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To Build or Not to Build, that is the Uncertainty: Fuzzy Synthetic Evaluation of Risks for Sustainable Housing in Developing Economies

Abstract

Sustainable housing development is essential for achieving the United Nation's Sustainable Development Goals. However, amid increasing housing deficits, investing in sustainable housing is widely perceived as a risky venture among policymakers and potential developers. This study explores the risk factors that hinder sustainable housing in developing economies using Ghana as a case study. Through a comprehensive literature review, a list of 30 risk factors was established and categorized into five thematic groups. These factors and groups were used to conduct a questionnaire survey among professionals in the Ghanaian housing market to assess progress on achieving sustainable development goals in housing and the risk factors that affect these. Fuzzy synthetic evaluation (FSE) analysis conducted on risk factors revealed that 'financing-related' is the most critical risk category followed by 'procurement-related', 'design and construction', 'operation and maintenance' and 'political-related' risk factors. By prioritizing the risk categories, the findings apprise policymakers and practitioners of the risk factors that require more attention to achieve sustainable housing development. Additionally, the study stipulates measures for mitigating critical risks and for promoting efficient eminent domain on land, energy efficient retrofitting, transparent procurement, effective contractual strategies and efficient co-production and co-designing for sustainable housing development.

Keywords: Multiple criteria evaluation; fuzzy system model; group decision-making; decision analysis; sustainable housing; risk factors

1. Introduction

"It is one world. And it's in our care." David Attenborough

To create the man-made built environment, construction activities have inevitably depleted natural resources and increased greenhouse gas emissions such as carbon dioxide (CO_2) and carbon monoxides (CO) (Huang et al., 2018). In turn, this environmental degradation has contributed to climate change which threatens socio-economic development and endangers all life on earth (Huang et al., 2018; Krause & Hawkins, 2021; Santos et al., 2021). Growing global awareness of the dire need for sustainable development has focused governments onto activities such as housing which is a major consumer of natural resources and contributor to detrimental environmental effects (Klopp & Petretta, 2017; Chan and Adabre, 2019; Grossi & Trunova, 2021). Sustainable development goals are embedded in the United Nation's (UN) policy, for example target 11.1 of the Sustainable Development Goal II requires access for all to sustainable housing facilities by 2030 (UN, 2015). Sustainable housing facilities are designed, constructed and managed as quality and safe facilities for ensuring optimum benefits with regard to the three main sustainability pillars, viz: economic sustainability; social sustainability; and environmental sustainability. Within these pillars are set goals such as: price or rental affordability of housing facilities; environmentally-friendly facilities; adequate connection to potable and affordable water, energy and sanitation facilities; and adequate accessibility to jobs, shops, health-care, education and other services. Moreover, sustainable housing facilities are adequately operated, maintained and timely refurbished and retrofitted (UN-Habitat, 2012; Biermann et al., 2017; Adabre & Chan, 2018). Whilst the UN's ambition is laudable, practical solutions to ensuring housing sustainability in low-and middle-income households (especially among cities of developing countries such as Ghana) have hitherto proven elusive (Awanyo et al., 2016). Consequently, the focus in most developing countries (especially in sub-Saharan African) has often been on price or rental affordability of housing facilities (i.e. affordable housing or low-cost housing) to the neglect of the other sustainable housing goals. Yet, there exist challenges that specifically affect affordable housing supply, which cumulatively affect sustainable housing development in general (Croese et al., 2016).

Policymakers in Ghana's era of neoliberalization provide a facilitative role to enable developers to improve the housing market and for self-builders to meet their housing needs (Arku, 2009). Although such policy intentions were commendable, housing commodification among private developers has inadvertently created exclusive housing facilities to the minority of high-income earners in major cities (ibid). Consequently, most of Ghana's low- and middle-income earners, especially in the administrative capital Accra, are socially excluded by exorbitant sale prices or advance rental charges (Gaisie et al., 2019; Adu-Gyamfi et al., 2019). In turn, this has unwittingly created an informal housing market and concomitant poor living conditions for inhabitants such as overcrowding in housing facilities and an increasing number of slum developments which affect economic, social and environmental sustainability attainment (Gaisie et al., 2019). Keivani and Werna (2001) expressed grave concerns about the facilitative role of the government (as recommended by the World Bank and other international aid agencies), stressing that current provisions are inadequate. Accordingly, Keivani and Werna (2001) and Adabre and Chan (2020) advocated for public housing supply for low- and middle-income earners in addition to providing the supporting role for private developers and self-builders.

The call for a dual role of governments (viz ensuring public housing supply and providing a facilitative role) is more commendable and socially inclusive (Awanyo et al., 2016). Essentially, a hybrid public policy/joint-venture approach has been adopted to augment Ghana's housing supply. Without governments' adoption of such policy approaches, most low-and middle-income earners (i.e. civil servants) will continue to be effectively priced-out of the country's housing market in most cities (Arku, 2009). Despite the housing needs, some properties remain abandoned, unoccupied or challenged with a low acceptability or low take up rate (cf. Twumasi-Ampofo et al., 2014; Grant et al., 2019; Agyemang et al., 2018). This issue is not unique to Ghana and doggedly persists in: Malaysia (Teck-Hong, 2012); and China (Yuan et al., 2018). In sub-Saharan Africa, Grant et al. (2019) described the potential fate of Ghana's abandoned Saglemi housing project as a ghost city in the worst-case scenario, a likely comparable fate of the Chinese-Angola ghost town. Arguments for high-rise residential buildings are persuasive and include: controlling urban sprawl by compact development, reducing vehicular emission; and optimizing utilization of the environment – however, high-rise apartment development is affected by a low social acceptability risk by some family households (cf. Agyemang et al., 2018). Therefore, in this vogue crisis of housing needs amidst abandoned facilities and low social acceptability risk or low take-up rate risk, governments under a neoliberal economy are uncertain as to whether to build or not to build. Likewise, risks in the prevailing global macroeconomic environment and national political conditions cast doubts on private sectors' certitude to invest in housing investment or partner with the government in housing supply. Thus, amidst the exigent need for housing facilities (especially among developing economies), critical risk factors (CRFs) in the built environment have affected public housing projects and the private sectors' initiatives in housing supply.

