately assess the attainment of sustainable development goals in affordable housing, a set of ultimate standards or assessment criteria (indicators) has to be specified. Assessment criteria or indicators are the set of principles or standards through which judgement can be made (Lim & Mohammed, 1999). They play essential roles in projects by enabling policy-makers and practitioners to measure the success level of their projects (Chan et al., 2002). Furthermore, they guide construction practitioners and policy-makers to appropriately plan resource allocation (Cox et al., 2003). Moreover, assessment criteria are key for benchmarking the performance levels of comparable projects

(Osei-Kyei & Chan, 2017). As such, various assessment criteria have been suggested in the literature. While general assessment criteria may apply to all construction projects (Atkinson, 1999; Chan & Chan, 2004), specific assessment criteria are required to evaluate sustainability performance in affordable housing (Ezennia & Hoskara, 2019; Saidu & Yeom, 2020).

2.1 Housing Price to Income Ratio (PIR) as an Assessment Criterion

Studies on assessment criteria for housing have progressed. Prior studies adopted the housing price / cost as an objective measure for assessing affordable housing projects (Cox et al., 2017). As proposed by the United Nations Human Settlement Programme (UNHSP) and the World Bank, the PIR was considered the best assessment criterion for evaluating housing affordability. "It is the ratio of the median free-market price of a dwelling unit to the median annual household income" (Lin et al., 2014, p. 42). High PIR indicates housing affordability crisis while low PIR, below 3.0, indicates improved housing affordability. In Cox et al. (2017), the PIR was deployed to compare the housing affordability situation of middle-income earners among some developed economies. Essentially, their study revealed housing markets that could be used as benchmarks such as Singapore because of her relatively low PIR ratio while showing housing markets that needed improvement in their price affordability such as Hong Kong, New Zealand and Australia. Though the PIR is simple to use and could provide a quick international comparison of price performance of housing markets, it has some limitations.

The PIR has some challenges on providing a complete and accurate assessment for SAH. It does not account for households' commuting cost. Though houses in the peripheral areas could be price affordable, they are not truly affordable if households incur high cost on transportation to places of employment, educational facilities, health and childcare centres, leisure facilities and city centre. Thus, household housing affordability cannot be measured by solely using the PIR. Furthermore, the PIR value may not reveal real financial constraints of households. In case of high micro PIR, households may be purchasing houses as part of asset accumulation or as investment (Lin et al., 2014). As investors, they may seek transactional rapidity and high profits and, therefore, may be comparatively unconcerned about housing affordability. Hence, measurement bias and statistical overestimation problems / inconsistency have been stated as some of the measurement challenges of using the PIR (Lin et al., 2014, p. 46-47). Moreover, the PIR only assesses an aspect of economic sustainability– housing price affordability. Besides, it does not provide an assessment coverage for environmental and social sustainability. Therefore, the PIR assessment is not adequate for considering an affordable housing facility as sustainable (Chan & Adabre, 2019).

Subsequently, studies have been conducted on broadening the coverage of PIR by integrating it with transportation cost. The Center for Neighborhood Technology (CNT) introduced the Housing plus Transportation (H + T) affordability index. This index is a combination of housing price or rental cost, commuting cost and housing operation cost; it provides an objective assessment of affordable housing facilities (Isalou et al., 2014). Notwithstanding the relevance of its usage, the omission of other social sustainability assessment criteria is still valid. Qualitative assessment criteria (i.e. household satisfaction, safety, aesthetic view of housing facility, output specification or technical specification and stakeholder relations / neighbourhood satisfaction) are not accounted for in the H+T index (Chan & Adabre, 2019). Though facilities (such as shops, educational facilities, health care services) could be provided to improve accessibility, the quality of these facilities measured as end users or household satisfaction cannot be assessed using the H+T index. For instance, a study by Zeng et al. (2019) revealed low levels of satisfaction with facilities, weak community attachment and the desire to move among residents in affordable housing communities. Arguably, such qualitative assessment criteria are subjective and relatively not lucidly measurable; however, policy-makers and practitioners should not underestimate their impact in ensuring SAH.

2.2 Green Building Rating System (GBRSs) for Assessment

GBRSs include a set of performance thresholds that buildings must meet to be certified. They also serve as guidelines in enabling project teams to attain or to exceed those performance thresholds (Mattoni et al., 2018). Policy-makers could use GBRS for baselining (i.e. developing an initial measurement as touchstone for regulating performance of future projects), for benchmarking (i.e. providing a basis for comparing one project to another) and for decision-making (i.e. allocating resources to meet targets) (Shan & Hwang, 2018). Various GBRSs have been established globally for assessing construction projects including housing. Typical among them from the earliest to the latest include: Building Research Establishment Environmental Assessment Method (BREEAM) from UK; Leadership in Energy and Environmental Design (LEED) from USA; Built Environmental Assessment Method (BEAM) from Hong Kong; Comprehensive Environmental Performance Assessment Scheme (CEPAS) from Japan; Green Star from Australia; Green Mark (GM) from Singapore and Global Sustainability Assessment System (GSAS) from Qatar (Shan & Hwang, 2018).

GBRSs offer specific versions for varied schemes (i.e. hostels, homes, schools and data centre) on certain assessment criteria. Shan & Hwang (2018) found that the most important assessment criteria among GBRSs are “energy”, followed by “site”, “indoor environment”, “land and outdoor environment”, “material”, “water” and “innovation”. However, studies have trenchantly criticized GBRSs as offering an insular perspective of sustainability assessment. Awadh (2017 – p. 25) contended that “(GBRSs) are environmental-oriented tools and should not be confused with sustainability assessments systems which are defined by the sustainability three pillars: economic, environmental and social.” Similarly, Zuo & Zhao (2014) concluded that the social and the economic aspects are largely overlooked in GBRSs. Furthermore, Fenner & Ryce (2008) stated that GBRSs are only being encouraged in the narrow perspective of stand-alone building assessment and assumptions are based on initial environmental assessment while ‘occupancy and operational performance variations of a scheme are mostly ignored’. Accordingly, GBRSs could minimize environmental impact of SAH but fail to sufficiently take into consideration social and economic indicators of sustainability.

Therefore, though most GBRSs could be useful frameworks for guiding environmental sustainability in affordable housing, it is also important to consider additional sustainability targets such as social and economic dimensions for an overall sustainable development. Based on the limitations, studies have been conducted on assessment criteria that could be integrated into GBRSs to improve sustainability assessment. For instance, Ye et al. (2015) developed a new rating tool known as Building Sustainability Score (BSC) for assessing buildings. The BSC provides coverage for the entire building lifecycle from inception to demolition. Some of the social sustainability assessment criteria stated by Ye et al. (2015) are summarised as stakeholder satisfaction (i.e. ‘impact on community’, ‘local impact’, ‘urban integration’ and ‘stakeholder relation’), ‘end-user’s satisfaction’ and ‘reduced commuting cost’ (i.e. ‘proximity to facilities’). Similarly, Liu et al. (2013) identified ‘stakeholder relation’ as one of the assessment criteria that are not included in the rating tools. According to Haider et al. (2018), two of the most neglected aspects of social sustainability include safety and security.

Consequently, GBRSs have evolved. There are currently neighbourhood sustainability assessment tools that provide a broader perspective of sustainability assessment of buildings and their environs as against a stand-alone building assessment by GBRSs. Some of these tools include LEED-ND, EarthCraft Communities (ECC), BREEAM Communities, CASBEE-UD, Green Star communities, Green Mark for Districts, Green Neighbourhood Index (GNI), Ecocity, HQE^2R and Cascadia Scorecard. With the exception of CASBEE-UD, all these tools have included criteria for affordable housing provision / supply. The relevance of these tools is evinced as most of them are ubiquitously applied in many scopes or countries (Kamal Mohammad Attia, 2013). However, Haapio (2012) identified some possible challenges associated with the selection of criteria and therefore, cautioned against the transferability of such tools to other context and scope. These tools are developed based on priorities and conditions (i.e. climatic, social and economic issues) of their countries. Hence, there is no one-size-fits-all tool. Another challenge with the current neighbourhood assessment tools is the subjectivity of the scoring and weighting of the criteria or sub-criteria. These tools are often vulnerable to ambiguity concerning the scoring and weighting of the criteria (Sharifi & Murayama, 2013). Moreover, though some of the tools ensure affordable housing supply, they are not suitable for assessing SAH.

Studies are still advancing in this regard. Tupenaite et al. (2017) provided nine main categories for assessing new housing projects in the Baltic states. The identified categories include: 'land use consideration'; 'water efficiency consideration'; 'energy and atmosphere consideration'; 'materials and waste management'; 'indoor environmental quality'; 'external pollution'; 'innovation and design process consideration'; 'accessibilities and neighbourhood'. Though some of these categories might be applicable for assessing sustainable development in affordable housing, yet a more specific assessment model for affordable housing projects entails additionally evaluating the projects / facilities vis-à-vis the affordability benchmarks. That is households will spend no more than 30% of their income on housing (Stone, 2006) or less than the 45% of households' income for housing and transportation (H + T) (Isalou et al., 2014).

Similarly, a study by Chan & Adabre (2019) focussed mainly on assessment criteria for sustainable affordable housing. Some of the social sustainability assessment criteria were summarised into 'stakeholders' satisfaction', 'household satisfaction' and 'quality-related'. Among the economic sustainability assessment criteria recapitulated in Chan & Adabre (2019) include 'housing operation cost (including maintenance cost, other housing lifecycle cost such as taxes or charges on housing facility); energy and water efficiency measures (cost of utilities); housing cost (i.e. housing price / rental cost in relation to household income). Though Chan & Adabre (2019) provided a comprehensive list of qualitative and quantitative assessment criteria for affordable housing, yet, their study is rather illustrative of the sustainability assessment criteria. For a decision making involving such multi-criteria with different decision makers (such as architects, developers and materials engineers), illustrative assessment criteria as benchmarks are susceptible to vagueness and subjectivity of experts' opinion (Haider et al., 2018). Owusu et al. (2019) attributed the cause of the subjectivity to partial, linguistic rating scale and unquantifiable information. Therefore, an objective and quantifiable sustainability assessment model for calibrating and judging performance of affordable housing within a specific scope is still exigent.

