# Modelling the Impact of Barriers on Sustainable Housing in Developing Countries

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## Abstract

Sustainable housing has been an overarching goal globally, and Ghana is no exception vis-à-vis the country's energy and housing affordability challenges particularly in cities. Yet, its implementation has been plagued by barriers. This study assesses the influence of barriers on sustainable housing in Ghana. Forty-seven valid responses were obtained from questionnaire survey. Confirmatory factor analysis validated three main groupings of barriers: 'cost-related', 'incentive-related' and 'retrofit-related'. Partial least square structural equation modelling (PLS-SEM) of the responses showed that 'incentive-related barriers' have medium effect size (0.192) on 'sustainable housing' while 'retrofit-related barriers' have high effect size (0.430) on 'sustainable housing'. Furthermore, 'incentive-related barriers' have a significant impact on 'retrofit-related barriers'. 'Cost-related barriers' only had a significant impact on 'incentive-related barriers'. Accordingly, 'cost-related barriers' are secondary barriers to sustainable housing. The findings apprise policy-makers of barriers that require efficient resource allocation for sustainable housing for sustainable built environment.

**Keywords:** Sustainable Housing; Affordable Housing; Barriers; Indicators; PLS-SEM; Affordability

## Introduction

Policymakers and practitioners worldwide are advocating for sustainable development. This is in line with the need to abate environmental problems (i.e. greenhouse gas emissions) and to improve the standard of living of all income categories through economic development and social equity. Towards these sustainable development goals, one of the fundamental areas of focus has been housing. Thus, sustainable housing has become a policy goal globally with much emphasis on developing countries because of under development and imminent socio-economic problems. The pursuit for sustainable housing is evinced in the United Nations (UN) policy goal. Target 11.1 of the Sustainable Development Goal II states: 'By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums' (UN, n.d.). Ghana – a developing country – is no exception from this clarion call considering the country's housing affordability challenges, energy crisis and expected escalation of greenhouse gas emissions (Arku et al., 2012; Djokoto et al. 2014; Gyamfi et al., 2018).

Inadequate housing supply and housing affordability challenges are critical problems in major cities in Ghana. Estimated extra dwellings of 2,755,000 are required over 2000 in 2020 to curb the housing crisis in urban areas (Ghana Housing Profile, UN-Habitat, 2011). Accra, the nation's capital, suffers the most egregious housing shortage because of a continual flow of migrants and current influx of non-Ghanaian residents (Luginaah et al. 2010). The inadequate supply of housing has led to a high level of overcrowding, mainly in the poorest neighborhoods (Arku et al., 2012). Approximately 60 per cent of the residents in Accra and other urban households live in single rooms (Ghana Housing Profile, UN-Habitat, 2011). A study conducted by Arku et al. (2012) revealed the crisis in Ghana's rental market of which tenants expressed profound concerns about long-term advance rents, rising rent costs, threats of eviction, breaches of rental agreements and long searches for units. As such, it has been pressing on current and successive governments to embark on innovative measures of housing supply to meet the increasing Ghanaian population in most cities especially in Accra.

Compounding the housing affordability challenge is energy crisis. For instance, about 25% shortage of peak power was reported in 2014 - 2015. Besides, though the annual energy demand growth is estimated to be 10%, the installed capacity of the country has grown by only 7% (Gyamfi et al., 2018). Partly responsible for this energy supply-demand hiccup is increasing burden on the national grid with inefficient electrical appliances by households (Gyamfi et al., 2018). Consequently, there is an imbalance between demand and supply of electric power. This is evinced in the frequent interruptions in electric power supply (load shedding) and total blackout in some occasions (Diawuo et al., 2019). Moreover, rapid economic development in Ghana towards middle-income status has led to increase per capital income (Gyamfi et al., 2018). Therefore, the number of households who can afford major appliances is expected to increase (Diawuo et al., 2019). Speculatively, the energy gap could even be wider due to the economic development and population growth (Sakah et al., 2019).

Considering the housing affordability and residential energy crises, governments' strides to provide sustainable housing could have immense benefits. Sustainable housing refers to housing that is reasonably adequate in standard and location for a whole range of households and does not cost so much that a household is unlikely to meet other basic living costs on a sustainable basis (National Summit on Housing Affordable, 2006). In addition to alleviating the negative effects of the country's housing price / rent affordability challenges, energy crisis and greenhouse gas emissions, sustainable housing could improve the quality of life and enhance residents' health. It could also lead to cost saving to households over the lifecycle of the housing facility (Birkeland, 2012; Ansah et al., 2020). However, attaining these potential benefits of sustainable housing has been marred by barriers. Successive governments in the past decades made commitments for aiding parastatal organizations such as State Housing Cooperation (SHC), Tema Development Cooperation (TDC) and Social Security and National Insurance Trust (SSNIT) to improve supply in public housing (i.e. a form of housing tenure in which the facility is fully owned by a government authority or assigned organization). Some of these houses are often tagged by varied forms of names such as 'public housing', 'state housing', 'affordable housing' or 'low-cost housing'. Notwithstanding the essence of such governments' role, Arku et al. (2012) acknowledged that such commitments faltered since the early 1990s. Although most of these institutions now operate as private institutions following neoliberalization in the 1990s, the state mostly provides an enabling environment. One of the enablers provided by governments is the financing of infrastructure development to motivate housing supply. Besides, some of the institutions that assist the private sector in housing delivery are relatively strengthened. Moreover, various incentive schemes have been provided by the state; some of which are available to private developers such as the Ghana Real Estate Developers Association (GREDA) and suppliers of locally produced building materials. An example is tax enticement (i.e. reduction of corporate tax from 55 per cent to 45 per cent, a five-year tax holiday) (Arku, 2009). Despite the state's largess, housing supply among most of these formal institutions have only remained at most 10%. On energy efficient housing, retrofitting incentives from successive governments have also not been adequate to curb the energy crisis of households. Therefore, assessing the impact of barriers is important to better developing policies for sustainable housing in the Ghanaian construction industry (Adabre et al., 2020).

This study seeks to develop a sustainable housing model by establishing a relationship between barriers and indicators of sustainable housing. The study findings could inform the government and other decision makers on the potential barriers and the possible strategies for sustainable housing. Besides, findings of the study seek to apprise policy-makers of the indicators that are relevant for defining the scope of sustainable housing in the Ghanaian housing sector. This study is organized as follows: It begins with an elaboration on the housing affordability and energy crises in Ghana. Then, indicators of sustainable housing and barriers to sustainable housing are identified from a comprehensive literature review. Next, through a questionnaire survey, data are collected on the potential indicators and barriers. Subsequently, the data are analyzed. This is followed by a discussion on the results and drawing conclusion and recommendations to policymakers and practitioners for sustainable housing development especially in urban areas.

## Literature Review

Studies have espoused the triple-bottom-line (TBL) approach to explain the concept of sustainability. The TBL principle includes the environment, economic and social facets of sustainable development (Yang & Yang, 2015). Thus, sustainable housing seeks to optimize the environmental, economic and social goals. Additionally, contemporary studies have advocated for an institutional or governance element as the fourth dimension to facilitate the execution of sustainable housing (Adabre et al., 2020). Various concepts such as ‘low-carbon’, ‘zero-energy’, ‘green building’ and ‘high performance’ have been used to describe sustainable housing. A general definition according to the National Summit on Housing Affordable (2006) indicates that sustainable housing 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 demands.

Subsequently, the UN-Habitat (2012 p. 9) cited in Smets & van Linder (2016) provided a comprehensive definition of sustainable housing. Sustainable housing includes: 'houses that are designed, constructed and managed as quality and safe facilities; price or rental affordable for the whole range of income levels, using environmental-friendly and affordable building materials and technology; connected to decent, safe and affordable water, energy, sanitation and recycling facilities; energy and water efficient and equipped with certain on-site renewable facilities; suitably located with regard to jobs, shops, health-care, education and other services; properly integrated into and enriching the cultural, social and economic fabric of the local community and the wider urban areas and adequately operated, maintained and timely refurbished and retrofitted'. While maintaining most of the indicators of sustainable housing as stated in UN-Habitat (2012), Adabre & Chan (2018) expatiated further on sustainable housing indicators at the project phases of housing. Accordingly, sustainable housing project should be timely completed as budgeted (cost performance) at the required quality without project-related disputes and litigation and guaranteeing stakeholders' satisfaction. Moreover, 'end-user satisfaction', 'take-up rate of housing facility' and 'waiting time of potential household before being allocated a facility' were suggested as essential indicators after the project management phase. Combining the indicators from these studies (i.e. UN-Habitat, 2012; Adabre & Chan, 2018), Chan & Adabre (2019) established a set of 21 indicators, following an international survey, as possible critical success criteria for measuring sustainable housing. The 21 indicators from Chan & Adabre (2019) are adopted and adapted for this study.

Attaining at least one of the sustainable development goals in housing has been a challenge in Ghana notwithstanding the evolution of policies. Following the era of neoliberalization from the 1990s, successive governments adopted austerity measures to reduce public housing supply due to inadequate fiscal resources. Besides, these measures were recommended by multinational organizations such as the World Bank. Accordingly, the state's funding for housing reduced from about 6.5 per cent to 1-2 per cent. Consequently, the operations of parastatal organizations (such as TDC, SHC, SSNIT, SIC etc.) that provided state housing for civil servants were affected. Most of these institutions currently operate as private institutions. As such some rental facilities were privatized as owner facilities, in part, due to maintenance cost burden. Moreover, the tax law, which taxed 'unearned' rental income higher than 'earned salaries' in addition to rent control law and planning regulations on compound houses has adversely affected the availability and affordability of rental facilities and the general affordability situation in urban areas. Though the state currently provides an enabling environment for most of these institutions and private developers (such as GREDA), price / rental affordability crisis of housing remains an intractable challenge to the majority middle- and low-income earners in urban centers.

On price / rental affordability of the Ghanaian housing market in Accra, Arku et al. (2012) posited that the housing affordability challenges are due to 'constraints in land acquisition', 'income inequality', 'rising cost of building materials', 'high cost of capital and inadequate financing schemes for housing'. Furthermore, through descriptive statistical analysis, Owusu-Ansah et al. (2019) found that the underlying barriers that hinder housing development in urban Ghana include: 'high interest rates', 'complex loan provisions', 'complex tenure arrangement on land acquisition', 'difficult land registration process', 'lengthy permit approval', 'high approval and registration fees', 'high cost of serviced land and construction materials', 'inadequate skilled labor', 'undeveloped mortgage market', 'housing price inflation' and 'inadequate infrastructure'. Moreover, Agyemang & Morrison (2018) highlighted 'lack of central government commitment', 'weak enforcement of planning legislation on land development', 'inadequate autonomy of local planning departments', and 'the dominance of customary land ownership and informal housing supply system' as the core barriers that could impede effective policies for successful affordable housing projects. Twumasi-Ampofo et al. (2014) averred that insufficient maintenance and policy instability (abandoned or neglected public housing facilities by succeeding governments) are possible causes of the housing deficits in Ghana.