Extant literature reveals a current dearth of studies that provide an objective, quantitative assessment of the impact of risk factors vis-à-vis the sustainable development goals in housing. Considering the prevalence of pertinent risk factors and the need for effective policies to mitigating them, this study adopts the fuzzy synthetic evaluation (FSE) technique to objectively quantify the impact of risk factors on attaining the sustainable development goals in housing. This technique is appropriate for eliminating the subjectivity and biases that are inherent in risk assessment by multi-stakeholders in the built environment (Ameyaw and Chan, 2015; Zhao et al., 2016; Ekanayake et al., 2021). Associated objectives are to: apprise policymakers of CRFs and suggest policies for sustainability attainment in housing supply; engender greater social equality by creating affordable and sustainable homes in major cities.

2. Risks Factors from Extant Literature

Sustainable development in housing can be inferred or measured by observable variables (Adabre and Chan, 2020). Past erudite studies (cf. Mulliner et al., 2013; Nuuter et al. 2015; Gan et al., 2017; Adabre and Chan, 2018; Nasrabadi & Hataminejad, 2021; Ahmad et al., 2021) have provided a list of these variables/goals for assessing sustainable housing development towards ensuring optimum economic, social and environmental benefits for a range of households. Gan et al. (2017) asserted that considering the changing climatic conditions, unaffordable housing crises in cities and energy crisis, it is germane to ensure that housing supplies are not only price affordable but are also energy efficient and well-located to reduce vehicular emissions/cost and to meet households' transient shelter needs. According to Adabre and Chan (2018), 21 goals were identified for sustainable development in housing. Some of these goals include: timely completion of projects within budgeted cost and to a desirable level of quality; safety project performance; end-users' satisfaction; project team satisfaction; eco-friendly housing facility that is energy efficient in addition to reducing maintenance and lifecycle cost; rental/price affordability; commuting cost reduction; aesthetic housing facility that is functionally adequate in addition to meeting its technical specification. These goals are also inveterate indicators/criteria of sustainable housing development in Chan and Adabre (2019).

Studies on projects' performance have concluded that in most cases, not all the goals are achieved because projects are fraught with risks (Ashley et al., 1987; Osei-Kyei and Chan, 2017). El-Sayegh and Mansour (2015) define risk as an uncertain event or condition that, if it occurs, could have either a positive or negative effect on at least one project objective or goal. For this study, risks entail factors that, if not appropriately managed, could affect any of the project goals or could culminate in barriers that lead to project failure. Thus, risks are precursors to barriers. Risk is a joint function of both likelihood and severity and therefore, should be assessed as such.

Various risk factors have been identified from prior studies and some are general and are applicable in many countries and projects. For instance, key risk factors identified by Ameyaw and Chan (2015) in the Ghanaian construction industry include 'foreign exchange rate fluctuation', 'corruption', 'political interference', 'high operational costs', 'inflation and interest rates volatility'. Similarly, a comparative study between Hong Kong and Ghana on general infrastructure procurement through public-private partnership, (cf. Osei-Kyei and Chan (2017) confirmed most of these risk factors. In the United Arab Emirates, El-Sayegh and Mansour (2015) concluded that the most significant risks include: 'quality and integrity of design'; 'delays in approvals'; and 'delays in land expropriations'. Likewise, in Singapore, 'currency and interest rate volatility'; 'inflation rate fluctuation'; 'poor construction quality'; and 'risk of design changes' are confirmed in studies by Hwang et al. (2017) and Zhao et al. (2016) on sustainable buildings. Although most of these risk factors pertain to varied construction projects, they also affect most affordable or low-cost housing projects/facilities and consequently affect the attainment of the sustainable development goals for sustainable housing.

In a comparative study by Fernandez-Dengo et al. (2013) on risk assessment in the housing market, 'monetary inflation'; 'economic growth'; 'bureaucratic delays'; 'social conflicts'; and 'financing risks' were ranked relatively high by both Mexican and U.S. firms. Furthermore, most of these risk factors were established in Sanda et al. (2020) on housing projects in Nigeria and in Yu et al (2017) as social risks in housing demolition in China. Additionally, Lundin et al. (2015) identified 'contractors' financial crisis'; 'difficulties with payments'; and 'litigations' as risks to public housing projects in Ghana. Notably, the relatedness of these risk factors to housing projects could be attributed to the varied characteristics of housing projects. Considering that a housing facility could be a public facility that must be procured based on laid-down procedures, it could be affected by political-related risks and inefficiencies in the procurement process (Owusu et al., 2019). Besides, given that it could be a public or private investment that requires extensive financial resources for construction, a housing project is influenced by financial-related risks (macroeconomic factors and availability of fiscal resources) (Frimpong and Marbuah, 2010; Donkor-Hyiaman et al., 2019) and inherent risks in project design and construction (Lundin et al., 2015).

As a product for the accumulation of wealth and a driver of economic growth, housing could be affected by policy inefficiencies or risk inherent in policies. For instance, in Hong Kong, Ho (2004) and Zheng et al. (2017) concluded that public housing privatization stands the risk of exacerbating the inequitable distribution of housing resources. Similarly, Fields and Uffer (2014, p. 1486) revealed that "financialization heightened existing inequalities in housing affordability and stability, and rearranged spaces of abandonment and gentrification in both New York and Berlin." However, focusing solely on Berlin, Kitzmann (2017) concluded that following privatization of housing in Germany, private companies provided more housing facilities to the socially disadvantaged than Berlin's state-housing companies. Strategic measures such as avoidance of high vacancy rate and changes in policies of Berlin's state housing companies to a more market-oriented approach were stated as the reasons for the different impact of privatization in Berlin as compared to that in Hong Kong, New York and London. In the Ghanaian housing sector, privatization of housing also entails the transfer of the state's role of housing supply to the private sector and the sales of state rental facilities to existing households who can afford such facilities (Grant and Yankson, 2003). 'Limited fiscal resources' and 'operation and maintenance cost burden' were identified for the former and latter forms of privatization, respectively. Similar the negative effect of privatization experienced in New York and London has also been observed in Ghana (Taruvinga and Mooya, 2018).