Table I is a summary of the literature review conducted on assessment criteria / indicators that could be relevant for affordable housing facilities. It can be concluded from the review that current studies on assessment of affordable housing have progressed from using price of housing to housing price plus transportation cost. However, this criterion is not adequate since it does not include qualitative criteria. Although GBRSs and advanced GBRSs tools such as neighbourhood sustainability assessment tools include some qualitative criteria, a major challenge is the subjectivity in the scoring and weighting of the criteria. This is attributed to the differences in the priorities and interests of the various stakeholders involved in rating these criteria. Based on this problem, Sharifi & Murayama (2013) recommended that the utilization of fuzzy technique is appropriate to tackle the issues of subjectivity of weightings. Besides, since the tools and models have been developed in different context and scope, it is preferable to develop country-specific model from the Ghanaian perspective. This could be an appropriate strategy to abreast policy-makers of a reliable level of sustainable development on affordable housing. Therefore, this study focuses on developing a sustainability assessment model for affordable housing from the Ghanaian perspective using fuzzy synthetic evaluation technique.

Table I: Criteria / Themes, Indicators and Sub-Indicators for Assessing Sustainability Attainment in Affordable Housing (SAH) (Adapted from Chan & Adabre, 2019; Tupenaite et al., 2017)

Criteria / Themes	Indicators	Sub-Indicators / Issues to be Considered Under Each Indicator
Location affordability	Housing price to income	Housing price affordability; mortgage interest rates
	Rental cost to income	Rental cost affordability (advance rent charges)
	Reduced commuting cost	Access to shops; access to health care services; access to childcare; access to leisure facilities; access to open green public space; access to employment opportunities; access to public transportation facilities; access to educational institutions or facilities; access to the city center; access to library facilities
Operation & Maintenance cost	Maintainability of housing (cost of maintenance or retrofitting)	Refurbishment, repairs, retrofitting cost; low-cost maintenance features in house; ease of maintenance, effort in upkeep of housing facility
	Other lifecycle cost of housing	Taxes or charges on housing facility
	Energy & water efficiency (utility bills)	Operation cost of major electrical appliances; lighting efficiency; renewable energy use; efficient energy design of housing facility; access to quality & portable water; water conservation strategies (rainwater harvesting); availability of low-flow aerators in household faucets
	Environmental friendliness	Reduction in emissions of greenhouse gasses (NO_2, CO); environmental friendly waste management; environmental friendly design; environmental-friendly materials; circular economy (materials and products reused)
Household satisfaction	Functionality of housing facility	Size of room or house; housing floor plan; positioning of different rooms; adequacy of ancillary areas (kitchen design, bathroom), privacy availability in room; ability of housing facility to meet the evolving needs of households
	Safety performance of housing facility (crime rate)	Safe indoor and outdoor environment; number of crimes (burglary and robbery cases) recorded in housing facilities
	End user's satisfaction on facilities	End user's satisfaction level on supplementary facilities such as shopping facilities; educational facilities; healthcare facilities; recreation facilities; transportation facilities; childcare facilities; leisure facilities; open, green public

		space; community living space and community attachment; adequate drainage system & waste management facilities
Efficient Stakeholder Management	Stakeholders' / neighborhoods' satisfaction	Community cohesion; compatibility between housing design and neighboring housing facilities; neighborhood reputation; neighborhood satisfaction; reduced number of crimes (robbery and murder) recorded within the neighborhood; impact of housing facility on price of neighboring housing facilities; impact of housing facility on neighboring community
	Reduced disputes occurrence	Cohesion among households and neighbors in the community; sense of community
Quality-related	Aesthetic view of completed house	Compatibility of design features of affordable housing facility with neighboring housing facilities; landscaping design; color of materials or building elements; preservation of key local / traditional architecture / designs
	Quality performance of housing facility	Quality of indoor and outdoor environment; quality of materials or workmanship
	Technical specification of housing facility	Entails assessing the level that elements of housing facilities meet technical requirements / performance output
	Technology transfer	Innovation in design and construction of affordable housing facilities to improve quality, energy efficiency and reduce housing cost

2.3 Conceptual Assessment Framework for SAH

Based on the groupings of the various criteria established by Chan & Adabre (2019), a conceptual framework was developed for sustainability assessment in affordable housing (shown in Fig. I). In this framework, sustainable affordable housing is the main scheme with the three main sustainability pillars – economic, environment and social – as the goals. Under the sustainability goals are five main criteria / themes. These criteria include: H+T criterion which is an integration of 'location-affordability cost' and 'operation and maintenance cost'; household-satisfaction; efficient stakeholder management and quality-related criteria (shown in Fig. I).

From the framework (shown in Fig. I), economic sustainability could be achieved through price or rental affordability of housing and reduced commuting cost (location affordability cost). It could also be realized through reduced utility bills (operation and maintenance cost). Regarding environmental sustainability, reduced commuting cost through improved accessibility will reduce greenhouse gas emissions from vehicular movement. Moreover, ensuring energy efficiency and water efficiency in the operation and maintenance of housing facility will reduce the consumption of non-renewable resources in addition to alleviating carbon dioxide emissions. This could lead to environmental sustainability in housing. Concerning social sustainability, household satisfaction and quality of housing are essential criteria for adequate housing or shelter. Besides, by ensuring efficient stakeholder management through stakeholders' / neighbours' satisfaction and reduced occurrence of disputes, social cohesion could be achieved among residents and neighbours. This will enhance a sense of community and improve social sustainability.

The criteria are measured by their indicators. Indicators are qualitative or quantitative bits of information on performance, which could show a chronological change and are comparable (Rahdari & Rostamy, 2015). Thus, each criterion has indicators for assessment. For instance, the indicators for household-satisfaction include 'functionality of housing facility', 'end-user's satisfaction', 'safety performance (crime rate)'. On efficient stakeholder management, 'stakeholders' or neighborhoods' satisfaction' and 'reduced occurrence of disputes and litigation' are the main indicators. Finally, the indicators under 'quality-related criterion' include 'aesthetic view of housing facility', 'quality performance', 'technical specification of housing facility' and 'technology transfer' (shown in Table I & Fig. I). The indicators are further divided into sub-indicators as shown in Table I. The estimation of the weights of the criteria / themes was done using a bottom-up approach. This approach involves developing aggregation methods to determine the overall weights of the criteria using values obtained from their indicators (Moussaoui et al., 2018). Besides, due to the manual calculation, this study uses the scores of the indicators for the computation of the weights of the criteria / themes.

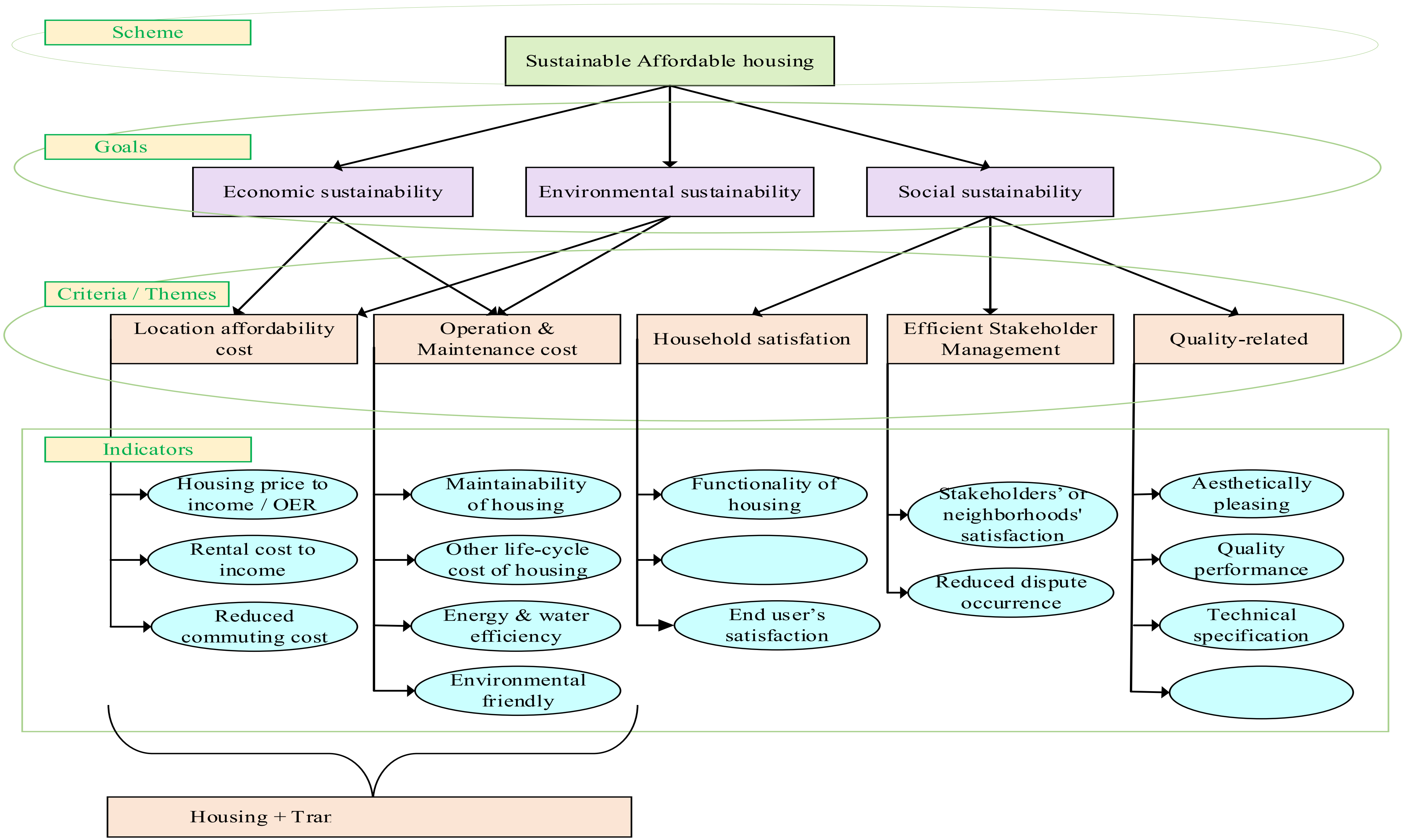

Fig. I: Conceptual Framework of Sustainability Assessment Model for Affordable Housing (Adapter from Chan & Adabre, 2019)

3. Research Methodology

3.1 Pilot Survey and Data Collection

A questionnaire survey was adopted in this study for data collection. Questionnaire survey offers a valid and reliable source of information at a less cost (Hoxley, 2008). It also guarantees anonymity and protection of respondents' identification data (Owusu et al., 2019). Before conducting the questionnaire survey, a pilot survey was carried out among respondents in the Ghanaian housing sector, who are knowledgeable in both affordable housing and sustainable housing. Four experts including two professors and two-postdoctoral research fellows participated in the pilot survey. This form of survey was conducted to check three main aspects of the questionnaire: (1) the completeness of the number of sustainability indicators for affordable housing; (2) the clarity on expression of questions and suitability of technical terms of the indicators; (3) the time required for answering the questionnaire. The time was checked by soliciting for feedback from the pilot survey participants on the number of minutes they spent on the questionnaire. It is worthwhile checking for these aspects in a questionnaire to ensure that the finalized questionnaire is correctly displayed for all potential respondents. This could increase the likelihood of success of the survey. After receiving and implementing the constructive comments from the pilot-survey participants, the questionnaire was completed for data collection.