Considering that price or rental affordability is a modicum of the overall sustainable development Goals, global policies are geared towards sustainable housing. Yet, attaining the indicators of sustainable housing is often hindered by various barriers in developed and developing countries. Using a questionnaire survey and interviews, Yang & Yang (2015) identified some barriers to sustainable housing from the views of professionals in the Australian housing industry. 'High upfront cost', 'inadequate fiscal incentives', 'inadequate code of policies as guidelines', 'slow administrative process in certifying and policy-making' and 'inadequate subsidies' were recognized as barriers to sustainable housing. Besides, Sourani & Sohail (2011) conducted a study in the UK on the overriding challenges faced by public clients on sustainable development. Through an interview, 12 barriers were identified. Some of the highly ranked barriers include: 'lack of funding', 'restrictions on expenditure and reluctance to incur higher capital cost'; 'insufficient and inconsistent policies, regulation and incentives'. Among developing countries, a study conducted by Durdyev et al. (2018) in Malaysia found 'high upfront cost of sustainable technologies', 'inadequate incentives' and 'lack of codes and policies' as key barriers to sustainable construction. In China, Shi et al. (2013) stated that additional cost, time and inadequate information are critical barriers to green construction. On land accessibility, Hu and Qian (2017) concluded that inadequate access to land for housing supply to low-income earners was a critical concern in China. This was found to be a typical case in fiscal autonomous cities that are dependent on land finance. Furthermore, comparative studies among two or more countries have often revealed common barriers. For example, Chan et al. (2016) conducted a comparative study among the United States of America, Canada and Australia using a questionnaire survey. They found that 'high extra cost of adopting green measures' was a common barrier to sustainable development among these countries. Besides, by analyzing an unbalanced panel data of 48 developing countries from 1996 to 2016, Sulemana et al. (2019) found evidence of a positive correlation between urbanization and income inequality in sub-Sharan African countries. It was concluded that income inequality could lead to inadequate access to housing in most urban centers.

Moreover, inadequate upgrading of unsustainable aged housing facilities to sustainability standards is among the barriers to sustainable housing. According to Gianfrate et al. (2017), cultural aspects, social aspects, user behavior / comfort and cultural values are some of the social barriers that can lessen the frequency of efficient retrofit initiatives. Retrofitting of housing is often compromised by cost saving objectives, low-end / inadequate guidelines or standards and inadequate maintenance operation, which eventually cause performance obsolescence in housing facilities. On similar study about retrofitting in Australia, Alam et al. (2019) developed a comprehensive list of barriers that impede the upgrading of public stock to energy efficient facilities. Through thematic analysis, some of the barriers identified include: 'inadequate political commitment', 'financing protocols' and 'misaligned incentives'. In the case of Israel, Friedman et al. (2014) found that retrofit costs are higher than the expected benefits. Thus, except for roof insulation, most of the retrofit strategies were not cost effective to households. Even for roof insulation, its payback period is very long. Similarly, Desogus et al. (2013) concluded that though thermal performance upgrades of housing facilities are compulsory, they are not cost effective in a mild Mediterranean climate region (such as Italy) regarding payback time. In the case of UK, Dowson et al. (2012) stated that 'lack of appropriate skills' and 'cost-effective components' are major barriers to the effective implementation of the Green Deal scheme.

In the Ghanaian construction industry, some of the barriers identified bear resemblance to the barriers from general literature. Djokoto et al. (2014) conducted a questionnaire survey on barriers to sustainable construction. The data were analyzed using relative importance index. Among the top 10 ranked obstacles, three are related to inadequate policy for sustainable construction (i.e. lack of building codes & regulation; inadequate strategies, lack of measurement tool); while two of the obstacles are related to higher cost of sustainable technologies (i.e. higher investment cost; higher final cost). Other barriers such as 'inadequate local professional skill' and 'lack of government support' (i.e. inadequate public funding and inadequate incentives) were identified. Similarly, using mean score analysis of questionnaire data, Ametepey et al. (2015) concluded that the top five challenges to sustainable construction include: 'low level of government's commitment', 'fear of incurring high cost for sustainable construction', 'inadequate local professional skills' and 'lack of sustainable construction regulations'.

In summary, Table 1 shows the various barriers identified from the comprehensive literature review. It can be concluded from the literature review that though the indicators stated by the UN-Habitat (2012), Adabre & Chan (2018) and Chan & Adabre (2019) could provide a broad approach for measuring the general concept of sustainable housing, the prioritization of these indicators could vary from country to country based on the context and socio-economic problems. Therefore, it is important to identify the indicators that are of priority for sustainable housing in the Ghanaian housing market. It can also be surmised from the literature that most studies on sustainable housing provide separate analysis on indicators of sustainable housing on one hand and / or barriers to sustainable housing on the other hand. As such, there is dearth study on the influence of the barriers on the indicators of sustainable housing. To ensure effective decision making, it is essential to assess how the barriers could influence the potential indicators of sustainable housing from the Ghanaian perspective. This could aid policymakers and practitioners on the strategies of resource allocation vis-à-vis the influence of the barriers in Ghana and other sub-Saharan African countries that face similar challenges (Adabre et al., 2020; Croese et al., 2016). Therefore, this paper seeks to bridge the knowledge gap by developing a model of barriers impact on sustainable housing.

[Please, insert **Table 1.** Barriers to Sustainable Housing]

## Conceptual Model

Based on the literature review on the indicators of sustainable housing and barriers, a conceptual model was developed. The barriers are categorised into three main groups, namely, 'cost-related', 'incentive-related' and 'retrofit-related' barriers. These three main groups are developed based on the theme of their underlining barriers and based on classifications from previous studies (i.e. Gianfrate et al., 2017; Adabre et al., 2020). Cost-related barriers include 'delays in permit approval'; 'high upfront cost of materials and technologies for sustainable housing'; 'high cost of land'; 'high interest rates'; 'high inflation rate'; 'high cost of permit approval' and 'income inequality'. Though 'delays in permit approval' could be an incentive-related barrier, it was considered as a cost-related barrier from the Ghanaian perspective. This is because high interest rates as noted in the case of Ghana increases cost of capital. Therefore, 'delays in permit approval' could further exacerbate the cost of capital and, thus, increase cost of sustainable housing among developers. Regarding 'income inequality', as stated in Reardon (2011), housing facilities are more expensive in high-income neighbourhood than in low-income neighbourhood. Thus, 'income inequality' is a key determinant of neighbourhood affordability and was, therefore, considered a 'cost-related barrier'.

Incentive-related barriers include eight underlying barriers: 'inadequate incentives for investors'; 'inadequate access to land among developers'; 'lack of planning control on land development'; 'inadequate subsidies on sustainable technologies'; 'poor location of housing facilities'; 'inadequate infrastructural development'; 'inadequate mortgage / financing schemes' and 'tight credit conditions' (shown in Fig. 1). The underlying barriers under 'retrofit-related' include: 'low level or inadequate retrofitting (maintenance operation)'; 'inadequate standards / guideline and tools for retrofitting'; 'lack of routine maintenance / poor maintenance culture of housing facilities'; 'policy instability / abandoned public housing facilities or projects' and 'inadequate local professional skills' for retrofitting activities (i.e. Dowson et al., 2012).

## Development of Hypotheses

Though the classification of the underlying barriers into the three groups is based on the themes and on the literature, their categorisation will be confirmed by a confirmatory factor analysis during data analysis. It is also worth noting that these categories of barriers have negative impact on one another on one hand and on the three main facets of sustainable development or the sustainable housing indicators on the other hand (Adabre et al., 2020). For instance, 'income inequality' could lead to mortgage redlining by banks. This could influence 'tight credit conditions', which is listed under 'incentive-related barrier'. On the impact of barriers on sustainable development, for example, the cost related-barriers could translate into high cost of housing facilities. This could mainly affect economic sustainability (such as price or rental affordability) while incentive-related barriers could mostly affect economic and social sustainability. Furthermore, though retrofitting-related barriers could influence social sustainability, these barriers are more likely to affect environmental sustainability due to energy inefficient housing and inadequate utilization of land due to abandoned housing facilities or projects. Thus, based on these epistemological assumptions on how the groups of barriers interact with one another, on one hand, and among the sustainable housing indicators, on the other hand, the following hypotheses were established.

*Hypothesis 1*: Cost-related barriers have a significant negative impact on 'incentive-related barriers'.

*Hypothesis 2*: Incentive-related barriers have a significant negative impact on 'retrofit-related barriers'.

*Hypothesis 3*: Cost-related barriers have a significant negative impact on 'retrofit-related barriers'

*Hypothesis 4:* Cost-related barriers have a significant negative impact on 'sustainable housing development'.

*Hypothesis 5:* Incentive-related barriers have a significant negative impact on 'sustainable housing development'.

*Hypothesis 6:* Retrofit-related barriers have a significant negative impact on 'sustainable housing development'.

[Please, insert **Fig 1.** A Conceptual Model of the Impact of Barriers on Sustainable Housing]

**Research Methodology**

The methodological assumptions of the conceptual model involve building the hypothetical model (which has already been achieved as shown in Fig. 1) and assessing what it conveys about the 'real world' on sustainable housing (Jaabreen, 2009). The latter normally entails data collection. As observed in the literature review on barriers to sustainable housing, questionnaire survey has widely been deployed for data collection (i.e. Yang & Yang, 2015; Chan & Adabre, 2019). Questionnaire survey offers expedient approach for data collection from a cross section of participants, and it is cost-effective (Adabre & Chan, 2019). Therefore, it was utilized in this study for data collection to model the impact of barriers on sustainable housing.

The questionnaire contains five sections. Section one consists of questions that sought to collect background data of potential respondents. Section two covered a list of indicators / criteria for measuring sustainable housing. In Section three, respondents were asked to rate the importance of success factors for attaining sustainable housing. Section four and five contained questions on barriers and risks factors, respectively, that could hinder the development of sustainable housing. This study reports only the findings on the indicators and barriers to sustainable housing.

For both the indicators and barriers to sustainable housing, a five-point Likert scale was employed for rating the various variables. Respondents were requested to rate the importance of the indicators of sustainable housing using a 5-point Likert scale of 1=not important to 5=very important. Similarly, respondents ranked the criticality of the barriers using a scale of 1=not critical to 5=very critical. The 5-point Likert scale was applied in this study due to its succinctness to enable expedient response to the questionnaire. Prior to the survey, a pilot study was conducted among four experts. This is important to check the validity, clarity and response time of the questionnaire; this could enhance the response rate. After the pilot survey, constructive comments from the pilot survey participants were used to revise and finalize the questionnaire before administering it.