Furthermore, as a facility for providing daily shelter needs, belonging and esteem needs, housing could be affected by risks from households' preference(s). For example, while Hong Kong and some economies show high demand for housing facilities, the 'low-take up rate of housing facilities' has been identified as a risk factor in Malaysia (Teck-Hong, 2012) and in Mainland China (Yuan et al., 2018). In Ghana, Agyemang et al. (2018) identified low-social acceptability as a risk factor to high-rise apartment development. Concerning the Saglemi housing project, Grant et al. (2019) identified related risk factors such as socio-spatial segregation and inadequate infrastructural supply. Moreover, in Australia, Susilawati (2009) found that developers agreed that risk of community rejection of low-cost housing projects is among the main risk factors to developers. A similar risk factor of opposition to low-cost housing projects was identified in the U.S. with associated risk factors such as 'declining values of neighboring housing facilities' and 'congestion on existing amenities/infrastructure due to new households' (Tighe, 2010; Nguyen et al., 2013). Although the former has not been highlighted in Ghana, Avogo et al. (2017) identified the latter due to transformation of Government constructed housing at Madina Estates in Accra. Awanyo et al. (2016) stated that 'opposition to large public-private housing project' was one of the risk factors that led to the cancelation of the STX (System Technology Excellency, South Korea) housing project in Ghana. Unlike the U.S. case, Awanyo et al. (2016, p. 50) attributed the cancelation to "housing as a product for wealth accumulation." Disagreement over accumulation and opposition by neoliberal estate developers and their political-class collaborators were highlighted by Awanyo et al. (2016). Thus, developers in the country were more financially motivated while government were more socially motivated.

In identifying and assessing the various forms of risk factors, both qualitative techniques (cf. Ho, 2004; Susilawati, 2009; Fields and Uffer, 2014) and quantitative techniques (cf. El-Sayegh and Mansour, 2015; Kitzmann, 2017) have been deployed. Yet, these techniques could yield different outcomes even within same country and/or on the same project. For instance, while Fields and Uffer (2016) concluded that privatization could contribute to housing unaffordability and inequality in Berlin using qualitative techniques, Kitzmann (2017) conversely concluded, using quantitative techniques, that privatization in Berlin has led to housing of the socially disadvantaged more than Berlin state housing-companies'. Notwithstanding other reasons for disparity in the results, these studies could be influenced by subjectivity and biases based on the data collection techniques and statistical analysis employed. Subjectivity is even more problematic in multi-criteria decision making i.e. involving multiple professional stakeholders (such as architects, surveyors, developers) and using multivariate qualitative and quantitative data. Risk is a complex multivariate factor that consists of varied forms. Table 1 provides a summary of the varied forms and categorizations of prominent risk factors that could affect sustainable housing. Since housing projects involve multiple stakeholders, decision-makers tend to assess risks based on their experience, aims, goals and knowledge using vague linguistic terms (Ameyaw and Chan, 2015). It is this group decision-making in the real world that leads to subjectivity and uncertainties in risk assessment (ibid). The literature reviewed in this present study revealed a notable dearth of research that provides an objective and quantitative assessment of the impact of the risk factors (refer to Table 1) vis-à-vis the sustainable developments goals in housing. This knowledge provides the premise upon which to unravel CRFs that affect the build or not build uncertainties among developers and policymakers for sustainable housing.

Table 1: Potential Critical Risk Factors (CRFs) to Sustainable Housing

Risk Categories	No.	Risk Factors	References 1	2	3	4	5	6	7	8	9	10	11	12	13
Political-Related Risks	PRF01	Political continuity risks/change of government	√		√		√						√		
	PRF02	Risk associated with land acquisition/land expropriations for housing	√		√					√			√		
	PRF03	Risk associated with opposition to large public-private housing projects						√			√				
	PRF04	Risk due to policy instability/political opposition to public housing projects	√			√	√						√		
	PRF05	Risk due to delays in project permit approval/delays in obtaining construction permits or issuance of documents	√										√		
Financing-Related Risks	FRF01	Inflation rate volatility (price fluctuation of materials & labour & sustainable technologies)	√	√		√	√						√		√
	FRF02	Fluctuations in exchange rate	√	√	√								√		√
	FRF03	Fluctuating cost of finance (interest rates)	√				√						√		√
	FRF04	Privatization risks (changes from government/public financing to private/market financing strategies)	√										√		√
	FRF05	Poor/inadequate financial market	√			√							√		√
	FRF06	Increasing tax rates and fees on developers	√	√	√										
	FRF07	Delays in payments by governments/clients	√	√			√			√					
	FRF08	Litigations over claims payment		√						√					
Procurement Risks	CRF01	Corruptions in project procurement	√			√							√		
	CRF02	Inadequate competition during project tendering													
	CRF03	Errors and omissions in tender documents (i.e. inaccurate cost estimation)			√								√		
Design & Construction Related Risks	DRF01	Construction time overruns	√										√	√	
	DRF02	Construction cost overruns	√										√	√	
	DRF03	Construction deficiencies/defects											√		
	DRF04	Resource unavailability risks (local skill labour & sustainable technologies and materials)													
	DRF05	Design and construction variation orders/alteration and rework due to construction variations				√	√								
	DRF06	Technical complexity risk associated with project		√		√									
	DRF07	Force majeure (unforeseen adverse conditions at project site)				√	√			√					
	DRF08	Construction accidents and injuries		√		√	√			√					
Operation & Maintenance Risks	ORF01	Fluctuating market demand or preference/low social acceptability							√			√			
	ORF02	Socio-spatial segregation												√	
	ORF03	Operation/maintenance cost overruns	√										√		
	ORF04	Utilities/infrastructure supply risks											√	√	
	ORF05	Congestion on existing amenities/infrastructure due to new households									√				
	ORF06	Privatization risk (privatization of existing public rental stock)													√