The questionnaire consists of five main sections. The first section covers questions on respondents' profile. The second section contains questions on the indicators while the third section comprises of questions on success factors. The fourth and fifth sections include questions on barriers and risk factors to SAH, respectively. This manuscript reports only findings on the indicators for SAH. Non-probability sampling techniques, namely, purposive sampling and snowballing were deployed for data collection. These techniques were employed due to the non-availability of a comprehensive sampling frame of housing experts in the Ghanaian construction industry.

To identify survey respondents, the office of the Ghana Real Estate Developers Association (GREDA) was first visited. A brochure containing the list of some of the registered housing developers was provided on request. Then, most of the developers were contacted on phone (phone numbers obtained from the brochure) for brief introduction to the research topic and purpose of the study before soliciting for their participating in the survey. Registered housing developers who showed interest and willingness to participate in the survey were sent emails with an attached word document of the questionnaire. Potential respondents were entreated to forward the questionnaire to other developers or provide the contact addresses of other developers / housing experts. Thus, through snowballing, other potential respondents were identified and contacted. The questionnaires were also administered personally to members of the Ghana Institution of Surveyors (GhIS) at their 50th Annual General Meeting, which was held in Accra at GIMPA on 2nd March 2019. Moreover, employees in public institutions that are responsible for housing supply (such as Public Works Department, PWD and Ministries of Works and Housing) were contacted.

Respondents were asked to rate the criticality of the indicators using a five-point Likert scale defined as 1=not important, 2=less important, 3=neutral, 4=important and 5=very important. Previous studies on FSE adopted a 5-point Likert scale (Zhao et al., 2016; Ameyaw et al., 2016). Therefore, this scale was espoused to maintain consistency. Out of 110 questionnaires administered, 47 valid responses were received after a three-month period. A response rate of 42.7% was estimated which compares favorably with previous surveys in the Ghanaian construction industry (Osei-Kyei and Chan, 2017; Darko et al., 2018).

Table II shows the institution types, profession, number of housing projects handled, housing type handled by the respondents and the years of experience of the respondents. As shown in Table II, in terms of institution type, 17 respondents (35%) are in academic / research institutions; 23 respondents (48%) belong to public institutions while 8 respondents (17%) are private developers / contractors. Concerning profession, most of the respondents (55%) are quantity surveyors, followed by project / construction managers (19%), architects (13%), engineers (6%) and researchers (4%). On number of housing projects handled, 17 respondents (37%) have handled between 1-2 housing projects; 12 respondents (26%) have been involved in at least seven projects while nine respondents (20%) have participated in 3-4 projects. The housing type mostly handled by the respondents is public housing (55%). Concerning the years of experience in the Ghanaian construction industry, 36% of the respondents have 1-5 years of experience; 28% have 6-10 years of experience; 21% have 11-15 years of experience; 6% have 16-20 years of experience while 9% have > 20 years of experience in the Ghanaian construction industry. Based on the respondents' profile, it can be concluded that most of the respondents are well abreast of the Ghanaian construction industry and housing market; therefore, they are capable of providing adequate information for developing a sustainability assessment model for affordable housing projects / facilities.

Table II: Respondents' Profile

Category	Characteristics	Number of Responses	Percentage (%)
Institution Type	Academic / research institution	17	35.4
	Public sector agency / department	23	47.9
	Private developers / contractors	8	16.7
Profession	Architect	6	12.8
	Project / construction manager	9	19.1
	Engineer	3	6.4
	Quantity surveyor	26	55.3
	Researcher	2	4.3
	Others	1	2.1
Number of Housing projects handled	0 project	5	10.9
	1-2 projects	17	37.0
	3-4 projects	9	19.6
	5-6 projects	3	6.5
	7 and above projects	12	26.1
Housing Types Handled	Public housing	27	55.1
	Social housing	17	34.7
	Cooperative housing	3	6.1
	Others	2	4.1
Years of Experience	1-5 years	17	36.2
	6-10 years	13	27.7
	11-15 years	10	21.3
	16-20 years	3	6.4
	Above 20 years	4	8.5

3.2 Data Analysis Tools

The Statistical Package for Social Science (SPSS version 20) was used to conduct statistical analysis of the data. Analytical techniques such as mean score ranking and fuzzy synthetic evaluation (FSE) were utilized for data analysis. Essentially, the mean score ranking technique has been used in housing studies to establish the relative importance of a set of criteria (Chan & Adabre, 2019). Similarly, in this study, it was used to ascertain the importance of each of the sustainability assessment indicators.

3.3 Fuzzy Synthetic Evaluation (FSE)

Decision-makers and practitioners often encounter challenges in assessing the sustainability of projects (Haider et al., 2018). After the selection of indicators, appraising the non-quantifiable indicators has always been a problem in establishing a sustainability assessment model for a project. Benchmarks from indicators defined on linguistic scale as 'not important', 'less important', 'neutral', 'important' and 'very important' aid respondents to qualitatively assess the criticalities of assessment indicators. However, Haider et al. (2018) indicated that such benchmarks may contain inherent uncertainties as a result of vague non-mathematical claims and subjectivity in experts' opinion. Besides, multi-criteria decision making (decision making on qualitative data with many indicators and many decision-makers) are prone to uncertainties and are often difficult to be assessed.

Therefore, Zadeh (1965) developed the fuzzy synthetic evaluation (FSE) technique as a robust tool for handling such uncertainties (i.e. data limitations and linguistic scale for indicators assessment are prone to subjectivity). The FSE is a modelling technique for quantifying multi-attributes and multi-variates (Owusu et al., 2019; Osei-Kyei & Chan, 2017). It is appropriate for aggregating scores of indicators towards developing an overall sustainability index. Therefore, by converting respondents' subjective opinions into mathematical indices, FSE provides an objective and quantitative assessment model for projects. The FSE has been applied in studies on different fields for developing sustainability assessment model for small-size urban neighbourhood (Haider et al., 2018) and mathematical models of project success for public-private partnership (Osei-Kyei & Chan, 2017).

In this study, FSE is utilized to develop a sustainability assessment model for affordable housing. The step-by-step guidelines for developing the model using FSE technique include the following (Osei-Kyei & Chan, 2017):

Stage 1: First, a set of fundamental assessment indicators is developed. $I = \{I_1, I_2, I_3 \ldots I_n\}$; where n represents the number of indicators

Stage 2: Then, labels for the set of grade alternatives are established as $L = \{L_1, L_2, L_3 \ldots L_n\}$. For this study, the 5-point Likert scale is the set of grade alternatives. Therefore, L_1 = not important, L_2 = less important, L_3 = neutral, L_4 = important, L_5 = very important

Stage 3: Afterward, the weighting for each indicator is established. The weighting (W) could be determined from the survey results using eqn. (1):

$$W_i = \frac{M_i}{\sum_{i=1}^{k} M_i}, 0 < W_i < 1, \text{ and } \sum_{i=1}^{k} W_i = 1 \quad \ldots\ldots\ldots\ldots \text{eqn. (1)}$$

Where W_i = weighting; M_i = mean score of a particular indicator; K= number of indicators within a criterion; $\sum W_i$ = summation of weightings

Stage 4: Furthermore, a fuzzy evaluation matrix for each criterion / grouping is established. This matrix is expressed as $R_i = (r_{ij})_{m \times n}$, where r_{ij} is the degree to which alternative L_j satisfies the criterion C_j

Stage 5: Moreover, the final FSE results for the evaluation are determined through the weighting vector and the fuzzy evaluation matrix as expressed in eqn. (2):

$$D = W_i \circ R_i \quad \ldots\ldots\ldots\ldots \text{eqn. (2)}$$

Where D is the final FSE evaluation matrix; and " $\circ$ " is the fuzzy composition operator.

Stage 6: Finally, the FSE evaluation matrix is normalized to develop the sustainability assessment index (SAI) by using eqn. (3):

$$SAI = \sum_{i=1}^{5} D \times L \quad \text{...} \quad \text{eqn. (3)}$$

4. Data Analysis Results

4.1 Results of Mean Score Ranking

Mean scores and standard deviations were estimated and subsequently used for ranking the sustainability indicators. If two indicators have the same mean scores, decision on their ranking is made based on their standard deviation values. A lower standard deviation of an indicator implies a high level of consistency among respondents in rating the indicator and vice-versa. Therefore, for two indicators with the same mean values, the indicator with lower standard deviation is ranked higher. Results of the mean score rankings are shown in Table III. Based on the mean scores and the standard deviation values, 'quality performance' was ranked the highest followed by the indicator 'end users' satisfaction'. 'Housing price in relation to income of household' was ranked third while 'maintainability of housing facility (maintenance cost)' and 'rental cost of housing in relation to income of household' were ranked fourth and fifth, respectively. However, 'reduced occurrence of disputes and litigations' and 'technology transfer' were relatively ranked low (shown in Table III).

In previous study by Chan & Adabre (2019), a comparison between developed and developing countries on ranking of the indicators 'rental cost of housing' and 'price of housing' revealed that 'price of housing' was ranked higher among developing countries. This shows a higher preference for homeownership than for renting. However, among developed countries 'rental cost of housing' was ranked higher which implies higher preference for renting than for homeownership. Aside the prestige and esteem needs that are derived from homeownership over renting of houses, there are other possible reasons for the higher ranking of 'price of housing' (higher preference for homeownership) in the case of Ghana as a developing country. Due to limited investment options, the desire for homeownership as an investment could be relatively higher in Ghana as compared to the case of some developed countries (Chan & Adabre, 2019). Thus, even among low and middle-income earners in Ghana, the propensity for homeownership is high for the purpose of real investment and to hedge against the escalating inflation rate and high advance rent charges especially in cities. These could possibly be the reasons for the relatively higher rank of 'price of housing in relation to household income' (an indication of higher preference for homeownership) over 'rental cost of housing in relation to household income' (an indication of renting) among respondents in the Ghanaian housing market.