**Population and Sample**

For this study, the population of housing experts in the Ghanaian construction industry includes some registered members of GREDA, members of the Ghana Institution of Surveyors (GhIS) and architects among parastatal organizations (such as SHC, TDC, SSNIT, Public Works Department (PWD) and Ministry of Water Resources, Works and Housing (MWRWH), Architectural and Engineering Services Limited (AESL)) and researchers and other professionals with expertise on sustainable housing. Though majority of the housing supplies (at least 90%) are from self-builders (informal sector), this study focused on the formal institutions due to their limited supplies despite the state provides an enabling environment. Besides, by focusing on these easily accessible institutions, some of the study findings could be relevant to the informal sector (i.e. households). Given the challenge in defining the sampling frame of the population of respondents, a random sampling technique could not be deployed for the selection of respondents. In such situation, non-probability sampling techniques could be used to select representative sample (Darko et al., 2018). Therefore, purposive and snowball were adopted in this study. The respondents were selected based on purpose of the study and their willingness to participate in the survey. The purposive sampling technique enables the selection of respondents based on their expertise for achieving the purpose of the study. On snowball sampling, respondents were identified through referral or social networks. Per the recommendation of some members of GREDA, only developers whose targets include middle-income earners in Ghana were contacted.

**Questionnaire Administration**

The questionnaires were administered face-to-face to the participants while other respondents were first contacted on phone (phone numbers were taken from a brochure that was obtained from the office of GREDA). On phone conversation, the potential respondents were briefly introduced to the research topic and the purpose of the questionnaire survey before soliciting for their participation in the survey. Most participants whom were contacted on phone provided their email addresses through which the authors sent them emails with the questionnaire attached. In the sent emails, the authors entreated the participants to forward the questionnaire to their colleagues who were capable of participating in the survey. Besides, some of the participants were asked to suggest potential respondents. Thus, through snowballing or referral, other participants were identified and contacted. Furthermore, the questionnaire was administered in person to some employees of SHC, TDC, SSNIT, PWD, and AESL while some members of the GhIS were contacted at their 50th Annual General Meeting, which was held in Accra at GIMPA on 2nd March 2019. A total of 110 questionnaires were personally administered. That was the maximum number of questionnaires that could be administered based on time constraint. Forty-seven (47) valid questionnaires were returned from both emails and face-to-face retrieval, which correspond to 42.7% response rate. This response rate compares approvingly with that of previous survey in the Ghanaian construction industry (i.e. Darko et al., 2018). Besides, Ott & Longnecker (2010) recommended that a sample size greater than 30 is sufficient to meet requirement of the central limit theorem. Therefore, the 47 valid responses are deemed adequate for modelling the impact of barriers on sustainable housing.

**Data Analysis Techniques - Structural Equation Modelling (SEM)**

To determine the impact of one or more independent variables on a dependent variable, the traditional multiple regression analysis (MRA) could be used. However, in a situation where the dependent variables are more than one, the MRA is not applicable. Besides, MRA is not appropriate to simultaneously examine the relationships among independent variables on one hand and the relationships between independent variables and dependent variables on the other hand. In this study, the dependent variables (indicators of sustainable housing) are more than one. Hence, a more robust multivariate method known as structural equation model (SEM) is espoused. SEM allows a concurrent evaluation of a set of relationships among constructs of barriers (independent constructs) on one hand and relationships between one or more constructs of barriers and the sustainable housing construct (dependent construct), on the other hand. Therefore, with the use of SEM, the stated hypotheses in this study could be tested (Lee et al., 2011).

Prior to using SEM, it is essential to specify two main variables, namely, latent variables and observable variables. Latent variables are variables that are not directly measured but are inferred or measured indirectly from observable variables. However, observable variables can be measured directly. Relating these two types of variables to this study, sustainable housing is a latent variable that can be inferred from the set of 21 indicators (as listed in Fig. 1 under *indicators of sustainable housing*). These indicators are collectively referred to as observable variables (henceforth referred to as indicators). Similarly, 'cost-related', 'incentive-related', and 'retrofit-related' barriers are all latent variables while their underlying barriers are known as observable variables (hereafter referred to as indicators / items of barriers).

Generally, SEM involves two forms of equation models, namely, the measurement model and the structural model. The measurement model shows the relationship between a construct and its indicators. For instance, a relationship between sustainable housing and its indicators or cost-related barrier and its indicators is a measurement model while a relationship between constructs (i.e. 'sustainable housing' and 'cost-related barriers') is a structural model. SEM could be conducted using covariance-based SEM (CB-SEM) or variance-based PLS-SEM. The choice between CB-SEM and PLS-SEM depends on the sample size and the nature of the data. A large sample size (about 200) that is normally distributed is required to accurately assess model fitness in CB-SEM (Hoelter, 1983; Lee et al., 2011). However, the PLS-SEM is suitable for a relatively small number of responses that are non-normally distributed. Due to these characteristics of the PLS-SEM, it is widely employed in construction management and sustainable development studies (Darko et al., 2018). Hence, smart-PLS version 3.2.7 was adopted for this study.

PLS-SEM, like other SEM techniques, is a merger of factor analysis and path analysis (Lee et al., 2011). Confirmatory factor analysis (CFA) was conducted to verify the classification of the various indicators under their respective constructs. After the CFA, the measurement models were specified. Next, the reliability and validity of the measurement models were examined. This is fundamental for specifying the structural model to evaluate the hypotheses. The reliability was assessed using composite reliability and Cronbach's alpha. Both indicate the internal consistency. Gefen et al. (2000) and Nunnally (1978) recommended values greater than 0.70 for both composite reliability and Cronbach's alpha. Validity of the measurement model was evaluated using convergent validity and discriminant validity.

Convergent validity assesses the internal consistency. It checks if the measurement items expected to measure each construct actually measure it and not measuring other constructs (Aibinu et al., 2010). It can be evaluated by using the factor loadings of the measurement items and average variance extracted (AVE). The factor loading of a measurement item is its bivariate correlation with its corresponding construct. The higher the factor loading, the stronger the relationship between the measurement item and its construct (Hair et al., 2014). Factor loadings above 0.50 are deemed satisfactory for convergent validity. Besides, the average variance extracted (AVE) of each construct should be above 0.50, which implies that at least 50% of the measurement variance is captured by the construct (Fornell & Larcker, 1981).

Discriminant validity is a prerequisite for analysing hypothetical relationships between constructs (Henseler et al., 2015). It was conducted to test the level at which a construct differs from other constructs. Three criteria, namely, Fornell & Lacker criterion, cross loading of the measurement items (indicators) and heterotrait-monotrait (HTMT) ratio of correlation were conducted to assess discriminant validity. Per the Fornell & Lacker criterion, the variance between a construct and itself should be higher than the variance between a construct and any other constructs. In using measurement items' cross loadings to test discriminant validity, the items' cross loading on a construct should be the highest as compared to the items' loading on other constructs. That is, the measurement items should have higher correlation with the construct that they are assumed to measure than any other construct in the model (Fornell & Larcker, 1981).

After assessing the measurement model, the structural model was developed through path analysis. In path analysis, the hypotheses (*Hypothesis 1* to *Hypothesis 6*) can be evaluated. It is conducted to determine the path coefficients which measure the level of associations among constructs. To test the significance of path coefficient, a bootstrapping technique was further employed in the path analysis. Bootstrapping is a robust technique useful for estimating the distribution of any statistic for any kind of distribution. Before conducting bootstrapping analysis, the normality of the data was checked. This was done using the Mardia's Multivariate skewness and kurtosis. Results of the PLS-SEM are shown in subsequent sections.

**Background Data of Respondents**

The essence of background data analysis is for assessing data credibility and for deciding the appropriate tool for further statistical analysis. On the background information of the survey respondents regarding the types of institution, 35%, 48% and 17% of the respondents work in academic / research institutions, public sector or department and private sector or as contractors, respectively. On profession, majority of the respondents (55%) are quantity surveyors followed by project / construction managers (19%), architects (13%) and researchers (4%). In terms of number of housing projects handled by the respondents, 52% respondents have handled more than two housing projects. Concerning the years of work experience, 36%

respondents indicated that they have 1-5 years of work experience, 28% respondents had 6 -10 years of work experience, 21% had 11-15 years of work experience and 15% had over 15 years of work experience. On housing type handled by these respondents, it was found that 55% of the respondents have handled public housing projects, 35% have handled social housing projects while 6% have worked on cooperative housing. It is worth noting that though vulnerable groups such as the youth, women, the unemployed and people who are HIV positive could have been housed in social facilities, per the country's legal provisions, majority of the respondents stated that no social housing exists in Ghana. However, since some of them indicated that they have been involved in social housing, it is possible that these few respondents have participated in such projects that are carried out beyond the scope of Ghana. It is also not surprising that low number of respondents have been involved in cooperative housing since it is still emerging in the Ghanaian housing sector. The outcome of the respondents' background data enhances the reliability of the survey data and therefore gives credence for subsequent statistical analysis.

**Descriptive Statistics**

Reliability analysis was conducted by evaluating the Cronbach alpha values for both the indicators of sustainable housing and the barriers. In both sets of data, Cronbach alpha values of 0.878 and 0.840 were obtained, respectively (shown in Table 2). These values are higher than the 0.70 threshold recommended in similar sustainable housing studies (Chan & Adabre, 2019; Adabre & Chan, 2019). Therefore, the Cronbach alpha values indicate that the survey data are adequately reliable for subsequent analysis.

Sequentially, the mean values, standard deviations and ranks based on the mean values were estimated for the indicators and the barriers to sustainable housing (shown in Table 2).

Concerning the indicators, the mean scores of the 21 indicators range from 4.468 (for ‘construction cost performance of housing facility’) to 3.468 (for ‘waiting time of potential household before being allocated a housing unit’). Therefore, the respondents considered the 21 indicators as important for measuring the concept of sustainable housing since none of the mean values was within the category of ‘*less important’* (< 2). Besides, the low standard deviations (< 1) of most of the indicators suggest a relatively high consistency level among the different respondents who ranked the indicators.