References: 1= Osei-Kyei and Chan (2017); 2= Zhao et al. (2016); 3= Fernandez-Dengo et al. (2012); 4= Hwang et al. (2017); 5= Chileshe et al. (2012); 6= Awanyo et al. (2016); 7= Sanda and Anigbogu (2016); 8= El-Sayegh and Mansour (2015); 9= Tighe (2010); 10= Teck-Hong (2012); 11= Ameyaw and Chan (2015); 12= Grant et al. (2019); 13= Taruvinga and Mooya (2018)

2.1 Conceptual Model – A Summary of the Literature

Fig. 1 shows a conceptual model for this present study. In this model, it is proposed that affordable housing or low-cost housing facilities, which are mostly focused on price or rental affordability (cf. Croese et al., 2016), lead to the attainment of an aspect of economic sustainability. Thus, price/rental affordable housing facilities are a subset of economic sustainability. Besides, economic sustainability, social sustainability and environmental sustainability are the three main dimensions of sustainable housing development. Each of these dimensions is a subset of the other beginning with economic sustainability followed by social sustainability and then environmental sustainability. Thus, economic sustainability is an element of social sustainability while both forms of sustainability are dependent upon environmental sustainability (Velenturf and Purnell, 2021). In most developing countries such as Ghana and other sub-Saharan African countries (i.e. Angola, Namibia, Ethiopia and South Africa), the identified risks mostly affect affordable housing or low-cost housing (Croese et al., 2016). However, adequate assessment of the risk factors could offer the basis for making recommendations for eliminating these risk factors. Such recommendations are essential for achieving each of the three sustainability dimensions of which affordable housing is part. This could ultimately lead to sustainable housing development. Although prior studies, in different context of construction, have assessed the criticalities of the risk factors, an objective quantification of the risks for ensuring sustainable housing is lacking globally and specifically in Ghana. Therefore, this conceptual model illustrates the existing knowledge gap in prior studies concerning the subjective and qualitative evaluation of risk impact. The model also shows how this study seeks to bridge the existing knowledge gap by providing an objective and quantitative evaluation of risk impact via FSE towards policy recommendation for the various sustainability dimensions and an overall sustainable housing development.

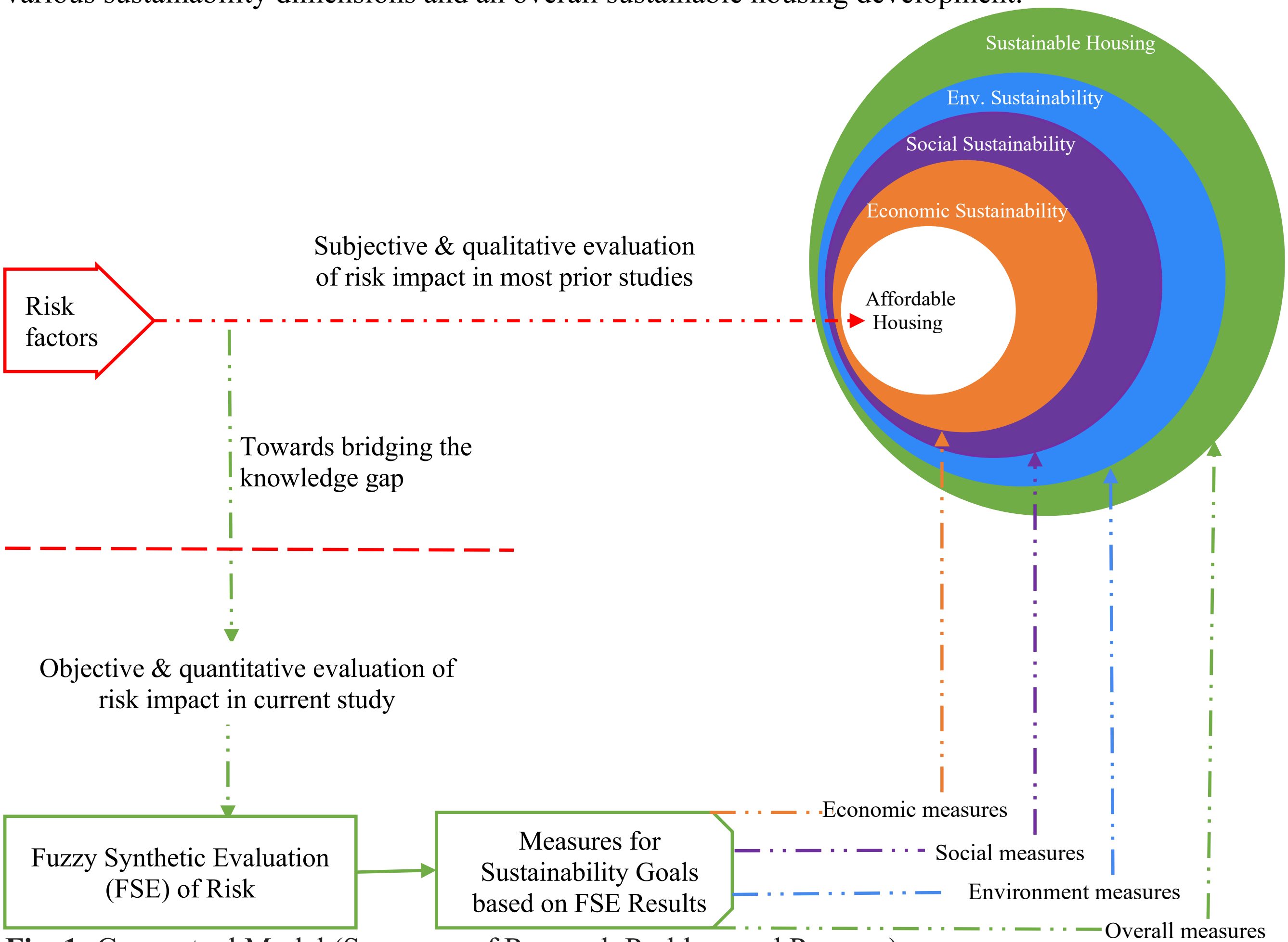

Fig. 1: Conceptual Model (Summary of Research Problem and Purpose)