From Table III, environmental sustainability-related indicators such as 'energy efficiency of housing facility', 'eco-friendliness of housing facility' and 'commuting cost' are ranked high (> 3.5) per their mean scores. However, indicators related to economic sustainability such 'price of housing' and 'rental cost of housing' are ranked relatively higher than the environmental sustainability-related indicators. Yet, these economic assessment indicators are not considered in most of the widely adopted GBRSs such as BREEAM and LEED. Furthermore, social sustainability-related indicators such as 'end user's satisfaction of housing facility', 'functionality of housing facility', 'safety performance of housing facility' and 'quality performance of housing facility' were relatively ranked higher than some of the environmental sustainability-related indicators such as 'energy & water efficiency of housing facility' and 'environmental performance / impact of housing facility' (eco-friendliness)'. Yet, most of the internationally recognised GBRSs and neighbourhood sustainability assessment tools do not adequately consider these social sustainability indicators for evaluating sustainability of projects or housing facilities. Similarly, Ameen & Mourshed (2019) concluded that prominent GBRSs and neighbourhood sustainability assessment tools paid less attention to safety factors. This is evinced in the low weightings allocated to the safety indicator by BREEAM Community (0%) and LEED-ND (1.9%) and 0.70% and 0.65% weightings from PCRS and GSAS, respectively. Nonetheless, safety is a crucial indicator for not only social sustainability attainment but for general sustainable development. It includes the right to be safe in addition to adopting security measures and adaptations to prevent future harm and casualties (Eizenberg & Jabareen, 2017).

Therefore, though most of the GBRSs are more inclined towards the environment than to the social and economic aspects of sustainability, it is worth noting that priority on sustainability indicators vary among schemes. Regarding affordable housing schemes, socio-economic assessment indicators featured highly from the perspective of respondents from the Ghanaian construction industry. The inadequate consideration of this disparity in the rating of these indicators among recognized rating tools and frameworks may reduce their effectiveness in promoting sustainable development across affordable housing schemes. Accordingly, subsequent improvement in GBRSs should pay more attention to these socio-economic indicators to enhance the coverage and thorough sustainability assessment of affordable housing.

Table III: Mean Score Ranking of the Indicators

Code	Indicators (I)	Mean (M_i)	Standard Deviation (SD)	Rank
I 1	Rental cost of housing facility in relation to household income	4.196	0.824	5
I 2	Housing price in relation to income of household	4.298	0.749	3
I 3	Maintainability of housing facility	4.283	0.851	4
I 4	End users' satisfaction	4.319	0.980	2
I 5	Functionality of housing facility	4.174	0.789	6
I 6	Other life cycle cost of housing facility	3.933	0.918	11
I 7	Safety performance of housing facility	4.085	0.803	8
I 8	Commuting cost from the location of housing facility to public facilities	3.787	0.999	14
I 9	Quality performance	4.343	0.644	1
I 10	Energy & water efficiency of housing facility	3.915	0.880	12
I 11	Environmental performance of housing facility (Eco-friendly)	4.085	0.803	8
I 12	Aesthetic view of completed housing facility	3.913	0.717	13
I 13	Reduced occurrence of disputes and litigations	3.660	1.027	15
I 14	Stakeholders' / neighborhoods' satisfaction with housing project	3.957	0.833	10
I 15	Technical specification of housing facility	4.128	0.824	7
I 16	Technology transfer	3.468	0.856	16

4.2 Developing A Sustainability Assessment Model

In this study, the FSE technique is the main tool used for developing the sustainability assessment model. Prior to using the FSE, two different levels were established based on the groupings of the various indicators as shown in Fig. I. The four main criteria / groupings, namely, housing and transportation (H+T); household satisfaction, efficient stakeholder management and quality-related criteria are defined as the first level constructs and are represented as C_{H+T}, C_{HSC}, C_{ESM} and C_{QRC}, respectively. However, the indicators under each criterion are termed as second level or secondary constructs (Osei-Kyei & Chan, 2017; Owusu et al., 2019). Both levels could be expressed as follows:

$$C_{H+T} = \{I_{(H+T)1}, I_{(H+T)2}, I_{(H+T)3}, I_{(H+T)4}, I_{(H+T)5}, I_{(H+T)6}, I_{(H+T)7}\}$$

$$C_{HSC} = \{I_{HSC1}, I_{HSC2}, I_{HSC3}\}$$

$$C_{ESM} = \{I_{ESM1}, I_{ESM2}\}$$

$$C_{QRC} = \{I_{QRC1}, I_{QRC2}, I_{QRC3}, I_{QRC4}\}$$

The variables of the secondary level are the input variables for the fuzzy synthetic analysis. For instance, $I_{(H+T)1}$ is an input variable that represents the indicator 'rental cost of housing facility in relation to household income'. It is under the criterion 'housing and transportation' that is denoted as C_{H+T}.

4.3 Determining Input Variables' Weightings

The weightings of an indicator (input variable) denotes its relative significance as rated by the survey respondents. The weightings of the input variables within each of the criteria groupings were estimated using eqn. (1). Recall eqn. (1):

$$W_i = \frac{M_i}{\sum_{i=1}^{k} M_i}, 0 < W_i < 1, \text{and } \sum_{i=1}^{k} W_i = 1 \quad \ldots\ldots\ldots\ldots\text{eqn. (1)}$$

From eqn. 1, the explanation of the variables is given as follows: W_i represents the calculated weighting of an indicator within a particular grouping. This is obtained by dividing the mean score, represented as M_i, of an indicator by the sum of all the means scores within that particular grouping. For instance, using the 'H+T criterion', the weighting of the indicator 'rental cost in relation to household income' is given as

$$W_i = \frac{4.196}{4.196+4.298+3.787+4.283+3.933+3.915+4.085} = \frac{4.196}{28.497} = 0.147$$

Similarly, the weighting of a criterion is calculated by dividing the mean score of that criterion (obtain by summing mean scores of all the indicators under the criterion) by the summation of the mean scores of all the criteria. For instance, the weighting for the 'H+T criterion' is given as

$$W_c = \frac{28.497}{28.497+12.578+7.617+15.852} = \frac{28.497}{64.544} = 0.442$$

Therefore, the weightings of all the other indicators and criteria (shown in Table IV) are calculated using the same approach.

Table IV: Calculated Weightings of Indicators and Criteria

Criteria and their Underlying Indicators	Code	Mean (M_i)	Weightings of Indicator (W_i)	Total Mean of each Criterion (M_c)	Weightings of each Criterion (W_C)
Criterion 1: H + T					
1. Rental cost in relation to household income	I 1	4.196	0.147		
2. Housing price in relation to income of household	I 2	4.298	0.151		
3. Commuting cost from the location of housing to public facilities	I 8	3.787	0.133		
4. Maintainability of housing facility	I 3	4.283	0.150		
5. Other life-cycle cost of housing facility	I 6	3.933	0.138		
6. Energy & water efficiency of housing facility	I 10	3.915	0.137		
7. Environmentally friendliness of housing facility	I 11	4.085	0.143	28.497	0.442
Criterion 2: Household Satisfaction					
1. End user's satisfaction with housing facilities	I 4	4.319	0.343		
2. Functionality of housing facility	I 5	4.174	0.332		
3. Safety performance (crime rate)	I 7	4.085	0.325	12.578	0.195
Criterion 3: Efficient Stakeholder Management					
1. Stakeholders' satisfaction with housing facility / project (neighborhood satisfaction)	I 14	3.957	0.519		
2. Reduced occurrence of dispute and litigation	I 13	3.660	0.481	7.617	0.118
Criterion 4: Quality-Related					
1. Quality performance of project	I 9	4.343	0.274		
2. Aesthetically pleasing view of completed house	I 12	3.913	0.247		
3. Technical specification of housing facilities	I 15	4.128	0.260		
4. Technology transfer	I 16	3.468	0.219	15.852	0.246
Total mean and total weighting values				64.544	1.000

4.4 Determining the Membership Functions of Indicators

Membership functions (i.e. the degree of an element's membership in a fuzzy set) normally ranges between 0 and 1. They are derived from Level 2 to level 1 (Ameyaw & Chan, 2016). This implies that the membership functions of the indicators are obtained first before calculating the membership functions for each of the criteria. Membership functions are obtained from the ratings provided by the respondents in the survey with regard to the 5-point Likert scale (i.e. L_1 = not important to L_5 = very important) (Osei-Kyei & Chan, 2017). For instance, 26.1% of the respondents were neutral with regard to rating 'rental cost of housing in relation to household income'. 28.3% of the respondents rated it as important and 45.7% as very important. Given that $X_{\mathrm{I(H+T)1}}$ is the percentage of responses received per each rating, then the membership function ($MF_{\mathrm{I(H+T)1}}$) for this indicator is given as follows:

$$MF_{\mathrm{I(H+T)1}} = \frac{X_{1\mathrm{I(H+T)1}}}{L_1} + \frac{X_{2\mathrm{I(H+T)1}}}{L_2} + \cdots + \frac{X_{5\mathrm{I(H+T)1}}}{L_5}$$

$$MF_{\mathrm{I(H+T)1}} = \frac{X_{1\mathrm{I(H+T)1}}}{\text{not important}} + \frac{X_{2\mathrm{I(H+T)1}}}{\text{less important}} + \cdots + \frac{X_{5\mathrm{I(H+T)1}}}{\text{very important}}$$

Thus,

$$MF_{\mathrm{I(H+T)1}} = \frac{0.00}{L_1} + \frac{0.00}{L_2} + \frac{0.26}{L_3} + \frac{0.28}{L_4} + \frac{0.46}{L_5}$$

In FSE, the "+" denotes a notation and not an addition (Ameyaw & Chan, 2016). Therefore, the membership function can also be expressed as (0.00, 0.00, 0.26, 0.28, 0.46). Using the same procedure, the membership functions of the remaining 15 indicators can be obtained (shown in Table V).

4.5 Determining the Membership Functions of the Criteria (the Groupings)

Establishing the membership functions of the indicators at Level 2 is the precursor for calculating the membership function for each criterion at Level 1. To do so, recall eqn. (2),

$D = W_i \circ R_i$ .... eqn. (2)

Where W_i = weightings of all indicators within a particular criterion and R_i is the fuzzy evaluation matrix.