On the barriers (shown in Table 2), mean scores of the 21 barriers range from 4.761 (for ‘high interest rates’) to 3.255 (for ‘lack of / inadequate local professional skills’). Most of the highly ranked barriers such as ‘high interest rates’, ‘high inflation rate’, ‘high upfront cost of materials and sustainable technologies’ and ‘high cost of serviced land’ are barrier items from the ‘cost-related barriers’ construct. The results show that ‘cost-related barriers’ are the most impediments to sustainable housing in Ghana. Besides, among the ‘incentive-related barriers’, ‘tight credit conditions’, ‘inadequate mortgage institution’, ‘lack of planning control on land development’, ‘inadequate access to land’ and ‘inadequate infrastructural development’ are ranked high (above 4.00). Furthermore, the barriers that ranked high (above 4.00) under ‘retrofit-related barriers’ include: ‘policy instability / abandoned housing facilities or projects by succeeding government’ and ‘lack of routine maintenance / poor maintenance culture of housing facilities’. Therefore, in addition to ‘cost-related barriers’, sustainable housing in Ghana could be hindered by ‘incentive-related’ and ‘retrofitting-related’ barriers.

The values in the columns of ‘Corrected Item-Total Correlation’ and ‘Cronbach’s Alpha if Item Deleted’ were used as guide to delete items / indicators that might not be relevant for further consideration in the PLS-SEM (Yuan et al., 2018). The conditions for deleting an item /

indicator are that if the item's 'Corrected Item-Total Correlation' is less than 0.40 and its 'Cronbach's Alpha if Item Deleted' is greater than overall Cronbach's Alpha for all items (i.e. 0.878 for sustainable housing indicators and 0.840 for barriers), then the item should be deleted. Based on these conditions, the indicator 'take up rate of housing facility' (in Table 2) could be deleted before further analysis. Similarly, the barrier item 'inadequate local professional skills for retrofitting activities' (in Table 2) could be deleted.

[Please, insert **Table 2.** Descriptive Statistics of Constructs and Indicators of Barriers to Sustainable Housing]

**Results of PLS-SEM – Estimation of Measurement Model**

All the measurement items were specified as reflective indicators and not formative indicators. Reflective indicators are interchangeable and therefore omitting an item does not essentially change the nature of the underlying construct. However, for formative indicators, omitting an indicator is omitting a part of the underlying construct (Hair et al., 2014; Diamantopoulos & Winklhofer, 2001). Besides, reflective indicators have high correlations with one another. Studies by Chan & Adabre (2019) and Adabre et al. (2020) showed that there are high correlations among sustainable housing indicators and barriers. Therefore, the analysis was conducted after specifying all the measurement items as reflective indicators. It is recommended that factor loadings of the measurement items should be above 0.5. As suggested by Nunnally (1978), items with loading below 0.5 do not contribute significantly to the explanatory power of the constructs. Therefore, during the data analysis, measurement items / indicators whose factor loadings were below 0.5 were deleted and the analysis was repeated until a reliable and valid measurement model was obtained.

Results of the measurement model are shown in Table 3. Though, one the underlying barriers 'income inequality' was classified as a cost-related barrier, it was successfully loaded (loading $\geq 0.5$) under 'incentive-related barriers'. From Table 3, the estimated composite reliability values and Cronbach's alpha values of all constructs are above the required threshold of 0.7, which indicate that internal consistent reliability is acceptable. Furthermore, the factor loadings and the average variance extracted (AVE) values are above the recommended 0.5, which indicate a satisfactory level of convergent validity of the indicators and constructs, respectively.

[Please, insert **Table 3.** Measurement Model Evaluation]

## Measurement Model Assessment: Discriminant Validity (Vertical Collinearity)

### Fornell and Lacker Criterion

After estimating the measurement model, the next step is to assess its vertical collinearity. This was done by estimating the discriminant validity using the Fornell & Lacker criterion. The criterion of assessment is that a construct should share more variance with its measures than it shares with other constructs in the model. Using the AVE, Fornell & Lacker stated that the AVE of constructs should be greater than the variance shared between the constructs and other constructs. From the results in Table 4, the highest correlation of a construct is the correlation between a construct and itself. These correlations are the diagonal values as indicated in Table 4. The values are the square root of the AVE of the latent variable and indicate the highest in any column or row. Therefore, the discriminant validity was satisfactory using the Fornell & Lacker criterion (Chin, 1998).

[Please, insert **Table 4.** Discriminant Validity (Fornell & Larcker Criterion)]

### Indicators' Cross Loading

Another approach for estimating the discriminant validity of the measurement model is by evaluating the measurement items' cross loadings. As shown in Table 5, each measurement item had the highest factor loading on the construct it was theoretically identified to measure than any other constructs in the model. Therefore, this further buttresses the fact that the measurement model is valid and reliable for structural path modelling.

[Please, insert **Table 5.** Indicators' Cross Loading]

**Discriminant Validity (HTMT)**

The measurement model was finally judged through the HTMT (shown in Table 6). Using the HTMT as a criterion to evaluate the discriminant validity entails comparing the HTMT with predetermined threshold. If the HTMT value is higher than the threshold, then there is a lack of discriminant validity (Henseler et al., 2015). Though the threshold for HTMT is debatable, Gold et al. (2001) and Teo et al. (2008) proposed a value of 0.90 ($HTMT_{0.90}$), which is the adopted threshold for this study. As shown in Table 6, since all the inter-construct correlations are below 0.90, the discriminant validity has been further established.

[Please, insert **Table 6.** Discriminant Validity (HTMT)]

**Estimation of Structural Model / Path Analysis**

After the assessment of the measurement model on reliability, convergent validity and discriminant validity, it was concluded that the constructs are within the satisfactory limit for estimating the structural model (relationships among constructs). Therefore, path analysis was conducted (shown in Fig. 2). The values between constructs are the respective path coefficients. The higher the path coefficient between constructs, the stronger the influence of the independent construct on the dependent construct. As stated by Murari (2015), path coefficients from 0.1 to 0.3 indicate weak influence, between 0.3 to 0.5 suggest moderate influence and 0.5 to 1.0 show strong influence.

The results (shown in Fig. 2) indicate that the path connecting the 'cost-related barriers' to the 'incentive-related barriers' shows a moderate influence (0.464). However, there is high influence (0.698) from 'incentive-related barriers' on 'retrofitting-related barriers' while the path linking ‘cost-related barriers’ to ‘retrofitting-related barriers’ revealed weak influence (0.105). Concerning the paths linking the constructs of the barriers to the sustainable housing construct, it was found that there is weak influence from ‘cost-related barriers’ on ‘sustainable housing’. In contrast, the path linking ‘incentive-related barriers’ to ‘sustainable housing’ indicates high influence (-0.556). Furthermore, ‘retrofitting-related barriers’ have high influence (0.783) on the ‘sustainable housing’ construct.

[Please, insert **Fig. 2.** Structural Model of Construct of Barriers and Sustainable Housing Construct]

## Assessment of the Structural Model

Assessment of the structural model includes: evaluating collinearity issues (using the inner variance inflation factor values), assessing the significance and relevance of the structural model relationships, assessing the coefficient of determination ($R^2$); assessing the effect sizes ($f^2$) and the predictive relevance ($q^2$).

## Assessing the Structural Model for Multi-Collinearity

Multicollinearity in the structural equation model was judged using the inner variance inflation factor (VIF) values. All the VIF values were below five which indicates that there is no multicollinearity. Thus, the structural model has passed the test of multicollinearity.

## Assessing the Significance and Relevance of Structural Model (Bootstrapping)

Bootstrapping was conducted to assess the significance of the relationships among constructs. It estimates the spread, shape and bias of the sampling distribution of the population from which the sample under study was obtained. Prior to conducting the bootstrapping, the normality of the data was assessed using the Mardia's Multivariate skewness and kurtosis. The skewness value obtained was 8.81 while the kurtosis value was 38.96. Comparing the outputs of the skewness and the kurtosis with the cut offs (Mardia multivariate –skewness ±1; kurtosis ±20), it can be concluded that the data is not normally distributed since the estimated values are above the predetermined values (Chin, 1998). Hence, bootstrapping was conducted for the data set. Bootstrapping analysis was used for statistical testing of the direct effects of all the hypothesized relationships. If $t_{0.05} > 1.96$ (for a 2-tailed test), hypothesis is supported (Peng & Lai, 2012; Hair et al., 2016).

Results of the bootstrapping are shown in Fig. 3. The t-values are indicated on the various paths that link the constructs. The explanatory power of the structural model was evaluated by the coefficient of determination ($R^2$). $R^2$ measures the proportion of variance in the sustainable housing construct explained by all the barrier constructs linked to it (Chin, 1988). It ranges between 0 and 1, with higher values indicating higher levels of predictive accuracy of the overall structural model. As shown in Fig. 3, the $R^2$ for ‘sustainable housing’ is 0.433. This means that about 43% of the challenges in sustainable housing development are due to the three constructs of barriers. This value indicates a satisfactory level of the predictive accuracy and quality of the structural model (Hair et al., 2014).

[Please, insert **Fig. 3.** Bootstrapping Results on Impact of Barriers Construct on Sustainable Housing Construct]

## Validation of the Hypotheses

The hypotheses (hypotheses 1 to 6) were evaluated based on the structural model. Each path represents a hypothesis. Tests of the hypotheses were achieved by evaluating the statistical significance of the path coefficients. Table 7 is a summary of path analysis results and their corresponding t-values. For all the paths, a two-tail t-test was used (Aibinu & Al-Lawati, 2010). The hypotheses were considered based on the conventional significance levels of 0.01 and 0.05. Table 7 shows that out of the six hypotheses, four hypotheses were significant. The path coefficient between 'cost-related' and 'incentive-related' barriers (hypothesis1) is significant. Furthermore, the path linking 'incentive-related barriers' to 'retrofitting-related barriers' is significant (hypothesis 2). Moreover, the coefficient of the path linking 'incentive-related barriers' to 'sustainable housing' is statistically significant (hypothesis 5) and likewise the path between 'retrofitting-related barriers' and 'sustainable housing' (hypothesis 6). Therefore, hypothesis 1, hypothesis 2, hypothesis 5 and hypothesis 6 were accepted because their t-values are all greater than the 1.96 ($t_{0.05} > 1.96$).

## Assessing the Effect Sizes ($f^2$)

The structural model was also assessed by calculating the effect sizes of the constructs. Effect size ($f^2$) measures how strongly one independent construct contributes to explaining a certain dependent construct in terms of $R^2$. The effect size was evaluated by investigating the changes in $R^2$ to find out if there is a substantive impact of any of the construct of barriers on the 'sustainable housing' construct. Then, based on the obtained $R^2$ value, the effect size was calculated using eqn.1:

$$f^2 = (R^2_{included} - R^2_{excluded}) / (1 - R^2_{included}) \quad \text{......eqn. (1)}$$

where $R^2_{included}$ and $R^2_{excluded}$ are the $R^2$ values of the dependent construct when a selected independent construct is included or excluded from the model. The change in the $R^2$ values is calculated by estimating the PLS path model twice: Once with the independent construct included (yielding $R^2_{included}$) and the second time with the independent construct excluded (yielding $R^2_{excluded}$). The effect size of a construct is small if $0.02 \leq f^2 < 0.15$; medium if $0.15 \leq f^2 < 0.35$ and large if $f^2 \geq 0.35$ (Cohen, 2013). Table 7 shows the results on estimates of the effect size for some of the constructs that could be estimated.