3. Research Methodology

The research adopted a positivist philosophical stance (Edwards et al., 2019; Aghimien et al., 2020) to undertake deductive reasoning to empirically test theories (Hou et al., 2020; Ghansah et al., 2020) on the CRFs impacting upon special housing development in Ghana using primary data. The study was conducted in iterative stages: stage 1 entailed a comprehensive review of the literature which led to the identification of the research problem and then a list of potential CRFs and the appropriate research method for the study (refer to Fig. 2). Prior to the questionnaire design at the beginning of stage of 2 (refer to Fig. 2), the list of identified CRFs were piloted with Ghanaian experts to assess content validity and rephrase the wording of factors appropriately. Six Ghanaian experts were selected using non-probability purposeful sampling where entry criteria were based on their expertise (at least five years relevant 'housing' experience) and willingness to participate in the pilot study – of these, four agreed to participate.

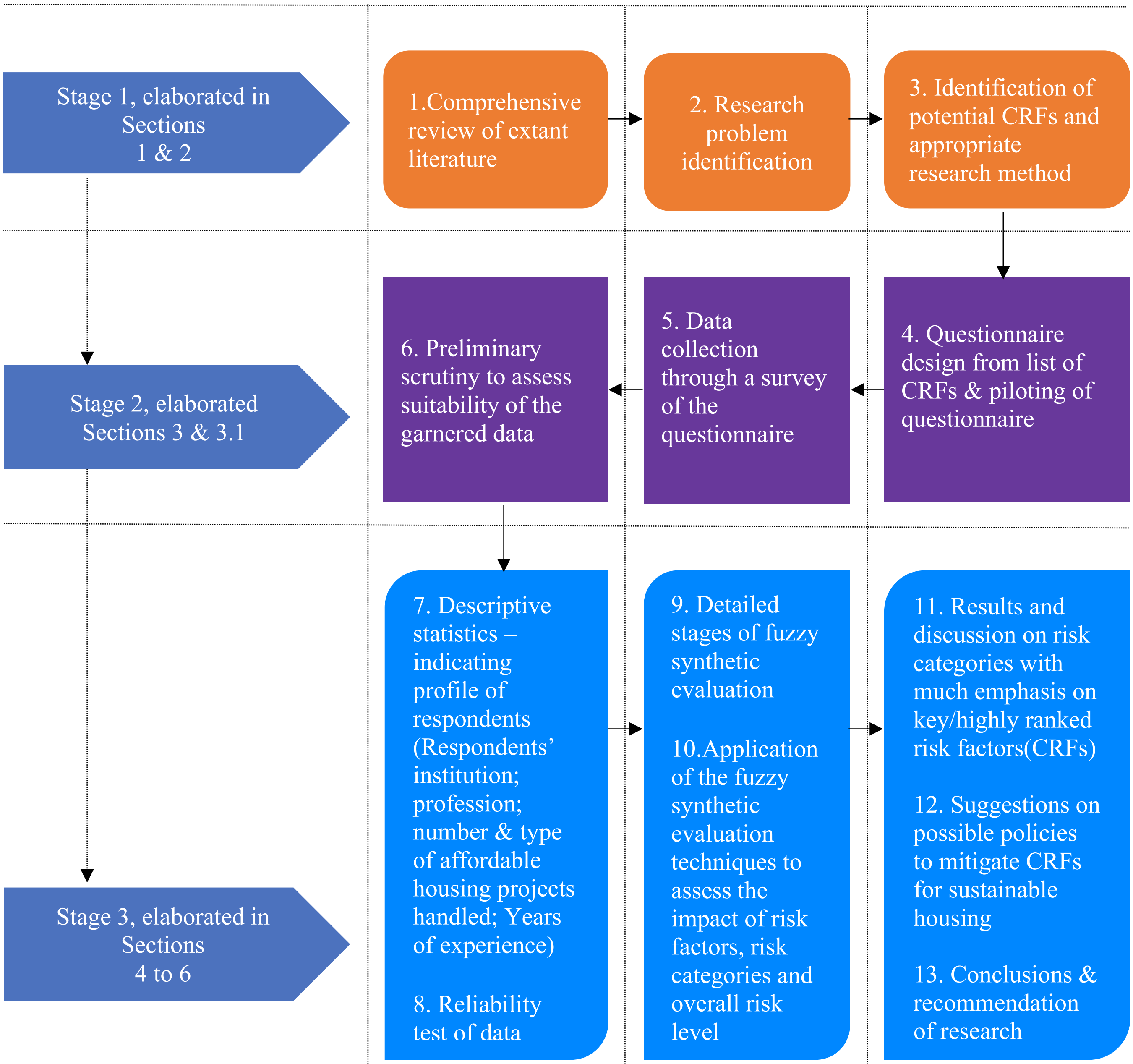

Fig. 2: Research Process of the Study

3.1 Questionnaire Survey and Participants

Using the pilot study feedback, the main survey questionnaire was designed. The questionnaire design and data collection processes are outlined in stage 2 (refer to Figure 2). After securing their demographic data, respondents were requested to rate a list of sustainable development goals in housing (e.g. price or rental affordability, reduced transportation cost, safety, energy efficiency, eco-friendly, aesthetics etc.) prior to rating the risk factors that could influence the attainment of the goals. A 5-point rating scale of 1-not important; 2-low importance; 3-neutral; 4-important and 5-very important was provided for respondents to rate the goals. Similarly, respondents were requested to rate both the likelihood of occurrence (LO) and severity of impact (SI) of each risk item using a two-dimensional five-point grading system (1=very low and 5 = very high). A closed ended 5-point grading system is ubiquitous in construction management science because it offers advantages in terms of brevity, efficiency of completion and economy (Adabre et al., 2020). This study presents a report on the findings concerning the impact of the risk factors.