For example, using 'H + T criterion', its fuzzy matrix R_{i} can be expressed as

$$R_{\mathrm{i}} = \begin{bmatrix} MF_{\mathrm{I(H+T)1}} \\ MF_{\mathrm{I(H+T)2}} \\ MF_{\mathrm{I(H+T)3}} \\ MF_{\mathrm{I(H+T)4}} \\ MF_{\mathrm{I(H+T)5}} \\ MF_{\mathrm{I(H+T)6}} \\ MF_{\mathrm{I(H+T)7}} \end{bmatrix} = \begin{bmatrix} X_{1\mathrm{I(H+T)1}} & X_{2\mathrm{I(H+T)1}} & X_{3\mathrm{I(H+T)1}} & X_{4\mathrm{I(H+T)1}} & X_{5\mathrm{I(H+T)1}} \\ X_{1\mathrm{I(H+T)2}} & X_{2\mathrm{I(H+T)2}} & X_{3\mathrm{I(H+T)2}} & X_{4\mathrm{I(H+T)2}} & X_{5\mathrm{I(H+T)2}} \\ X_{1\mathrm{I(H+T)3}} & X_{2\mathrm{I(H+T)3}} & X_{3\mathrm{I(H+T)3}} & X_{4\mathrm{I(H+T)3}} & X_{5\mathrm{I(H+T)3}} \\ X_{1\mathrm{I(H+T)4}} & X_{2\mathrm{I(H+T)4}} & X_{3\mathrm{I(H+T)4}} & X_{4\mathrm{I(H+T)4}} & X_{5\mathrm{I(H+T)4}} \\ X_{1\mathrm{I(H+T)5}} & X_{2\mathrm{I(H+T)5}} & X_{3\mathrm{I(H+T)5}} & X_{4\mathrm{I(H+T)5}} & X_{5\mathrm{I(H+T)5}} \\ X_{1\mathrm{I(H+T)6}} & X_{2\mathrm{I(H+T)6}} & X_{3\mathrm{I(H+T)6}} & X_{4\mathrm{I(H+T)6}} & X_{5\mathrm{I(H+T)6}} \\ X_{1\mathrm{I(H+T)7}} & X_{2\mathrm{I(H+T)7}} & X_{3\mathrm{I(H+T)7}} & X_{4\mathrm{I(H+T)7}} & X_{5\mathrm{I(H+T)7}} \end{bmatrix}$$

Where $X_{\mathrm{jI(H+T)\,n}}$ is an element of the fuzzy matrix; it is one of the weighting elements of an indicator. The fuzzy evaluation matrix is then obtained by using the weighting function set of the indicators in the 'H + T criterion' as follows:

$$D_{H+T} = (W_{i1}, W_{i2}, \ldots, W_{in}) \times \begin{bmatrix} X_{1I(H+T)1} & X_{2I(H+T)1} & X_{3I(H+T)1} & X_{4I(H+T)1} & X_{5I(H+T)1} \\ X_{1I(H+T)2} & X_{2I(H+T)2} & X_{3I(H+T)2} & X_{4I(H+T)2} & X_{5I(H+T)2} \\ X_{1I(H+T)3} & X_{2I(H+T)3} & X_{3I(H+T)3} & X_{4I(H+T)3} & X_{5I(H+T)3} \\ X_{1I(H+T)4} & X_{2I(H+T)4} & X_{3I(H+T)4} & X_{4I(H+T)4} & X_{5I(H+T)4} \\ X_{1I(H+T)5} & X_{2I(H+T)5} & X_{3I(H+T)5} & X_{4I(H+T)5} & X_{5I(H+T)5} \\ X_{1I(H+T)6} & X_{2I(H+T)6} & X_{3I(H+T)6} & X_{4I(H+T)6} & X_{5I(H+T)6} \\ X_{1I(H+T)7} & X_{2I(H+T)7} & X_{3I(H+T)7} & X_{4I(H+T)7} & X_{5I(H+T)7} \end{bmatrix}$$

Thus, D_{H+T} of 'H + T criterion', can be calculated as

$$D_{H+T} = (0.147, 0.151, 0.133, 0.150, 0.138, 0.137, 0.143) \times \begin{bmatrix} 0.00 & 0.00 & 0.26 & 0.28 & 0.46 \\ 0.00 & 0.00 & 0.17 & 0.36 & 0.47 \\ 0.02 & 0.09 & 0.23 & 0.40 & 0.26 \\ 0.02 & 0.02 & 0.07 & 0.44 & 0.46 \\ 0.02 & 0.02 & 0.27 & 0.38 & 0.31 \\ 0.02 & 0.02 & 0.23 & 0.47 & 0.26 \\ 0.00 & 0.04 & 0.15 & 0.49 & 0.32 \end{bmatrix}$$

$$= (0.01, 0.03, 0.20, 0.40, \text{ and } 0.37)$$

Similarly, the membership function for the 'household satisfaction criterion' is calculated as follows:

$$D_{HSC} = (0.343, 0.332, 0.325) \times \begin{bmatrix} 0.02 & 0.04 & 0.11 & 0.26 & 0.57 \\ 0.00 & 0.04 & 0.11 & 0.48 & 0.37 \\ 0.02 & 0.00 & 0.13 & 0.45 & 0.41 \end{bmatrix}$$

$$= (0.00, 0.03, 0.12, 0.39, \text{ and } 0.45)$$

Likewise, the membership function for 'efficient stakeholders' management criterion' can be estimated as

$$D_{ESM} = (0.519, 0.481) \times \begin{bmatrix} 0.02 & 0.04 & 0.11 & 0.62 & 0.21 \\ 0.04 & 0.11 & 0.17 & 0.51 & 0.17 \end{bmatrix}$$

$$= (0.03, 0.07, 0.14, 0.57, \text{ and } 0.19)$$

Lastly, the membership function for 'quality-related criterion' can be determined as follows:

$$D_{QRC} = (0.274, 0.247, 0.260, 0.219) \times \begin{bmatrix} 0.00 & 0.00 & 0.07 & 0.38 & 0.55 \\ 0.00 & 0.02 & 0.24 & 0.54 & 0.20 \\ 0.00 & 0.06 & 0.09 & 0.51 & 0.34 \\ 0.04 & 0.04 & 0.38 & 0.47 & 0.06 \end{bmatrix}$$

$$= (0.01, 0.03, 0.19, 0.47, 0.30)$$

Table V: Membership Function of Indicators and Criteria

Criteria	Code	Weightings of each Indicator	MF for Level 2	MF for Level 1	Criteria's Weightings
H + T					
	I 1	0.147	0.00,0.00,0.26,0.28,0.46	0.01,0.03,0.20,0.40,0.37	0.442
	I 2	0.151	0.00,0.00,0.17,0.36,0.47		
	I 8	0.133	0.02,0.09,0.23,0.40,0.26		
	I 3	0.150	0.02,0.02,0.07,0.44,0.46		
	I 6	0.138	0.02,0.02,0.27,0.38,0.31		
	I 10	0.137	0.02,0.02,0.23,0.47,0.26		
	I 11	0.143	0.00,0.04,0.15,0.49,0.32		
Household satisfaction					
	I 4	0.343	0.02,0.04,0.11,0.26,0.57	0.01,0.03,0.12,0.39,0.45	0.195
	I 5	0.332	0.00,0.04,0.11,0.48,0.37		
	I 7	0.325	0.02,0.00,0.13,0.45,0.41		
Efficient Stakeholder Management					
	I 14	0.519	0.02,0.04,0.11,0.62,0.21	0.03,0.07,0.14,0.57,0.19	0.118
	I 13	0.481	0.04,0.11,0.17,0.51,0.17		
Quality-Related					
	I 9	0.274	0.00,0.00,0.07,0.38,0.55	0.01,0.03,0.19,0.47,0.30	0.246
	I 12	0.247	0.00,0.02,0.24,0.54,0.20		
	I 15	0.260	0.00,0.06,0.09,0.51,0.34		
	I 16	0.219	0.04,0.04,0.38,0.47,0.06		

4.6 Determining a Sustainability Assessment Index for Each Criterion

After estimating the membership functions at level 1, the index for each criterion is determined using eqn. (3). For instance, the assessment index (AI) for 'H+T criterion' is calculated as follows: Recall eqn. (3)

$AI_{H+T} = D_n \times L_n = (D_1, D_2, D_3, D_4, D_5) \times (L_1, L_2, L_3, L_4, L_5)$ ……………………....eqn. (3)

Where $D_n = (D_1, D_2, D_3, D_4, D_5)$ is the fuzzy evaluation matrix or MF for level 1 and $L_n = (1, 2, 3, 4, 5)$ is the grade alternative. Thus, the assessment index (AI) for 'H+T criterion' is calculated as follows:

$AI_{H+T} = (0.01, 0.03, 0.20, 0.40, 0.37) \times (1, 2, 3, 4, 5)$
$= 4.087$

Using similar approach, the AI for the other three criteria are computed as follows (shown in Table VI):

$AI_{HSC} = (0.01, 0.03, 0.12, 0.39, 0.45) \times (1, 2, 3, 4, 5)$
$= 4.254$

$AI_{ESM} = (0.03, 0.07, 0.14, 0.57, 0.19) \times (1, 2, 3, 4, 5)$
$= 3.816$

$AI_{QRC} = (0.01, 0.03, 0.19, 0.47, 0.30) \times (1, 2, 3, 4, 5)$
$= 4.023$

Table VI: Assessment Index for the Criteria

No.	Criteria	Criterion's Index	Coefficient[a]
Criterion 1	H+T	4.087	0.253
Criterion 2	Household Satisfaction	4.254	0.263
Criterion 3	Efficient Stakeholders' Management	3.816	0.236
Criterion 4	Quality-Related	4.023	0.249
Total		16.18	1.000

[a]Coefficient = (Criterion Index ⁄ Sum of Indices of all Criteria)

4.7 Developing an Overall Sustainability Assessment Model (SAM) for Affordable Housing

In this study, a linear, additive approach is employed to establish a combined-criterion model for assessing sustainable development in affordable housing. A linear model is chosen to enable the calculation of a composite index or figure that depicts the level of sustainability attainment in an affordable housing facility or project with regard to 'H+T criterion'; 'household satisfaction criterion'; 'efficient stakeholders' management criterion' and 'quality-related criterion'. Similarly, previous studies (Osei-Kyei & Chan, 2017; Hu et al., 2016) developed an assessment index using the linear and additive approach. Prior to establishing the sustainability assessment model, the indices for all the criteria are normalized so that they sum to one (shown in Table VI). The normalized values are the coefficients in the model. Normalizing the indices is important to provide a better reflection of the relative criticality of each criterion in the sustainability assessment model (SAM). Besides, it allows various measurement scale for the criteria to be employed in the model for affordable housing assessment (Osei-Kyei & Chan, 2017). The SAM for affordable housing could therefore be expressed in the following equation:

SAM = 0.253(H+T) + 0.263(Households' Satisfaction) + 0.236 (Efficient Stakeholders management) + 0.249(Quality-related) ……………..…………. eqn. (4)

5. Discussion of Results

In subsequent subsections, a discussion is presented on the various criteria together with their indicators and how each criterion could be assessed.

5.1 Housing and Transportation (H+T)

This criterion has an index of 4.087 and a coefficient of 0.253 (shown in Table VI). Current studies on assessment of affordable housing have developed a composite cost of housing (i.e. rental cost or mortgage or owner rental equivalent, utility cost and other life cycle cost) and transportation cost in relation to household income. Prior studies employed only 'rental cost / price of housing to household income ratio' for measuring housing affordability. The conventional benchmark of housing affordability was that low-income household would spend at most 30% of their income on housing. However, this measure of affordability is limited since it does not include the cost of transportation.