From Table 7, 'cost-related barriers' have small effect size (0.034) on 'retrofitted-related barriers'. However, 'incentive-related barriers' have a high effect size (0.675) on 'retrofitting-related barriers'. Between the construct of barriers and sustainable housing construct, 'incentive-related barriers' have a medium effect size (0.192) on 'sustainable housing' while the effect size of 'retrofitting-related barriers' on 'sustainable housing' is large (0.430). The effect size of 'cost-related barriers' on 'sustainable housing' is small (0.086).

**Assessing the Predictive Relevance ($q^2$)**

The rigorousness or how well observed values are reproduced by the structural model was evaluated by calculating the predictive relevance. Predictive relevance ($q^2$) of exogenous constructs uses blindfolding procedure where every $n^{th}$ data point in the dependent construct's indicators is omitted to estimate the parameters with the remaining data points (Henseler et al., 2009). While estimating parameters for a model under blindfolding procedure, this technique omits data for a given block of indicators and then predicts the omitted part based on the calculated parameters (Akter et al., 2011). Then, the predictive relevance can be estimated using eqn. (2). A construct's predictive relevance is small if $0.02 \leq q^2 < 0.15$; medium if $0.15 \leq q^2 < 0.35$ and large if $q^2 \geq 0.35$ (Cohen, 2013; Hair et al., 2014). Results of the constructs predictive relevance are shown in Table 7. The results indicate that the path linking ‘incentive-related barriers’ to ‘retrofit-related barriers’ has medium predictive relevance (0.210) and likewise the path linking ‘retrofitting-related barriers’ to ‘sustainable housing’ (predictive relevance 0.184). However, a small predictive relevance (0.053) was obtained for the path between ‘incentive-related barriers’ and ‘sustainable housing’ (shown in Table 7).

$q^2 = (Q^2_{included} - Q^2_{excluded}) / (1 - Q^2_{included})$ ……………..…………………………………eqn. (2)

$Q^2 = 1 - ( \sum_D SSE_D) / ( \sum_D SSO_D)$

Where D is the omission distance, SSE is the sum of squares errors, and SSO represents the sum of squares total. To set D, the rule of thumb is $5 \leq D \leq 10$. Therefore, in conducting the blindfolding in smart PLS-SEM, a D value of 6 instead of 7 was selected considering that the total number of indicators in 21.

[Please, insert **Table 7.** Direct Relationships for Hypothesis Testing]

## Discussion of Results on Measurement Model

### Sustainable Housing Construct

From the results of the measurement model, sustainable housing was reflectively and significantly measured by seven indicators, namely, energy efficient housing (ISH10); rental cost of housing facility (ISH16); commuting cost of household (ISH17); technology transfer (ISH19); safety performance (ISH04); end-user's satisfaction (ISH05) and stakeholders' satisfaction (ISH06). These indicators are critical for defining the scope of sustainable housing in the Ghanaian construction industry.

For sustainable housing from the perspective of Ghana, there should be an efficient supply of energy. However, the energy supply situation in Ghana is unreliable, which is exacerbated by increasing residential electricity demand. Gyamfi et al. (2018) stated that seven appliances and one lighting technology consisting of refrigerator, air conditioner, television, freezer, fan, electric iron, washing machine and CFL constituted about 93% of residential electricity consumption in 2015. It is projected that electricity consumption by these appliances could be reduced by 24-51% in 2050 through energy efficient technologies. Therefore, the adoption of energy efficient or sustainable technologies that are environmentally friendly would ensure sustainable housing development in Ghana.

Furthermore, between 'rental cost of housing' (an indicator of preference for renting) and 'price of housing facility' (an indicator of preference for homeownership) (Adabre and Chan, 2020), only the former was significantly loaded as an indicator for sustainable housing. However, the higher ranking of 'price of housing' than 'rental cost of housing' in the descriptive statistics (shown in Table 2) could be an indication that there is high preference for homeownership over renting in the case of Ghana. This was also inveterate in prior study by Chan & Adabre (2019) among developing countries. Generally, economic development among developing countries leads to increasing preference for homeownership over renting. This is not only attributed to reasons for shelter but also for investment. Besides, housing facilities serve as assets for hedging against the rapid escalation of general inflation rate and high advance rent charges. These could possibly be the reasons 'price of housing facility' (indicator of ownership) was rated higher than 'rental cost of housing facilities' (an indicator of renting) in the descriptive statistics (in Table 2).

Consequently, in the past decades, successive governments in Ghana built and sold out some housing facilities to civil servants. Besides, some rental facilities were privatised as owner facilities for some of the citizenry. Though this practice is good to meet the desire for home ownership among the citizenry, it may not be a laudable policy for sustainable housing development as indicated in the measurement model of the sustainable housing construct. For instance, a study by Owusu et al. (2019) highlighted challenges of transparency in the distribution of public resources in the Ghanaian construction industry. Thus, most of the public houses that are sold out are often bought by the rich or political party members and rented or sold out at exorbitant charges to the general public. This increases the housing affordability crisis and income inequality in cities (Sulemana et al., 2019). Moreover, maintenance of such public housing facilities could be problematic if various apartments are sold out to different households. Inadequate maintenance of such housing facilities, which is mostly the situation in major cities in Ghana such as Accra and Kumasi, affects the quality of life in these cities (Węziak-Białowolska, 2016). Hence, for sustainable housing from the Ghanaian perspective, ensuring affordability of 'rental cost of housing facilities' is more sustainable than ensuring affordability of 'price of housing facilities'. The availability of public rental facilities in major cities in Ghana (i.e. Accra) will ensure access to housing facilities among the 40.9% of all urban households that depend on rental facilities.

Furthermore, technology transfer or innovation was significantly loaded as an indicator for sustainable housing. Prior studies identified technology transfer as one key indicator for housing in Ghana (Ahadzie et al., 2008; Adinyira et al., 2012). Technology transfer entails the use of new technologies that are cost effective to improve energy and housing supply. Improved technologies on the use of alternative materials for construction could advance sustainable housing development in Ghana. Currently, the Ghanaian construction industry relies so much on cement and its products for the construction of most housing facilities. Yet, aside being expensive, cement contributes to the emission of greenhouse gases. Approximately a ton of $CO_2$ is emitted into the environment for each ton of cement produced. Besides, concrete production is one of the construction processes that emit the highest amount of $CO_2$ (Djokoto et al., 2014). Through innovative measures, environmental-friendly materials such as burnt bricks and hydraform bricks could be used together with cement for constructing housing facilities. This will reduce the number of bags of cement used for constructing housing facilities. Consequently, the rent of such housing facilities could be affordable to low-income household, and this could have ripple effects on the market equilibrium rent of housing facilities charged by developers or property owners. Besides, the amount of $CO_2$ emission could be mitigated since the quantity of cement used for constructing housing facilities will be reduced.

Moreover, for sustainable housing, end-user's satisfaction and stakeholders' satisfaction are crucial indicators. Ensuring security provision is important for end-user's satisfaction. In addition, housing design features (i.e. separate bedrooms for parents and children), availability of public facilities (i.e. kindergarten and other basic level educational facilities) and social design features (i.e. leisure facilities) within the neighbourhood are critical for households' satisfaction and stakeholders' satisfaction (Chan and Adabre, 2019).

Though the measurement model for the sustainable housing constructs revealed the critical indicators for sustainable housing, the attainment of these indicators is often hindered by key barriers. Besides, some of the strategies that are stated within the various indicators may not be attainable because of barriers to sustainable housing. These barriers that pertain to the Ghanaian housing market are discussed in subsequent sections. Although the data were collected from a limited number of participants in formal institutions, the findings are broadly discussed to enhance the relevance of the study's outcome to the state, self-builders and developers.

**'Cost-Related Barriers' Construct**

'Cost-related barriers' were significantly measured by four-indicator items, namely, 'delays in government approval process' (CRB1); 'high upfront cost of building materials and technologies' (CRB2); 'high cost of serviced land' (CRB3) and 'high inflation rate' (CRB4). From the structural equation model (shown in Fig. 3), the construct for 'cost-related barriers' was not significant related to the constructs for 'sustainable housing' and 'retrofit-related barriers'. However, there was a significant relationship between 'cost-related barriers' and 'incentive related barriers'. Thus, although it has been stated that 'cost-related barriers' are critical barriers to sustainable development (Yang & Yang, 2015; Chan et al., 2016), surprisingly, 'cost-related barriers' do not have a direct significant impact on 'sustainable housing' from the Ghanaian perspective. Similarly, a study conducted by Darko et al. (2018) revealed that 'cost and risk-related barriers' did not have significant impact on green building adoption from the Ghanaian perspective. In Darko et al. (2018), 'incentive-related barriers' were significant as found in this study. Since 'cost-related barriers' rather have a direct significant influence on 'incentive-related barriers' (as shown in Fig.3 & Table 7), this implies that the 'cost-related barriers' are as a result of inadequate incentives in the Ghanaian housing sector. Similarly, Kaygusuz (2012) asserted that 'cost-related barriers' are secondary to other barriers such as lack of financing, education or proper incentives among most developing countries.

Accordingly, 'cost-related barriers' affect 'incentive-related barriers' which could then significantly influence one or more of the sustainable housing indicators. For example, 'delays in permit approval or government approval process' was significantly loaded as a 'cost-related barrier'. Such delays in the Ghanaian construction industry is evinced in prior study. Gough & Yankson (2000) found that only 40% of land acquirers / developers were able to register their plots of land. Further analysis showed that among the 40%, some were able to register their plots of land in 12 months while some did so in five years. Bureaucracy on land registration delays sources of funding or prevents lands from being used as a collateral since most banks will usually require statutory approval as one of the requirements for granting loans. Besides, 'delays in permit approval' increases the cost of capital / interest payment on borrowed funds since it interrupts development on land. Consequently, this increases the cost of housing construction, making such construction economically unsustainable. This does not incentivize or motivate developers to provide affordable housing since developers or landlords may increase the price / rent to expedite payment on borrowed capital for constructing the housing facilities (Owusu-Ansah et al., 2019).