The questionnaire was restricted to professionally qualified practitioners from the formal sector /regulated institutions of the Ghanaian housing market to ensure consensus of opinion was obtained. Since there was no population frame at the time of the questionnaire administration, probability sampling techniques such as random sampling could not be conducted. However, non-probability sampling, namely, purposive sampling and snowballing techniques were adopted. Private real estate developers were initially identified from a brochure that was provided by the head office of the Ghana Real Estate Developers Association (GREDA). A list of 154 companies was obtained from the brochure as companies that undertake real estate activities. Postal addresses, region of operation, mobile phone numbers, telephone numbers, email-addresses and contact person's details were all provided in the brochure. All the companies as listed were contacted through phone calls at the initial stage to confirm their business operations and to solicit their willingness to participate in the questionnaire survey. Through phone calls made, some companies stated that they no longer build houses while other companies indicated that they provide housing facilities but their targets are non-Ghanaians since the prices of the housing facilities are relatively high and beyond the affordability of most Ghanaians. Other companies admitted that they target the Ghanaian households but were not willing to participate in the survey (due to for example, non-disclose agreements) while others could not be reached by the telephone numbers. Therefore, 23 developers agreed to participate in the survey, 15 requested for the questionnaires to be administered in person while six via email. Through follow ups, six were retrieved from the personal administration while two from emails.

Furthermore, the questionnaire was administered at the 50th Annual General Meeting (AGM) of the Ghana Institution of Surveyors (GhIS), which was held on 2nd March, 2019 in Accra, Ghana's administrative capital. At the AGM, experienced professionals on housing projects from both public or private institutions were identified through snowballing. The questionnaires were administered to twenty-five (25) professionals who willingly agreed via informed consent (cf. Fisher et al., 2018; Ahmed et al., 2021) to participate in the survey after a brief introduction on the study's purpose. The timing for the questionnaire administration could not be planned to coincide with AGMs of other professional bodies due to limited time allocated for the study. However, to avoid data bias as practicable as possible, views of other professionals were solicited from some parastatal institutions that supply housing facilities or render services (i.e. research and consultancy) related to housing. Some experienced professionals from parastatal institutions were contacted and personally given a hard copy of the questionnaire. These institutions together with the number of administered questionnaires include: State Housing Corporation (SHC), 9 administered questionnaires; Tema Development Cooperation (TDC), 10 administered questionnaire; Social Security and National Insurance

Trust (SSNIT), 5 administered questionnaires; Public Works Department (PWD), 5 administered questionnaires; Building and Road Research Institute (BRRI), 10 administered questionnaires; Architectural and Engineering Service Limited (AESL), 9 administered questionnaires in addition to 8 administered questionnaires to experts (i.e. including 3 lecturers) identified through referrals (snowballing) by employees at AESL; and Ministry of Water Resources, Works and Housing, 6 administered questionnaires. The questionnaires were mostly administered in Accra due to the high affordability crisis. The timing and the techniques of the questionnaire administration were taken into consideration to ensure that the questionnaires were administered to a wide number of professionals to eliminate or reduce sampling biases. Within a three-month duration, a total of 110 questionnaires were administered and in total, forty-nine answered questionnaires were received as follows: 8 questionnaires were retrieved from GREDA (6 through personal contacts while 2 via email); 17 from the AGM of the GhIS; 4 from TDC, 3 from SHC, 4 from AESL in addition to 3 from the referrals, 1 from SSNIT, 2 from PWD, 2 from Ministry of Water Resources, Works and Housing and 5 from BRRI. However, two questionnaires were considered invalid due to incompleteness and therefore, 47 returned questionnaires were deemed valid (constituting a 42.7% response rate). The 47 returned questionnaires are deemed suitable for statistical analysis since a minimum sample size of 30 is appropriate to meet the central limit theorem for statistical analysis (Ott and Longnecker, 2015).

4. Data Analysis & Results

Data collected was analyzed using a combination of descriptive statistics, reliability test and fuzzy synthetic evaluation (FSE) analysis via the Statistical Package for Social Science (SPSS version 21.00). The data analysis is outlined in stage 3 of Fig. 2.

4.1 Respondent Demographics

Regarding professional status, most of the respondents (55.3% or frequency (f) = 26) are quantity surveyors of which 4.3% *(f = 2)* are employed in companies under GREDA; 19.2% *(f = 9)* are architects who are employees in some of the parastatal institutions; 12.8% *(f = 6)* are construction or project managers of companies registered with GREDA; while 12.8% are planners and engineers *(f = 3 planners; f =3 engineers)* who work in various institutions concerning housing. Most respondents (52.2% or f = 24) have handled at least three housing projects in the Ghanaian housing sector of which 55.1% (f = 27) are public housing projects. 63.9% (f = 30) of the respondents have over 5 years of relevant work experience. Based on the respondents' demographic profile, it can be concluded that they offer considerable tacit knowledge and experience of the phenomena under investigation and therefore, provide reliable and valid information for assessing the impact of risk on sustainable housing development.

4.2 Reliability Test

Prior to conducting the FSE analysis, a reliability test was conducted (using Cronbach's Alpha) to evaluate the broader applicability and internal consistency of the 30 risk factors identified. With Cronbach's alpha values of 0.935 and 0.928 for both the LO and SI of the risks, respectively, it was confirmed that these values rank favorably high with respect to the 0.70 minimum thus confirming a high internal reliability and consistency of the data (Field, 2013; Ameyaw and Chan, 2015).

4.3 Fuzzy Synthetic Evaluation (FSE)

Since the construction of sustainable housing involves multi-stakeholder professionals, their perceptions on the LO and SI of the various risk factors are generally subjective and could be biased (Zhao et al., 2016; Tsai et al., 2020). However, the FSE technique is appropriate for dealing with such subjectivity in responses on the multi-variate (i.e. risk factors). Using the

FSE, the linguistic rating scale (5-point Likert scale) could be quantified to determine the magnitude of impact (MI) of the risk factors, risk categories and overall risk level on sustainable housing in Ghana.