Therefore, with the adoption of the H+T criterion / index, policy makers such as planners could achieve additional sustainable development goals. It could be used to identify suitable locations for sitting affordable housing projects and to advice households on an appropriate housing location for affordable transportation cost. Concerning policies on price increases or decreases on fuel cost, the H+T criterion could be used to evaluate possible cost burden or saving, respectively, on household income. Thus, this criterion could lead to more sustainable development such as economic sustainability (i.e. reduced transportation cost), environmental sustainability (i.e. energy conservation and reduction in pollution emissions) and social sustainability (i.e. improved access to economic opportunities and reduction in accident risks) (Isalou et al., 2014). However, based on its calculated index (shown in Table VI), the H+T criterion accounts for 25.3% of sustainability attainment in affordable housing. Therefore, much will not be accomplished on sustainable development in affordable housing if policy-makers focus solely on the H+T criterion to the neglect of the other criteria.

To assess the 'H+T' performance on SAH, the Center for Neighborhood Technology (CNT) estimated that 15% of household income should be an achievable goal for transportation affordability. Combining the 15% benchmark for transport affordability with the conventional 30% of housing cost on household income results in a 45% benchmark for the H+T criterion (Dewita et al., 2018). The H+T index could be estimated using the following eqn. 5:

$$\mathrm{H+T\ index} = \frac{(\text{housing costs} + \text{Transportation costs})}{\text{Income}} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{eqn. (5)}$$

Housing costs are monthly accommodation expenses of the household. These include rent for tenants or mortgage payment, regular operation cost (including utility bill) and maintenance cost and other lifecycle cost (property tax, neighborhood maintenance fees). For the case of homeownership, the 'owner equivalent rent (OER)' is used in replace of rent for tenants. The OER is an expected rent value that owner-occupants would fetch in the competitive market for their houses. It is calculated by soliciting for the opinion of the owners on the amount they think their housing facility would rent for in the market (Dewita et al., 2018). Regarding transportation, transportation costs are calculated by adding all household's expenses incurred in traveling to work, school, market or shopping, recreation and visiting of relatives or friends (as listed in Table I under sub-indicators of commuting cost). After determining the housing cost and transportation cost, these cost variables are summed up and divided by the monthly household income. The result is then multiplied by 100 to convert the cost to percent. For households who spend at most 45% of their income on both housing and transportation, their housing facilities are considered affordable. Therefore, using the 45% limit as a benchmark, a percentage scale could be developed for allocating points in order to calculate the level of sustainability attainment by the H+T index. The percentage scale is developed based on pro-rata of the 45% benchmark (as shown in Table VII). An H+T that is ≤ 45% of household income is scored 100%. An estimated H+T that is 46-55% of household income, is rated 98-82%. The exact percentage is obtained on pro-rata basis. For instance, the range for 46-55 is calculated as follows:

45 -----> 100%
46 -----> ?
46 -----> 98%

Similarly,

45 -----> 100%
55-----> ?
55-----> 82%

After determining the points (%) to be allocated, its H+T index is obtained by multiplying the appropriate point (in %) by the estimated weight i.e. (0.253 x (H+T point in %). For example, if a household spends ≤ 45% of their income on housing and transportation, the points (in %) to be allocated will be 100 and the overall sustainability attainment by the H+T criterion will be calculated as

H+T Index = (0.253 x (H+T)) = (0.253 x (100%)) = 25.3%

Table VII: Scale for Assessing H + T Index in SAH

Scale	Points (in %) to be awarded
≤ 45	100
46 - 55	98 - 82
56 - 65	80 - 69
66 - 75	68 - 60
76 - 85	59 - 53
≥ 86	≤ 52

5.2 Household Satisfaction

This criterion has the highest index of 4.254 and a coefficient of 0.263. Household satisfaction is one of the relevant and subjective criteria in post-construction evaluation of affordable housing facility. Assessing residential satisfaction enables decision makers to develop successful housing policies for the attainment of social sustainability (Riazi & Emami, 2018). The household satisfaction criterion consists of three main indicators: end user's satisfaction with the housing facility and infrastructure (or supplementary facilities), functionality of housing facility and safety performance (crime rate). These three-main indicators account for 26.3% of sustainability attainment in affordable housing. The importance of this criterion could be evinced in low take-up rate of housing facilities due to the neglect of end user's needs at the design stage of housing projects. This problem could be attributed to the speculative nature of affordable housing projects. Decision on land acquisition, housing design and construction are mostly made without the participation of the target households (Ahadzie et al., 2008; Chan & Adabre, 2019).

To quantify this criterion, it is important to identify the variables which determine household satisfaction. Residential satisfaction of low-income households is derived from the availability of public facilities within the housing environs (Addo, 2016). Some of these facilities are listed as sub-indicators in Table I. Besides, safety and security of households influence residential satisfaction (Mohit et al., 2010; Tan, 2012). Variables such as 'safety of indoor space', 'safety of outdoor space', 'lighting of public areas', 'private open space' and 'the number of burglary / theft incidents in housing facilities or neighborhood' could provide adequate information for measuring the level of safety of households within their housing facility and their surroundings (Riazi & Emami, 2018; Hino & Amemiya, 2019). Moreover, the indicator – 'functionality of the housing unit' – could provide essential information for assessing household satisfaction. Functionality of a housing facility measures the adequacy of housing facility in meeting the current and evolving needs of households (adaptable design to prevent unsafe building appendages). It includes the availability of adequate physical amenities such as a sizable bathroom, sizable floor, adequate sanitary facilities (such as septic tank and garbage collection facility) (as listed in Table I) (Acolin & Green, 2017). Adequate functionality of a housing facility could prevent residential mobility, which could lead to housing abandonment. Most households abandon or make housing relocation decision because of 'lack of fit' of housing facility to meet their needs. 'Lack of fit' challenges are caused by changes in households' demographic factors such as age, household size, prestige etc., which can lead to households' dissatisfaction with current housing facility (Riazi & Emami, 2018).

To determine the level of sustainability attainment by household satisfaction, households' as respondents could be asked to indicate their satisfaction level on facilities within their environment, satisfaction level on safety features in the housing facility and their environment and their satisfaction level on the functionality variables (as listed in Table I). Satisfaction level could be rated using a 5-point Likert scale from 1(very dissatisfied) to 5 (very satisfied). The satisfaction score can then be calculated by adding up all scores on the various features / variables from the ratings of respondents. Then, the total scores obtained from the Likert scale is divided by the maximum possible total score and the result is multiplied by 100 to obtain a percentage score for households' satisfaction (Ogu, 2002). Afterward, the level of sustainability attainment by the household satisfaction is obtained by multiplying the coefficient of the satisfaction criterion by the percentage score for household satisfaction i.e. (0.265 x Households' percentage satisfaction score). The satisfaction percentage score can be calculated by using eqn. (6) as provided in Ogu (2002):

$$HSV = \frac{\sum_{i=1}^{N} y^i}{\sum_{i=1}^{N} Y^i} \times 100 \qquad \text{eqn. (6)}$$

Where HSV is the household satisfaction value (in percent) of a respondent, N is the number of variables being scaled, y^i is the actual score by a respondent on the ith variable and Y^i is the maximum possible score that *i* could have on the scale used (Addo, 2016; Mohit, et al., 2010).

5.3 Efficient Stakeholder's Management

This criterion has the lowest index of 3.816 and has a coefficient of 0.236. Two main indicators were used to determine the weight of efficient stakeholders' management (i.e. stakeholders' or neighborhoods' satisfaction and reduced occurrence of dispute / litigations). Attaining these indicators in affordable housing accounts for 23.6% of sustainability performance in affordable housing facilities or projects. Without adequate policies, social sustainability attainment in affordable housing could be affected (Chan & Adabre, 2019).

Aside stakeholders (such as government, developers, design team and households), residents in the neighborhood where an affordable housing facility is sited play a significant role in social sustainability attainment. According to Berardi (2011), tackling the social dimension of sustainable development entails contextual design of housing facility and linking the housing facility to its neighbourhood. This could be achieved by providing adequate facilities within the housing environs to encourage interaction among households and their neighbours. 'Interaction with neighbours' could positively affect residential satisfaction. For instance, Riazi & Emami (2018) confirmed that among three determinants of residential satisfaction such as 'design principles', 'interaction with neighbours' and 'planning policies', 'interaction with neighbours' was the most dominant influencing factor. Besides, effective interaction among households and residents in the neighborhood enhances their health and well-being by reducing depression (Yung et al., 2017).

To assess this criterion, the availability and the design features of parks and open spaces in the environs of the housing facility should be considered. Parks should be evaluated based on multiplicity of purpose with the following incorporated-relevant features: children play area, fitness area / facilities, multi-purpose plaza, pavilion, better integration of cultural heritage into design, cafeteria / refreshment kiosk, sanitary facilities, adequate lighting and Wi-Fi connections (Yung et al., 2016). Importantly, these amenities promote cross-generation integration in parks, which enhances social ties and satisfaction to a variety of stakeholders. Efficient stakeholder management could also be assessed by finding out the impact of an affordable housing facility on the neighboring housing facilities or community. Impact variables could include: effects of affordable housing facility on prices / rent of neighboring housing facilities or properties; possibilities of congestion on existing social amenities or infrastructure; crime rate within neighboring community; level of disputes / cordial interaction among residents in the neighborhood and households of the affordable housing facilities and fear of insecurity and noise level in the neighborhood (listed in Table I).

The presence and impact level of various variables for 'efficient stakeholder's management' (i.e. parks and open spaces, variables on 'occurrence of dispute or litigation' and impact variables of housing facility on neighborhood) could be rated on a Likert scale by some randomly selected residents in the neighborhood. Then, a percentage score of 'efficient stakeholder management' could be determined by using a similar approach as in eqn. (6). Afterwards, the level of sustainability attainment by efficient stakeholder management is obtained by multiplying its coefficient by the percentage score i.e. (0.236 x percentage score of efficient Stakeholder's Management).

5.4 Quality-Related Criterion

This criterion has a success index of 4.023, and a coefficient of 0.249. The scores of four main indicators, namely, 'quality performance'; 'aesthetic view of housing facility'; 'technical specifications or performance outputs' and 'technology transfer' were used to estimate an index of 4.023 for quality-related criterion. It accounts for 24.9% of sustainability attainment in affordable housing.