Concerning construction materials, cement is the main building material in most construction projects in Ghana. Within the past years, price of cement has increased exorbitantly. This has partly contributed to the high cost of housing construction which in turn acts as a disincentive or incentive-related barrier to sustainable housing (i.e. rental affordability) among property owners. Even if the houses were built in the past when costs of building materials were comparatively low, the current high cost of building materials and sustainable technologies could increase the sinking fund that private landlords have to deposit for the construction of similar facility after its lifespan or for maintenance of the facility. High sinking fund requirement implies higher rental charges as evinced in the current Ghanaian rental housing market (Arku et al., 2012).

Moreover, high interest rate among financial institutions is a cost-related barrier that affects most developers and households. Lending rate as high as 30 per cent per annum prevents the many middle- and low-income households from assessing credit. It is not surprising that many households in Ghana are averse to housing loans or mortgages for fear that they might not be able to amortise such loans (Ghana Housing Profile, UN-Habitat, 2011). The Banks and other financial institutions, therefore, deal with the richest few including developers. To be able to repay loans used for real estate, developers mostly target expatriates or high-income earners. Only the high-income categories can afford the exorbitant charges of such housing facilities provided by the developers. Thus, the high cost of finance has knock-on effects on 'inadequate incentives' for developers to provide housing facilities to most middle-income earners.

**'Incentive-Related Barriers' Construct**

The construct for 'incentive-related barriers' was significantly measured by 'inadequate incentive for private investors' (IRB1); 'inadequate access to secured land' (IRB2); 'income inequality' (CRB7) and 'lack of planning control on land development' (IRB3). From the structural equation model (as shown in Fig. 3), the construct for 'incentive-related barriers' had direct significant impact on the construct for 'sustainable housing'. It also has direct significant impact on 'retrofitting-related barriers'. These relationships mean that 'incentive-related barriers' could directly influence sustainable housing and indirectly by instigating 'retrofit-related barriers'.

A major incentive-related barrier to sustainable development is split incentive (Alam et al., 2019). In most tender documents for construction projects, tenderers are requested to provide tender security, advance payment security, tax payment certificates and other documents as prequalification requirements. However, project sustainability measures or policies are often not requested. Thus, though the tenderers may have the required expertise for sustainable housing they may be reluctant to integrate sustainable technologies / measures into such development. This is because if such technologies are integrated into housing projects, the beneficiaries of the technologies are the potential residents or households while the contractor may incur higher cost for sustainable development. The cost may not be reimbursed if borne out of contractual agreement. Besides, contractors are not incentivized (i.e. no certificate of recognition for sustainable development) to provide them a competitive advantage in subsequent tendering for public / private projects.

Another incentive-related barrier to sustainable housing is 'inadequate access to secured land'. This is attributable to the customary land tenure system in Ghana, which often results in litigations over land with ripple effects of delays in court proceedings. Inadequate plot lay-outs, time-consuming boundary disputes and conflicts are some of the problems associated with customary land tenure system in the Ghanaian construction industry (Gough & Yankson, 2000). Moreover,  the customary land tenure is bedevilled with problems of multiple land sales and boundary disputes due to the state of land transaction, inefficient data storage and unscrupulous land sales (Crook, 2004). For instance, land disputes pending in Ghanaian courts due to family disputes were 52.7% while 17.7% were boundary disputes and 12.8% were disputes due to unauthorized sales of land by chief or stranger and 4.9% were unauthorized sales by a family member (Crook, 2004).

Furthermore, income inequality is a major barrier to sustainable housing development in most urban centres in Ghana. Sulemana et al. (2019) found a positive correlation between income inequality and corruption. Similarly, Owusu et al. (2019) revealed that most procurement activities in Ghana are susceptible to corrupt practices. Thus, public housing facilities which could be economically sustainable in perpetuity through renting of such facilities are mostly bought by public officials or party members for investment purpose. This practice often leads to increasing income inequality between low-income earners and high-income earners in most developing countries. Moreover, income inequality could be exacerbated by weak enforcement of planning control on land development (Agyemang & Morrison, 2018). According to David Ricardo, as more and more land is brought into production, landowners capture a share of the total value accruing to land, which leads to general decline in economic growth (Obeng-Odoom, 2010). Explaining this further in the context of cities, Stilwell (2011) stated that increasing urbanization leads to widespread use of land for roads and housing. Consequently, the value of land appreciates which is captured by landowners. Therefore, there is an incentive for high-income earners (the rich) to buy and hold land till it accumulates values resulting from road and other infrastructure development provided by the government or public. Without planning control on land (i.e. time-limited holding on vacant land and taxes that capture values on land attributed to public infrastructure supply), speculations could increase prices of land

and, consequently, the prices / rent of housing facilities. Thus, housing facilities could be unaffordable to low- and middle-income earners. This could lead to high income disparity, income segregation, slum development in cities and urban sprawl.

The key challenge of lack of planning control on land is the conflict between the traditional and institutional levels of government in the delivery of land. Because land is customarily owned, it is allocated by the various traditional leaders or family heads. However, planning for land use is institutionally controlled by the Town and Country Planning Department (TCPD), which is a governmental institution. Aside conflicts between land allocation and land use, the TCPDs lack adequate human and fiscal resources to effectively carry out their duties. Therefore, by ensuring that the TCPDs are adequately resourced, the government could control development on land for sustainable housing. This control will enable the government to introduce redistributive policies (i.e. taxation to capture increase in land values due to public roads etc.) for additional infrastructure supply.

Based on the significant direct impact of 'incentive-related barriers' on sustainable housing, the provision of adequate incentive schemes to various stakeholders could motivate sustainable housing. For instance, in addition to the usual required documents (i.e. bid security, VAT & SSNIT Clearance Certificate), tenderers of a housing project should be assessed based on their sustainability attainment strategies on the project. Thus, evaluation of tenderers on sustainability strategies / performance should be conducted and the outcome of their sustainability strategies should form part of the prequalification and selection criteria (Sourani & Sohail, 2011). This approach could be a remedy for the problem of split-incentive. Besides, financial incentives such as interest free loans and non-financial incentives such as expedited permit approval could be offered to contractors or developers. This could reduce the cost of capital on borrowed funds incurred due to delays in land registration. In return for expedited permitting or low-interest loans, contractors or developers may be required to integrate some sustainable strategies or technologies into the housing facility.

Since ‘incentive-related barriers’ indirectly affect sustainable housing through ‘retrofit-related barriers’, policies on incentives could be developed to enhance retrofitting activities. An innovative financing incentive such as revolving fund could be established to incentivize sustainable housing development among developers and energy efficient retrofit among households. Though upfront investment for the revolving fund could be high, it is suitable for developing countries with frequently constrained public fund and financial austerity. This scheme could be cost-neutral in the long term (Gouldson et al., 2015). With revolving fund, initial deposits could be provided by the government and other financial institutions. Then, the fund can be offered as low-interest loans to low-income and middle-income households (i.e. civil servants) for energy efficient retrofitting. For instance, since the adoption of solar panels is at an incipient stage in Ghana, the fund could enable households to purchase tin film solar photovoltaic (PV) polymer for alternative source of energy for lighting and other minor domestic uses. Consequently, the savings in energy cost, attributed to the PV panels, after accounting for rebound effects and performance gaps, are used for the amortisation of the loan for subsequent funding of retrofitting activities. Arguably, most Ghanaian could be averse to loans that are linked to housing facilities. Therefore, to encourage households’ participation and to reduce rebound effects on energy savings, a percentage of the savings could be given as ‘cash-back’ to households who participate in the scheme.

Moreover, with regard to low-income households, effective cooperative housing could be an efficient strategy for housing supply and for upgrading some of the slum communities in major urban areas such as Accra and Kumasi. A typical example of this is the Amui Dzor cooperative housing in Ashaiman. Yet, sustaining and replicating this form of housing supply in other slum communities is hindered by inadequate access to finance. Therefore, to ensure sustainable housing, adequate incentives such as expedited permit approval and interest-free loans or a revolving fund could be established to promote cooperative housing in slum areas. The success of cooperative housing will involve coordination among members of the cooperative, financial institutions / banks (i.e. Republic Bank Ghana Limited) for loans or revolving fund management, owners of lands (i.e. chiefs and family heads) for land supply and parastatal institutions for accelerating permit approval and utilities supply.

**'Retrofit-related barriers' Construct**

The items / indicators that significantly measured 'retrofit-related barriers' include: 'low-level or inadequate maintenance operation / retrofitting of existing housing facilities' (RRB1); 'inadequate policies or sustainability assessment tools for retrofitting' (RRB2); 'lack of routine maintenance / poor maintenance culture of housing facilities' (RRB3) and 'policy instability / abandoned public housing facilities or projects by successive governments' (RRB4). From the structural model (shown in Fig. 3), 'retrofit-related barriers' have a direct significant impact on 'sustainable housing'.

Retrofit is the replacement of element or components of a building. In a broader perspective, the U.S. Green Building Council (USGBC) defined retrofit as "any kind of upgrade of an existing building that is wholly or partially occupied to improve energy and environmental performance, reduce water use and improve comfort and quality of the space in terms of natural light, air quality and noise – all done in a way that it is financially beneficial to the owner." 'Inadequate retrofitting or low-maintenance operation' is one of the critical barriers to sustainable housing in Ghana and other developing countries. Gyamfi et al. (2018) reported that through the replacement of six million incandescent lamps with compact fluorescent light (CFL), a saving of 200-240MW was achieved. However, without broadening this retrofitting or maintenance operation to other appliances, these savings are often lost as a result of rebound effects. Similar to the case of Ethiopia, a significant energy saving was achieved through CFL bulb distribution program. Yet, about 20% of the initial energy savings was loss to rebound effects within 18 months after the execution of the programs (Costolanski et al., 2013). Rebound effects are typical in a growing economy. As noted by Gyamfi et al. (2015), "rapid economic development in Ghana results in increased per capital income." As such, changes in households' behaviour such as demands for other electrical appliances (if the appliances are not energy efficient), could annul the energy savings from other energy efficient appliances. Thus, though the 2007 CFL bulb distribution and supply of energy efficient refrigerators in Ghana are laudable policies, there should be an extensive retrofitting regarding freezer, television, electric iron, washing machine and air-conditioners or electric fan. This could prevent rebound effects on the energy savings from using the CFL and the energy efficient refrigerators.

Furthermore, 'inadequate policies / standards and tools' is a key barrier to retrofitting aged housing facilities to sustainability standards. Information dissemination policies on energy saving techniques and energy efficient appliances to guide household in energy consumption and purchasing decisions are inadequate. Besides, directive-based policies or mandatory-based policies on retrofitting of existing housing facilities are lacking. Moreover, evaluation-based policies for assessing retrofitting operation on existing housing facilities and for new housing projects are inadequate in Ghana and other countries (Tan et al., 2018). Finally, sustainable construction and retrofitting of housing facilities are hindered by the absence of tailored sustainable policies for housing facilities. For instance, Green building rating systems such as leadership in energy and environmental performance (LEED), Global Sustainability Assessment System (GSAS) and Green Star do not provide complete assessment criteria for sustainable development (Awadh, 2017 and Hamid et al., 2014). According to Adabre and Chan (2020), these rating systems are environmental-oriented tools and are not sufficient to assess the social sustainability and economic sustainability development in housing facilities. Yet, these tools are often adopted for assessing sustainability of projects including housing facilities. Therefore, the provision of sustainable housing policies (i.e. sustainable housing codes and rating systems) in Ghana will not only be relevant for retrofitting existing housing facilities to sustainable standards but also for the construction of sustainable housing facilities. Moreover, 'lack of routine maintenance / poor maintenance culture of housing facilities' and 'policy instability / abandoned public housing facilities or projects by succeeding governments' are critical barriers (Twumasi-Ampofo et al., 2014) that could affect upgrading of unsustainable housing facilities to energy efficient facilities. These two barriers could be caused by insufficient time and financial resources to address sustainability issues. Sourani & Sohail (2011) argued that in a situation where funding is available within a limited period, public clients may not have enough time to address sustainability issues in retrofitting of aged housing facilities. Besides, due to short tenure of office coupled with limited resources and financial constraints, governments and politicians mostly favor their own interest of starting new projects while initiated projected by previous governments or aged unsustainable housing facilities are neglected.

Therefore, mandatory policies on passive designs of housing facilities such as cross ventilation could ensure energy efficient housing. By improving the ventilation design of housing facilities, households could reduce the use of fans and air conditioners and consequently reduce residential energy consumption. Furthermore, households are often ill-informed on energy efficiency of appliance when making purchasing-decision. As a result, most households may purchase appliance based on its initial cost. However, information on energy and lifecycle cost performance of appliances could enable households to make an informed decision (Ansah et al., 2020). Policies on '*caveat emptor* - let the buyer be aware' of energy efficiency and lifecycle cost of an appliance could avert purchasing decision made solely on the initial cost of appliance. This could be achieved by enforcing the placement of labels on appliance to inform households on its energy performance and its long-term cost performance.

**Conclusion**

This study investigated the impact of barriers on sustainable housing in the Ghanaian construction industry. A questionnaire survey was conducted among housing professionals in the formal sector. Valid data were collected from 47 respondents and analysed using descriptive statistics (i.e. mean score, standard deviation, 'corrected item-total correlation' and 'Cronbach's Alpha if Item deleted'). Furthermore, partial least square structural equation modelling (PLS-SEM) was employed in developing a model between sustainable housing and three categories of barriers: 'cost-related barriers', 'incentive-related barriers' and 'retrofit-related barriers'.

Findings of the study revealed some significant relationships among the constructs of the barriers on one hand and between constructs of the barriers and sustainable housing construct on the other hand. Significant relationships were found between 'cost-related barriers' and 'incentive-related barriers'; between 'incentive-related barriers' and 'retrofit-related barriers'. However, there was no significant relationship between 'cost-related barriers' and 'retrofit-related barriers'. Between the constructs of barriers and the sustainable housing construct, significant relationships exist between ‘incentive-related barriers’ and ‘sustainable housing’; between ‘retrofit-related barriers’ and ‘sustainable housing’. However, the relationship between ‘cost-related barriers’ and ‘sustainable housing’ was not significant.

Notwithstanding the relevance of the findings, the study has limitations that are worth noting. One limitation is the relative small sample size used for conducting the study. The number of stakeholders was restricted to include mostly respondents from the industry. Therefore, with a larger sample size, future study could use covariance-based structural equation modelling (CB-SEM) to corroborate the findings of this study, or otherwise. This could improve the generalization of the findings. Besides, the perspective of households, on potential barriers that hinder their attainment of sustainable housing, was not included. Future study on views of residents concerning barriers to sustainable housing could reveal interesting findings for policymaking on sustainable housing.

Albeit the limitations, the study findings have significant implication for policymakers and practitioners. High cost of sustainable housing development is as a result of inadequate incentives in the Ghanaian construction industry. Besides, inadequate retrofitting of public housing facilities and self-built housing facilities of most low-and middle-income earners is partly due to insufficient incentives. Moreover, the significant influence of ‘incentive-related barriers’ and ‘retrofitting-related barriers’ on ‘sustainable housing’ implies that policymakers in Ghana (i.e. Ministry of Works, Water Resources and Housing) could improve sustainable housing development through efficient allocation of resources on incentive policies and retrofitting schemes. More importantly, retrofitting schemes for housing facilities (including low-income self-build facilities) could yield greater impact on sustainable housing considering the higher effect size of ‘retrofit-related barriers’.

On incentive policies, prequalification requirements of potentials contractors and permit approval should include sustainable development strategies suggested by contractors, developers and households. This could be an incentive to expedite general sustainable development. Additionally, contractors should be awarded certificates based on their sustainable development track record on previous projects. These certificates could then be tendered by potential contractors at the prequalification stage for tender evaluation and possible award of contract based on the certificate and other required documents. Furthermore, low-interest loans, subsidies, revolving fund and policies (i.e. codes and regulations) could incentivize sustainable housing of subsequent facilities and could motivate retrofitting of unsustainable aged housing facilities to sustainability standards. The study's findings are relevant for urban development concerning the attainment of the UN Sustainable Development Goals in housing. They are key in apprising policymakers of major urban areas such as Accra, Kumasi, Sekondi-Takoradi and Tamale of the significant barriers that require utmost attention. Effective implementation of the findings could mitigate urban sprawl, promote smart growth and improve sustainable housing in Ghana and the continent at large. Theoretically, future study would investigate the impact of the suggested success strategies or policies on the identified indicators of sustainable housing.

**Data Availability Statement**

All data, models and code generated or used during the study appear in the submitted article.

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**Figure Caption List**

**Fig 1:** A Conceptual Model of the Impact of Barriers on Sustainable Housing

**Fig. 2:** Structural Model of Construct of Barriers and Sustainable Housing Construct

**Fig. 3:** Bootstrapping Results on Impact of Barriers Construct on Sustainable Housing Construct

**Table 1.** Barriers to Sustainable Housing

| Indicators of Barriers | References | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Arku et al. (2012) | Alam et al. (2019) | Sulemana et al. (2019) | Agyemang & Morrison (2018) | Gianfrate et al. (2017) | Obeng-Odoom (2010) | Chan et al. (2018) | Yang & Yang (2015) | Hu and Qian (2017) | Shi et al. (2011) | Sourani & Sohail (2011) | Owusu-Ansah et al. (2019) | Twumasi-Ampofo et al. (2014) |
| Delays in government approval process / lengthy building permit approval | – | X | – | – | – | – | – | X | – | X | – | X | – |
| High upfront cost of materials and technologies | X | – | – | – | – | – | – | – | – | X | – | – | – |
| High cost of serviced land | X | – | – | – | – | – | – | – | – | – | – | X | – |
| High inflation rate | X | – | – | – | – | – | – | – | – | – | – | – | – |
| High interest rates | X | – | – | – | – | – | – | – | – | – | – | X | – |
| Inadequate local professional skills for sustainable housing | – | X | – | – | – | – | X | – | – | – | – | – | – |
| High cost of permit approval (high taxes and fees on developers) | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Tight credit conditions | – | X | – | – | – | – | – | – | – | – | – | X | – |
| Inadequate incentive for private investors | – | – | – | – | – | – | X | – | – | – | X | – | – |
| Inadequate access to land | X | – | – | – | – | X | – | X | X | – | – | X | – |
| Income inequality | X | – | X | X | – | – | – | – | – | – | – | – | – |
| Lack of planning control on land development | – | – | – | X | – | – | – | – | – | – | – | – | – |
| Inadequate public funding / subsidies on technologies for sustainable housing | – | X | – | – | – | – | – | X | – | – | X | – | – |
| Inadequate infrastructure development | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Inadequate mortgage / financing schemes (mortgages & loans) | X | X | – | – | – | – | X | X | – | – | – | X | – |
| Inadequate policies & tools (standard or guidelines) for retrofitting | – | X | – | – | X | – | X | X | – | – | X | – | – |
| Lack of routine maintenance / poor maintenance culture of housing facilities | – | – | – | – | X | – | | – | – | – | | X | X |
| Policy instability / abandoned public housing facilities / projects by succeeding governments | – | – | – | – | – | – | – | – | – | – | – | – | X |
| Low level / inadequate retrofitting (maintenance operation) | – | – | – | – | X | – | – | – | – | – | – | – | – |
| Poor housing location (in peripheral of towns and cities) | – | – | – | – | – | – | – | – | X | – | – | – | – |