Housing quality can be assessed using both subjective and objective approaches. Subjective assessment includes perception and aspiration which are related to the psychosocial aspect of households (Mohit et al., 2010). The subjective description of quality is based on aesthetic of the housing facility. It could be assessed by finding out 'how well a housing facility blends with its environment', 'the psychological impact of the housing facility on the households, neighbouring residents and existing facilities' and 'the ability of landscaping plan to match the theme of nearby structures' and 'interesting design models that capture people's imagination' (Stasiowski and Burstein, 1994; Chan & Adabre, 2019). Aesthetic view of a housing facility enhances the pride / sense of place attachment and could encourage residential stability

(Eizenberg & Jabareen, 2017). A housing facility that meets the aesthetic expectation / aspiration of a household attains quality in perception.

The objective assessment of housing quality entails evaluating the quality of indoor and outdoor environment (adequate ventilation), quality of the materials and the specification outputs (or performance output). A facility that attains its technical requirement / specification output is said to have achieved 'quality in fact' (Arditi & Gunaydin, 1997). By ensuring material / product quality and construction or process quality, 'quality in fact' can be achieved in affordable housing facilities (Arditi & Gunaydin, 1997). Whereas 'product quality' is ensuring appropriate equipment and technology for construction and the use of suitable construction materials, 'process quality' includes attaining quality in the design and construction of the housing facility (Chan & Adabre, 2019).

In assessing the quality of materials for SAH, emphasis should be placed on circular economy and environmental impact of the construction materials. Circular economy involves the production and consumption of construction materials in closed loop material flows that internalize environmental externalities linked to virgin resource extraction and waste production (including pollution) (Pomponi & Moncaster, 2017). It takes into consideration impact of resource consumption and impact of waste on the environment. Circular economy ensures that post-consumption construction products get reintegrated upstream into the manufacturing process. This ensures efficient management of resources, which leads to a reduction in energy usage, CO_2 emissions and waste production.

For circular economy, materials should be assessed based on 'how easily they can be dismantled, demolished and recycled / reuse'; 'how effluent generated from demolition could serve as raw materials for other work' and 'how materials used for housing facilities could be recoverable for reuse' (Sauvé et al., 2016; Pomponi & Moncaster, 2017). For instance, at the micro-level, manufactured products / components (e.g. blocks and façade elements) should be such that they can be dismantled without much waste generation. Besides, quality of material assessment should include environmental impact of the materials on greenhouse gas emission, human toxicity, eco-toxicity to water and soil acidification and eutrophication.

Thus, by assessing the various variables concerning 'aesthetic view of housing facility', 'quality of materials', 'technical specification or performance output' and 'technology transfer or innovation' from the views of experts (such as architects, developers and materials engineers), a percentage score for the 'quality-related criterion' could be computed using eqn. (6). Then, the level of sustainability attainment by the 'quality-related criterion' is estimated by multiplying its coefficient by its percentage score (0.249 x percentage score of quality-related criterion).

5.5 Application of the Model to Affordable Housing Projects / Public Housing & Upgrading of Slum Communities

From the estimated indices of the various criteria, 'household-satisfaction' criterion should be the highest priority in resource allocation among policymakers. Resources should be allocated for ensuring adequate design and construction of housing facilities, safety facilities, adequate sanitary facilities (i.e. adequate drainage system, waste management / disposal) and the other facilities as listed in Table I under 'household satisfaction'. Availability of these facilities in affordable housing / public housing projects and slum communities has the greatest contribution (26.3%) to sustainable development. The next criterion of focus among policy-makers should be housing and transportation cost (H + T). This entails improving price or rental affordability of housing, accessibility to facilities, energy efficient design and circular economy (as stated in Table I). This criterion has the second highest contribution (25.3%) to sustainable development. Furthermore, resource allocation on sub-indicators of 'quality-related' criterion should be given greater priority than the sub-indicators of 'efficient stakeholder management' (sub-indicators are listed in Table I). This is based on the greater contribution that 'quality-related' criterion (24.9%) has over 'efficient stakeholder management' criterion (23.6%) toward sustainable development.

6. Conclusion

This study established a comprehensive model for assessing sustainability performance in affordable housing from the Ghanaian perspective. The sustainability model is an evaluation tool which accounts for the economic, social and environmental goals for sustainable low-cost housing. Through an extensive literature review, it was concluded that there is no assessment model for evaluating the various aspects of sustainable development in affordable housing in the Ghanaian construction industry. Besides, some of the key indicators that are relevant for developing a sustainability assessment model were identified from the literature review. Subsequently, a set of indicators for SAH were established for data collection using a questionnaire survey.

Through a questionnaire survey among respondents in the Ghanaian housing sector, data were collected and analyzed using mean score ranking and fuzzy synthetic evaluation (FSE). The research findings revealed that though environmental-related indicators (e.g. energy efficiency and eco-friendliness of housing facilities) are important, social sustainability indicators (i.e. end-users' satisfaction of housing facility, functionality of housing facility, safety, quality of housing) and economic sustainability indicators (i.e. price / rental cost of housing facilities) are rated higher concerning affordable housing. Besides, the indicators were used to develop a sustainability assessment model (SAM). The model consists of four main indices: housing and transportation (H+T) index; household satisfaction index; efficient stakeholder management index and quality-related index. These indices account for 25.3%, 26.3%, 23.6% and 24.9% of sustainability attainment in affordable housing, respectively. Among these indices, household satisfaction index accounts for the highest contribution to sustainability attainment in affordable housing from the Ghanaian perspective. A combined linear and additive model was developed to provide a composite sustainability index for SAH.

This study has some limitations which are worth stating. Data were collected from only respondents in the Ghanaian housing market. Therefore, the findings cannot be generalized to other developing and developed countries. Besides, the views of households on public housing facilities were excluded. Therefore, future study could provide a comprehensive view from the perspective of households concerning the various sustainability indicators. This could resolve problems of information asymmetry in the Ghanaian housing market. Finally, the manual computation of the criteria's indices is laborious. Future study could develop a software to expedite the computation process in determining the various indices. Like CASBEE-UD in which the weighted scores of sub-criteria are aggregated to give the total score of the criteria, future study could determine weights for the sub-indicators towards developing the final scores for the criteria.

Albeit the study's limitations, its findings have some practical applications worth stating. Unlike the HQE^2R and Ecocity, the model developed in this study could provide an aggregate index of sustainability attainment in affordable housing. The estimated index could provide a snapshot of the sustainability level of an affordable housing facility; it could also serve as a decision-aid tool for evaluating policies on SAH and slum communities. The model could help developers and housing authorities in assessing affordable housing facilities before and after embarking on green-retrofitting. Both stages could then be compared by using the assessment model to calculate their sustainability indices. This could inform decision making on subsequent retrofitting activities on projects. Moreover, public housing authorities and real estate developers could deploy this model to measure, to monitor and to effectively allocate resources for upgrading current sustainability performance of housing facilities. Finally, the model could serve as a point of reference for future study to develop the utmost sustainability assessment model for affordable / public housing projects and for upgrading slums. Using the model, future study could also deploy case studies of public housing facilities in the Ghanaian construction industry to assess their sustainability attainment.

References

Acolin, A., & Green, R. K. (2017). Measuring housing affordability in São Paulo metropolitan region: Incorporating location. *Cities*, *62*, 41-49.

Adabre, M.A. and Chan, A.P., 2018. The ends required to justify the means for sustainable affordable housing: A review on critical success criteria. *Sustainable Development*, 26, 1-14.

Adabre, M.A. and Chan, A.P., 2019. Critical success factors (CSFs) for sustainable affordable housing. *Building and Environment*, *156*, pp.203-214.

Addo, I.A., 2016. Assessing residential satisfaction among low income households in multi-habited dwellings in selected low income communities in Accra. *Urban Studies*, *53*(4), pp.631-650.

Ahadzie, D.K., Proverbs, D.G. and Olomolaiye, P.O., 2008. Critical success criteria for mass house building projects in developing countries. *International Journal of Project Management*, *26*(6), pp.675-687.

Ameen, R.F.M. and Mourshed, M., 2019. Urban sustainability assessment framework development: The ranking and weighting of sustainability indicators using analytic hierarchy process. *Sustainable Cities and Society*, *44*, pp.356-366.

Ameyaw, E.E. and Chan, A.P., 2016. A fuzzy approach for the allocation of risks in public–private partnership water-infrastructure projects in developing countries. *Journal of Infrastructure Systems*, *22*(3), p.04016016.

Ansah, M. K., Chen, X., Yang, H., Lu, L., & Lam, P. T. (2020). An integrated life cycle assessment of different façade systems for a typical residential building in Ghana. *Sustainable Cities and Society*, *53*, 101974.

Arditi, D. and Gunaydin, H.M., 1997. Total quality management in the construction process. *International Journal of Project Management*, *15*(4), pp.235-243.

Ashley, D.B., Lurie, C.S. and Jaselskis, E.J., 1987. Determinants of construction project success. Project Management Institute.

Asumadu-Sarkodie, S. and Owusu, P.A., 2016. A review of Ghana’s energy sector national energy statistics and policy framework. *Cogent Engineering*, *3*(1), p.1155274.

Atanda, J.O., 2019. Developing a social sustainability assessment framework. *Sustainable Cities and Society*, *44*, pp.237-252.

Atkinson, R., 1999. Project management: cost, time and quality, two best guesses and a phenomenon, its time to accept other success criteria. *International journal of project management*, *17*(6), pp.337-342.

Awadh, O., 2017. Sustainability and green building rating systems: LEED, BREEAM, GSAS and Estidama critical analysis. *Journal of Building Engineering*, *11*, pp.25-29.

Berardi, U., 2011. Beyond sustainability assessment systems: Upgrading topics by enlarging the scale of assessment. *International Journal of Sustainable Building Technology and Urban Development*, *2*(4), pp.276-282.

Casquero-Modrego, N. and Goñi-Modrego, M., 2019. Energy retrofit of an existing affordable building envelope in Spain, case study. *Sustainable Cities and Society*, *44*, pp.395-405.

Chan, A.P. and Adabre, M.A., 2019. Bridging the gap between sustainable housing and affordable housing: The required critical success criteria (CSC). *Building and Environment*, *151*, pp.112-125.

Chan, A.P. and Chan, A.P., 2004. Key performance indicators for measuring construction success. *Benchmarking: an international journal*, *11*(2), pp.203-221.

Chan, A.P., Scott, D. and Lam, E.W., 2002. Framework of success criteria for design/build projects. *Journal of management in engineering*, *18*(3), pp.120-128.

Chua, D.K.H., Kog, Y.C. and Loh, P.K., 1999. Critical success factors for different project objectives. *Journal of construction engineering and management*, *125*(3), pp.142-150.

Cox, R.F., Issa, R.R. and Ahrens, D., 2003. Management's perception of key performance indicators for construction. *Journal of construction engineering and management*, *129*(2), pp.142-151.