**Table 2.** Descriptive Statistics of Constructs and Indicators of Barriers to Sustainable Housing

| Constructs | Code | Observable Variables | Mean Score | Standard Deviation | Rank | Corrected Item-total correlation | Cronbach's Alpha if Item Deleted | Cronbach's Alpha |
|---|---|---|---|---|---|---|---|---|
| Sustainable Housing (Measured by Indicators of Sustainable Housing (ISH)) | | | | | | | | |
| ISH | ISH01 | Timely completion of project | 4.340 | 0.815 | 3 | 0.378 | 0.875 | 0.878 |
| | ISH02 | Construction cost performance | 4.468 | 0.584 | 1 | 0.231 | 0.878 | |
| | ISH03 | Quality performance | 4.343 | 0.644 | 2 | 0.496 | 0.872 | |
| | ISH04 | Safety performance (crime prevention) | 4.085 | 0.803 | 10 | 0.654 | 0.867 | |
| | ISH05 | End user's satisfaction | 4.319 | 0.980 | 4 | 0.646 | 0.866 | |
| | ISH06 | Stakeholders' satisfaction | 3.957 | 0.833 | 12 | 0.385 | 0.875 | |
| | ISH07 | Environmental-friendly (Eco-friendly) | 4.085 | 0.803 | 10 | 0.380 | 0.875 | |
| | ISH08 | Reduced lifecycle cost | 3.933 | 0.918 | 14 | 0.502 | 0.872 | |
| | ISH09 | Maintainability of housing facility | 4.283 | 0.851 | 6 | 0.566 | 0.869 | |
| | ISH10 | Energy efficient housing | 3.915 | 0.880 | 16 | 0.547 | 0.870 | |
| | ISH11 | Reduced disputes and litigation | 3.660 | 1.027 | 19 | 0.469 | 0.873 | |
| | ISH12 | Reduced public expenditure on housing management | 3.851 | 0.932 | 17 | 0.377 | 0.876 | |
| | ISH13 | Technical specification | 4.128 | 0.824 | 9 | 0.563 | 0.870 | |
| | ISH14 | Aesthetic view of housing facility | 3.913 | 0.717 | 15 | 0.363 | 0.876 | |
| | ISH15 | Price of housing facility | 4.298 | 0.749 | 5 | 0.393 | 0.875 | |
| | ISH16 | Rental cost of housing facility | 4.196 | 0.824 | 7 | 0.472 | 0.872 | |
| | ISH17 | Commuting cost of household to facility | 3.787 | 0.999 | 18 | 0.582 | 0.869 | |
| | ISH18 | Functionality of housing facility | 4.174 | 0.789 | 8 | 0.567 | 0.870 | |
| | ISH19 | Technology transfer | 3.468 | 0.856 | 20 | 0.621 | 0.868 | |
| | ISH20 | Take up rate of housing facility | 3.936 | 0.818 | 13 | 0.264 | 0.879 | |
| | ISH21 | Waiting time of potential households | 3.468 | 0.881 | 21 | 0.430 | 0.874 | |
| Potential Critical Barriers to Sustainable Housing | | | | | | | | |
| Cost-Related Barriers (CRB) | CRB1 | Delays in government approval process | 3.936 | 0.895 | 16 | 0.391 | 0.837 | 0.840 |
| | CRB2 | High upfront cost of materials and technologies for sustainable housing both new construction and retrofitting | 4.467 | 0.544 | 2 | 0.395 | 0.838 | |
| | CRB3 | High cost of serviced land | 4.467 | 0.710 | 3 | 0.386 | 0.837 | |
| | CRB4 | High inflation rate | 4.404 | 0.712 | 6 | 0.414 | 0.836 | |
| | CRB5 | High interest rates | 4.761 | 0.427 | 1 | 0.443 | 0.837 | |
| | CRB6 | High cost of permit approval (high taxes and fees on developers) | 4.170 | 0.637 | 10 | 0.326 | 0.839 | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | CRB7 | Income inequality | 3.979 | 0.737 | 15 | 0.427 | 0.835 |
| Incentive-Related Barrier (IRB) | IRB1 | Inadequate incentive for private investors | 3.872 | 0.924 | 19 | 0.553 | 0.829 |
| | IRB2 | Inadequate access to land among developers | 4.043 | 0.908 | 13 | 0.437 | 0.835 |
| | IRB3 | Lack of planning control on land development | 4.239 | 0.728 | 8 | 0.579 | 0.830 |
| | IRB4 | Inadequate subsidies / public funding for sustainable technologies | 3.893 | 1.047 | 18 | 0.420 | 0.836 |
| | IRB5 | Poor housing location (Inadequate policies on situating housing development in cities / towns) | 3.596 | 0.798 | 20 | 0.379 | 0.807 |
| | IRB6 | Inadequate infrastructural development | 4.043 | 0.806 | 12 | 0.488 | 0.833 |
| | IRB7 | Inadequate mortgage / financing institutions | 4.319 | 0.726 | 7 | 0.313 | 0.840 |
| | IRB8 | Tight credit conditions | 4.404 | 0.680 | 5 | 0.397 | 0.837 |
| Retrofit-Related Barriers (RRB) | RRB1 | Low-level or inadequate retrofitting (maintenance operation) | 3.935 | 0.818 | 14 | 0.527 | 0.831 |
| | RRB2 | Inadequate policies or sustainability assessment tools (standards or guidelines) for retrofitting housing facilities | 3.894 | 1.047 | 17 | 0.673 | 0.822 |
| | RRB3 | Lack of routine maintenance / Poor maintenance culture of housing facilities | 4.213 | 0.907 | 9 | 0.493 | 0.832 |
| | RRB4 | Policy instability / abandoned or neglected management of public housing facilities or projects by succeeding governments | 4.404 | 0.648 | 4 | 0.404 | 0.837 |
| | RRB5 | Inadequate local professional skills | 3.255 | 1.170 | 21 | 0.134 | 0.855 |

**Table 3.** Measurement Model Evaluation

| Constructs | Indicators | Loadings[a] | AVE[b] | CR[c] | CA[d] |
|---|---|---|---|---|---|
| Sustainable Housing | ISH10 | 0.715 | 0.504 | 0.876 | 0.812 |
| | ISH16 | 0.572 | – | – | – |
| | ISH17 | 0.701 | – | – | – |
| | ISH19 | 0.691 | – | – | – |
| | ISH04 | 0.694 | – | – | – |
| | ISH05 | 0.832 | – | – | – |
| | ISH06 | 0.741 | – | – | – |
| Cost-Related Barriers | CRB1 | 0.821 | 0.502 | 0.799 | 0.734 |
| | CRB2 | 0.735 | – | – | – |
| | CRB3 | 0.647 | – | – | – |
| | CRB4 | 0.613 | – | – | – |
| Incentive-Related Barriers | IRB1 | 0.853 | 0.542 | 0.823 | 0.737 |
| | IRB2 | 0.742 | – | – | – |
| | CRB 7 | 0.573 | – | – | – |
| | IRB3 | 0.749 | – | – | – |
| Retrofitting-Related Barriers | RRB1 | 0.697 | 0.545 | 0.826 | 0.727 |
| | RRB2 | 0.841 | – | – | – |
| | RRB3 | 0.722 | – | – | – |
| | RRB4 | 0.682 | – | – | – |

Items removed: indicator items below 0.5: - ISH01, ISH02, ISH03, ISH07, ISH09, ISH11, ISH12, ISH13, ISH14, ISH15, ISH18, ISH21, CRB5, CRB6; IRB5, IRB6, IRB7, IRB8, IRB9:

a. All indicator loadings > 0.5 means indicator reliability (Hulland, 1999).
b. All Average Variance Extracted (AVE) > 0.5 indicates Convergent Reliability (Fornell and Larcker, 1981).
c. All Composite Reliability (CR) > 0.7 indicates Internal Consistency (Gefen et al., 2001).
d. All Cronbach's Alpha (CA) > 0.7 indicates Indicator Reliability (Nunnally, 1978).

**Table 4.** Discriminant Validity (Fornell & Larcker Criterion)

| Constructs | Sustainable Housing | Cost-Related barrier | Incentive-Related barrier | Retrofitting-Related barrier |
|---|---|---|---|---|
| Sustainable Housing | **0.710** | – | – | – |
| Cost-Related barrier | 0.348 | **0.709** | – | – |
| Incentive-Related barrier | 0.126 | 0.464 | **0.736** | – |
| Retrofitting-Related barrier | 0.513 | 0.402 | 0.698 | **0.738** |

**Table 5.** Indicators' Cross Loading

| Indicators | Sustainable Housing | Cost-Related Barriers | Incentive-Related Barriers | Retrofitting-Related Barriers |
|---|---|---|---|---|
| ISH10 | **0.715** | 0.430 | 0.162 | 0.296 |
| ISH16 | **0.572** | 0.275 | 0.089 | 0.292 |
| ISH17 | **0.701** | 0.145 | 0.001 | 0.333 |
| ISH19 | **0.691** | 0.100 | 0.147 | 0.383 |
| ISH04 | **0.694** | 0.029 | 0.091 | 0.387 |
| ISH05 | **0.832** | 0.412 | 0.126 | 0.467 |
| ISH06 | **0.741** | 0.262 | 0.030 | 0.365 |
| CRB1 | 0.344 | **0.821** | 0.540 | 0.425 |
| CRB2 | 0.268 | **0.735** | 0.175 | 0.189 |
| CRB3 | 0.187 | **0.647** | 0.134 | 0.198 |
| CRB4 | 0.052 | **0.613** | 0.210 | 0.172 |
| IRB1 | 0.125 | 0.291 | **0.853** | 0.599 |
| IRB2 | 0.034 | 0.373 | **0.742** | 0.490 |
| CRB7 | -0.131 | 0.092 | **0.573** | 0.383 |
| IRB3 | 0.219 | 0.498 | **0.749** | 0.550 |
| RRB1 | 0.568 | 0.349 | 0.391 | **0.697** |
| RRB2 | 0.315 | 0.498 | 0.793 | **0.841** |
| RRB3 | 0.264 | 0.138 | 0.470 | **0.722** |
| RRB4 | 0.383 | 0.062 | 0.276 | **0.682** |

**Table 6.** Discriminant Validity (HTMT)

| Constructs | Sustainable Housing | Cost-Related Barrier | Incentive-Related Barrier | Retrofitting-Related Barrier |
|---|---|---|---|---|
| Sustainable Housing | – | – | – | – |
| Cost-Related Barrier | 0.403 | – | – | – |
| Incentive-Related Barrier | 0.281 | 0.495 | – | – |
| Retrofitting-Related Barrier | 0.663 | 0.412 | 0.883 | – |

**Table 7.** Direct Relationships for Hypothesis Testing

| Hypothesis | Relationships | Std. Beta | Std. Error | \|t-value\|^ | Decision | $f^2$ | $q^2$ | 95% CILL | 95%CIUL |
|---|---|---|---|---|---|---|---|---|---|
| H1 | Cost-Related Barriers -> Incentive-Related Barriers | 0.500 | 0.125 | 3.673** | Supported | – | – | 0.297 | 0.681 |
| H2 | Incentive-Related Barriers -> Retrofitting-Related Barriers | 0.651 | 0.122 | 5.316** | Supported | 0.675 | 0.210 | 0.420 | 0.818 |
| H3 | Cost-Related Barriers -> Retrofitting-Related Barriers | 0.118 | 0.165 | 0.637 | Not supported | 0.034 | 0.001 | -0.150 | 0.366 |
| H4 | Cost-Related Barriers -> Sustainable Housing | 0.273 | 0.186 | 1.507 | Not supported | 0.086 | 0.014 | -0.058 | 0.557 |
| H5 | Incentive-Related Barriers -> Sustainable Housing | -0.574 | 0.161 | 3.443** | Supported | 0.192 | 0.053 | -0.830 | -0.327 |
| H6 | Retrofitting-Related Barriers -> Sustainable Housing | 0.824 | 0.155 | 5.087** | Supported | 0.430 | 0.184 | 0.563 | 1.062 |

**$p < 0.01$, *$p < 0.05$

$R^2$ (Sustainable affordable housing = 0.433)

Effect Size ($f^2$) are according to Cohen (1988), $f^2$ values: 0.35 (large), 0.15 (medium), and 0.02 (small)

Predictive Relevance ($q^2$) of predictor independent construct as according to Henseler et al (2009), $q^2$ values: 0.35 (large), 0.15 (medium), and 0.02 (small).