Cox, W., Pavletich, H. and Hartwich, O., 2017. 13th annual demographia international housing affordability survey: 2017.

Darko, A., Chan, A. P. C., Yang, Y., Shan, M., He, B. J., & Gou, Z. (2018). Influences of barriers, drivers, and promotion strategies on green building technologies adoption in developing countries: The Ghanaian case. *Journal of Cleaner Production*, *200*, 687-703.

Dewita, Y., Yen, B.T. and Burke, M., 2018. The effect of transport cost on housing affordability: Experiences from the Bandung Metropolitan Area, Indonesia. *Land use policy*, *79*, pp.507-519.

Eizenberg, E. and Jabareen, Y., 2017. Social sustainability: A new conceptual framework. *Sustainability*, *9*(1), p.68.

Ezennia, I. S., & Hoskara, S. O. (2019). Exploring the Severity of Factors Influencing Sustainable Affordable Housing Choice: Evidence from Abuja, Nigeria. *Sustainability*, *11*(20), 5792.

Fenner, R.A. and Ryce, T., 2008, March. A comparative analysis of two building rating systems Part 1: Evaluation. In *Proceedings of the Institution of Civil Engineers-Engineering Sustainability* (Vol. 161, No. 1, pp. 55-63). Thomas Telford Ltd.

Haapio, A. (2012). Towards sustainable urban communities. *Environmental Impact Assessment Review*, *32*(1), 165-169.

Haider, H., Hewage, K., Umer, A., Ruparathna, R., Chhipi-Shrestha, G., Culver, K., Holland, M., Kay, J. and Sadiq, R., 2018. Sustainability assessment framework for small-sized urban neighbourhoods: An application of fuzzy synthetic evaluation. *Sustainable cities and society*, *36*, pp.21-32.

Hamid, Z.A., Roslan, A.F., Ali, M.C., Hung, F.C., Noor, M.S.M. and Kilau, N.M., 2014. Towards a national green building rating system for Malaysia. *Malaysian Constr. Res. J*, *14*, pp.0-16.

Hino, K., & Amemiya, M. (2019). Spatiotemporal analysis of burglary in multifamily housing in Fukuoka City, Japan. *Cities*, *90*, 15-23.

Hoxley, M., 2008. Questionnaire design and factor analysis.

Hsu, T.H. and Yang, T.S., 1997. The application of fuzzy synthetic decision to the human resource management. *Fu Jen Management Review*, *4*(2), pp.85-100.

Hu, Y., Chan, A.P., Le, Y., Xu, Y. and Shan, M., 2016. Developing a program organization performance index for delivering construction megaprojects in China: fuzzy synthetic evaluation analysis. *Journal of Management in Engineering*, *32*(4), p.05016007.

Huang, L., Krigsvoll, G., Johansen, F., Liu, Y. and Zhang, X., 2018. Carbon emission of global construction sector. *Renewable and Sustainable Energy Reviews*, *81*, pp.1906-1916.

Illankoon, I.C.S., Tam, V.W., Le, K.N. and Shen, L., 2017. Key credit criteria among international green building rating tools. *Journal of cleaner production*, *164*, pp.209-220.

Isalou, A.A., Litman, T. and Shahmoradi, B., 2014. Testing the housing and transportation affordability index in a developing world context: A sustainability comparison of central and suburban districts in Qom, Iran. *Transport policy*, *33*, pp.33-39.

Kamal Mohammad Attia, M. (2013). LEED as a tool for enhancing affordable housing sustainability in Saudi Arabia: The case of Al-Ghala project. *Smart and Sustainable Built Environment*, *2*(3), 224-250.

Lechtenböhmer, S. and Schüring, A., 2011. The potential for large-scale savings from insulating residential buildings in the EU. *Energy efficiency*, *4*(2), pp.257-270.

Lim, C.S. and Mohamed, M.Z., 1999. Criteria of project success: an exploratory re-examination. *International journal of project management*, *17*(4), pp.243-248.

Lin, Y.J., Chang, C.O. and Chen, C.L., 2014. Why homebuyers have a high housing affordability problem: Quantile regression analysis. *Habitat International*, *43*, pp.41-47.

Liu, G., 2014. Development of a general sustainability indicator for renewable energy systems: a review. *Renewable and sustainable energy reviews*, *31*, pp.611-621.

Liu, J., Li, Q. and Wang, Y., 2013. Risk analysis in ultra deep scientific drilling project—A fuzzy synthetic evaluation approach. *International Journal of Project Management*, *31*(3), pp.449-458.

Lützkendorf, T. and Lorenz, D.P., 2006. Using an integrated performance approach in building assessment tools. *Building Research & Information*, *34*(4), pp.334-356.

Mattoni, B., Guattari, C., Evangelisti, L., Bisegna, F., Gori, P. and Asdrubali, F., 2018. Critical review and methodological approach to evaluate the differences among international green building rating tools. *Renewable and Sustainable Energy Reviews*, *82*, pp.950-960.

Mohit, M.A., Ibrahim, M. and Rashid, Y.R., 2010. Assessment of residential satisfaction in newly designed public low-cost housing in Kuala Lumpur, Malaysia. *Habitat international*, *34*(1), pp.18-27.

Moussaoui, F., Cherrared, M., Kacimi, M. A., & Belarbi, R. (2018). A genetic algorithm to optimize consistency ratio in AHP method for energy performance assessment of residential buildings—Application of top-down and bottom-up approaches in Algerian case study. *Sustainable Cities and Society*, *42*, 622-636.

Mulliner, E., Smallbone, K. and Maliene, V., 2013. An assessment of sustainable housing affordability using a multiple criteria decision making method. *Omega*, *41*(2), pp.270-279.

Obeng-Odoom, F. (2010). An urban twist to politics in Ghana. *Habitat International*, *34*(4), 392-399.

Ogu, V. I. (2002). Urban residential satisfaction and the planning implications in a developing world context: The example of Benin City, Nigeria. *International Planning Studies*, *7*(1), 37-53.

Osei-Kyei, R. and Chan, A.P., 2017. Developing a project success index for public–private partnership projects in developing countries. *Journal of Infrastructure Systems*, *23*(4), p.04017028.

Owusu, E.K., Chan, A.P. and Ameyaw, E., 2019. Toward a cleaner project procurement: Evaluation of construction projects' vulnerability to corruption in developing countries. *Journal of cleaner production*, *216*, pp.394-407.

Pomponi, F. and Moncaster, A., 2017. Circular economy for the built environment: A research framework. *Journal of Cleaner Production*, *143*, pp.710-718.

Pullen, S., Arman, M., Zillante, G., Zuo, J., Chileshe, N., & Wilson, L. (2010). Developing an assessment framework for affordable and sustainable housing. *Australasian Journal of Construction Economics and Building, The*, *10*(1/2), 60.

Rahdari, A.H. and Rostamy, A.A.A., 2015. Designing a general set of sustainability indicators at the corporate level. *Journal of Cleaner Production*, *108*, pp.757-771.

Riazi, M. and Emami, A., 2018. Residential satisfaction in affordable housing: A mixed method study. *Cities*, *82*, pp.1-9.

Roufechaei, K.M., Bakar, A.H.A. and Tabassi, A.A., 2014. Energy-efficient design for sustainable housing development. *Journal of Cleaner Production*, *65*, pp.380-388.

Saidu, A. I., & Yeom, C. (2020). Success Criteria Evaluation for a Sustainable and Affordable Housing Model: A Case for Improving Household Welfare in Nigeria Cities. *Sustainability*, *12*(2), 656.

Sauvé, S., Bernard, S. and Sloan, P., 2016. Environmental sciences, sustainable development and circular economy: Alternative concepts for trans-disciplinary research. *Environmental Development*, *17*, pp.48-56.

Shan, M. and Hwang, B.G., 2018. Green building rating systems: Global reviews of practices and research efforts. *Sustainable cities and society*, *39*, pp.172-180.

Sharifi, A., & Murayama, A. (2013). A critical review of seven selected neighbourhood sustainability assessment tools. *Environmental Impact Assessment Review*, *38*, 73-87.

Stasiowski, F. A., & Burstein, D. (1994). *Total quality project management for the design firm: How to improve quality, increase sales, and reduce costs*. John Wiley & Sons.

Stone, M. E. (2006). What is housing affordability? The case for the residual income approach. *Housing policy debate*, *17*(1), 151-184.

Sullivan, E. and Ward, P.M., 2012. Sustainable housing applications and policies for low-income self-build and housing rehab. *Habitat International*, *36*(2), pp.312-323.

Sustainable Cities International., 2012. Indicators for Sustainability: How Cities Are Monitoring and Evaluating Their Success.

Tan, T.H., 2012. Meeting first-time buyers' housing needs and preferences in greater Kuala Lumpur. *Cities*, *29*(6), pp.389-396.

Teck-Hong, T. (2012). Housing satisfaction in medium-and high-cost housing: The case of Greater Kuala Lumpur, Malaysia. *Habitat International*, *36*(1), 108-116.

Tupenaite, L., Lill, I., Geipele, I., & Naimaviciene, J. (2017). Ranking of sustainability indicators for assessment of the new housing development projects: Case of the Baltic States. *Resources*, *6*(4), 55.

Winston, N., 2010. Regeneration for sustainable communities? Barriers to implementing sustainable housing in urban areas. *Sustainable Development*, *18*(6), pp.319-330.

Ye, L., Cheng, Z., Wang, Q., Lin, H., Lin, C. and Liu, B., 2015. Developments of green building standards in China. *Renewable Energy*, *73*, pp.115-122.

Yung, E.H., Conejos, S. and Chan, E.H., 2016. Social needs of the elderly and active aging in public open spaces in urban renewal. *Cities*, *52*, pp.114-122.

Yung, E.H.K., Ho, W.K.O., & Chan, E.H.W. 2017. Elderly satisfaction with planning and design of public parks in high density old districts: An ordered logit model. *Landscape and Urban Planning*, *165*, 39-53.

Zadeh, L.A., 1965. Fuzzy sets. *Information and control*, *8*(3), pp.338-353.

Zeng, W., Rees, P., & Xiang, L. (2019). Do residents of Affordable Housing Communities in China suffer from relative accessibility deprivation? A case study of Nanjing. *Cities*, *90*, 141-156.

Zhao, X., Hwang, B.G. and Gao, Y., 2016. A fuzzy synthetic evaluation approach for risk assessment: a case of Singapore's green projects. *Journal of Cleaner Production*, *115*, pp.203-213.

Zuo, J. and Zhao, Z.Y., 2014. Green building research–current status and future agenda: A review. *Renewable and sustainable energy reviews*, *30*, pp.271-281.