4.3.1 Procedures in FSE Data Analysis and Results

According to Zhao et al. (2016), risk assessment using the fuzzy synthetic evaluation requires three main elements, namely,

(1) A set of fundamental factors/risk attributes R = {R_1, R_2, R_3 … R_n}; where n represents the number of risk factors or attributes;
(2) A set of grade alternatives G = {G_1, G_2, G_3 … G_n}; for this study, the 5-point Likert scale is the set of grade alternatives. Therefore, G_1 = very low, G_2 = low, G_3 = medium, G_4 = high, G_5 = very high; and
(3) A fuzzy evaluation matrix for each set of risk attribute groupings. This matrix is expressed as $R_i = (r_{ij})_{m \times n}$, where r_{ij} is the degree to which alternative G_j satisfies the criterion R_j

Three systematic steps are then required for assessing the risks at the individual level (level 1 which is achieved in step 1), group level (level 2 which is achieved in step 2) and overall risk level (level 3 which is achieved in step 3). These steps include:

(1) Calculating the LO, SI and MI of risk factors;
(2) Calculating the LO, SI and MI of various categories of risk factors; and
(3) Calculating the LO, SI and MI of all the categories of risk factors.

Step 1. Calculating the LO, SI and MI of Risk Factors (Level 1)

To assess the LO, SI and MI of the various risk factors, respondents were asked to rate the various set of risk factors using a 5-point Likert scale. Therefore, the set of grade alternative for both the LO and SI of the risk factors includes the various elements of the scale previously delineated. These responses can be expressed as membership functions, using the LO for example, in the following equation forms:

$$R_{(\mathrm{LO})1} = \frac{LO_1}{G_1} + \frac{LO_2}{G_2} + \cdots + \frac{LO_5}{G_5}$$
$$R_{(\mathrm{LO})1} = \frac{LO_1}{\text{very low}} + \frac{LO_2}{\text{low}} + \frac{LO_3}{\text{medium}} + \frac{LO_4}{\text{high}} + \frac{LO_5}{\text{very high}}$$

$$R_{(\mathrm{LO})1} = \frac{LO_1}{1} + \frac{LO_2}{2} + \frac{LO_3}{3} + \frac{LO_4}{4} + \frac{LO_5}{5}$$

Similarly, the responses on the SI could be expressed in the membership function as follows:

$$R_{(\mathrm{SI})1} = \frac{SI_1}{G_1} + \frac{SI_2}{G_2} + \cdots + \frac{SI_5}{G_5}$$
$$R_{(\mathrm{SI})1} = \frac{SI_1}{\text{very low}} + \frac{SI_2}{\text{low}} + \frac{SI_3}{\text{medium}} + \frac{SI_4}{\text{high}} + \frac{SI_5}{\text{very high}}$$

$$R_{(\mathrm{SI})1} = \frac{SI_1}{1} + \frac{SI_2}{2} + \frac{SI_3}{3} + \frac{SI_4}{4} + \frac{SI_5}{5}$$

In FSE, the "+" denotes a notation and not an addition (Ameyaw and Chan, 2015; Oppong et al., 2021). Thus, the equation for the membership functions for both the LO and the SI of the risk factors can also be expressed as (LO_1, LO_2, LO_3, LO_4, LO_5) and (SI_1, SI_2, SI_3, SI_4, SI_5), respectively. After determining the membership functions, both the LO and the SI can be calculated using the following equations as stated in Zhao et al. (2016) and Osei-Kyei and Chan (2017).

$$\mathrm{LO_i} = \sum_{i=1}^{5} (G_i \text{ X } R_{(LO)1}) \ldots\ldots \text{eqn. (1)}$$

$$\mathrm{SI_i} = \sum_{i=1}^{5} (G_i \text{ X } R_{(\mathrm{SI})1}) \ldots\ldots \text{eqn. (2)}$$

The MI of each risk variable is calculated as a square root of a product of the LO and the SI as shown in eqn. (3).

$$\mathrm{MI}_i = \sqrt{\mathrm{LO_i} \text{ X } \mathrm{SI_i}} \ldots\ldots \text{eqn. (3)}$$

Step 2. Estimating the LO, SI and MI of Each Risk Category (Level 2)

The LO and SI of each category of risk factors are estimated by first determining the weightings of the various risk factors in the category. This is achieved by using eqn. (4) and eqn. (5):

$$W_{LOi} = \frac{\mathrm{LO_i}}{\sum_{i=1}^{n} \mathrm{LO_i}}, 0 < W_{LOi} < 1, \text{and } \sum_{i=1}^{n} W_{LOi} = 1 \ldots\ldots \text{eqn. (4)}$$

$$W_{SIi} = \frac{\mathrm{SI_i}}{\sum_{i=1}^{n} \mathrm{SI_i}}, 0 < W_{SIi} < 1, \text{and } \sum_{i=1}^{n} W_{SIi} = 1 \ldots\ldots \text{eqn. (5)}$$

Where W_{LOi} = weighting of the LO of a risk factor i; W_{SIi} = weighting of the SI of a risk factor i; $\sum W_{LOi}$ = summation of all weightings of the risk factors under the category (level 2) concerning LO; $\sum W_{SIi}$ = summation of all weightings of the risk factors under the category (level 2) concerning SI and n is the number of risk factors within a category.

The LO and SI of each risk category are obtained by using the weighting vector and the fuzzy evaluation matrix which can be expressed as:

$$\mathrm{D} = W_i \circ R_i \ldots\ldots \text{eqn. (6)}$$

Where W_i represents the weighting of all risk factors within a particular category and R_i is the fuzzy evaluation matrix. Given that $X_{1\mathrm{LO}\,\mathrm{n}}$ is an element of the fuzzy matrix which is one of the weighting elements of a category of risk factors, then the fuzzy evaluation matrix can be obtained by using the weighting function set as follows:

$$R_{(LO)i} = \begin{bmatrix} MF_{LO1} \\ MF_{\mathrm{LO2}} \\ MF_{LO3} \\ MF_{\mathrm{LO4}} \\ MF_{\mathrm{LO5}} \\ \ldots \\ MF_{\mathrm{LOn}} \end{bmatrix} = \begin{bmatrix} X_{1\mathrm{LO1}} & X_{2\mathrm{LO1}} & X_{3\mathrm{LO1}} & X_{4\mathrm{LO1}} & X_{5\mathrm{LO1}} \\ X_{1\mathrm{LO2}} & X_{2\mathrm{LO2}} & X_{3\mathrm{LO2}} & X_{4\mathrm{LO2}} & X_{5\mathrm{LO2}} \\ X_{1\mathrm{LO3}} & X_{2\mathrm{LO3}} & X_{3\mathrm{LO3}} & X_{4\mathrm{LO3}} & X_{5\mathrm{LO3}} \\ X_{1\mathrm{LO4}} & X_{2\mathrm{LO4}} & X_{3\mathrm{LO4}} & X_{4\mathrm{LO4}} & X_{5\mathrm{LO4}} \\ X_{1\mathrm{LO5}} & X_{2\mathrm{LO5}} & X_{3\mathrm{LO5}} & X_{4\mathrm{LO5}} & X_{5\mathrm{LO5}} \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ X_{1\mathrm{LOn}} & X_{2\mathrm{LOn}} & X_{3\mathrm{LOn}} & X_{4\mathrm{LOn}} & X_{5\mathrm{LOn}} \end{bmatrix}$$

$$D_{LOi} = (W_{i1}, W_{i2}, \ldots, W_{in}) \times \begin{bmatrix} X_{1LO1} & X_{2LO1} & X_{3LO1} & X_{4LO1} & X_{5LO1} \\ X_{1LO2} & X_{2LO2} & X_{3LO2} & X_{4LO2} & X_{5LO2} \\ X_{1LO3} & X_{2LO3} & X_{3LO3} & X_{4LO3} & X_{5LO3} \\ X_{1LO4} & X_{2LO4} & X_{3LO4} & X_{4LO4} & X_{5LO4} \\ X_{1LO5} & X_{2LO5} & X_{3LO5} & X_{4LO5} & X_{5LO5} \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ X_{1LOn} & X_{2LOn} & X_{3LOn} & X_{4LOn} & X_{5LOn} \end{bmatrix}$$

Therefore, the membership functions of LO and SI of a particular category of risk factors, C, are calculated as follows:

$$D_{LOc} = \sum_{i=1}^{n} (W_i \text{ X } R_{(LO)i}) \quad \text{eqn. (7)}$$

$$D_{SIc} = \sum_{i=1}^{n} (W_i \text{ X } R_{(SI)i}) \quad \text{eqn. (8)}$$

Using the estimated membership function of LO and SI from eqn. (7) and eqn. (8) for a category of risk factors, C, the LO, SI and MI can be estimated using eqn. (9), eqn. (10) and eqn. (11), respectively:

$$LO_c = \sum_{i=1}^{5} (G_i \text{ X } D_{LOC}) \quad \text{eqn. (9)}$$

$$SI_C = \sum_{i=1}^{5} (G_i \text{ X } D_{SIc}) \quad \text{eqn. (10)}$$

$$MI_c = \sqrt{LO_c \text{ X } SI_C} \quad \text{eqn. (11)}$$

4.3.2 Estimating the Overall LO, SI and MI of All Risk Categories (Level 3)

The overall LO, SI and MI of the overall risk level are calculated by first determining the weights of each category of risk factors. This is obtained by dividing the LO_c and the SI_C by the summation of LO and SI of all the risk categories, respectively. Given that there are k number of risk categories, the estimation could be expressed mathematically as follows:

$$W_{LOc} = \frac{LO_c}{\sum_{c=1}^{k} LO_c}, \; 0 < W_{LOc} < 1, \text{ and } \sum_{c=1}^{k} W_{LOc} = 1 \quad \text{eqn. (12)}$$

$$W_{SIc} = \frac{SI_c}{\sum_{c=1}^{k} SI_c}, \; 0 < W_{SIc} < 1, \text{ and } \sum_{c=1}^{k} W_{SIc} = 1 \quad \text{eqn. (13)}$$

Then, using the estimated W_{LOc} and W_{SIc} , the overall membership functions of LO and SI, respectively, represented as $D_{LOoverall}$ and $D_{SIoverall}$ are calculated as follows:

$$D_{LOoverall} = \sum_{c=1}^{k} (W_{LOc} \text{ X } R_{(LO)c}) \quad \text{eqn. (14)}$$

$$D_{SIoveral} = \sum_{c=1}^{k} (W_{SIc} \text{ X } R_{(SI)c}) \quad \text{eqn. (15)}$$

Using the grade point alternatives, G_i, with the $D_{LOoverall}$ and $D_{SIoverall}$ obtained from eqn. (14) and eqn. (15), the overall likelihood of risk occurrence ($LO_{overall}$); overall severity of risk impact ($SI_{overall}$) and overall magnitude of risks impact ($MI_{overall}$) could be estimated as follows:

$$LO_{overall} = \sum_{i=1}^{5} (G_i \text{ X } D_{LOoverall}) \quad \text{eqn. (16)}$$

$$SI_{overall} = \sum_{i=1}^{5} (G_i \text{ X } D_{SIoveral}) \quad \text{eqn. (17)}$$

$$MI_{overall} = \sqrt{LO_{overall} \text{ X } SI_{overall}} \quad \text{eqn. (18)}$$

4.3.3 Application of the FSE Approach to Data Analysis

The evaluation matrix is established based on the rating of the respondents regarding the LO and SI of the risk factors. For example, on 'political continuity risks/change of government', 4% of the respondents indicated that its LO is very low, 7% rated it as low, 27% as medium, 33% as high and 29% as very high. Similarly, 5% of the respondents indicated that the SI of this risk factor is very low, 5% rated it as low, 16% as medium, 32% as high and 42% as very high. Regarding the LO, these responses can be expressed as membership functions in the following equation forms:

$$R_{(\mathrm{LO})1} = \frac{LO_1}{G_1} + \frac{LO_2}{G_2} + \cdots + \frac{LO_5}{G_5}$$

$$R_{(\mathrm{LO})1} = \frac{0.04}{\text{very low}} + \frac{0.07}{\text{low}} + \frac{0.27}{\text{medium}} + \frac{0.33}{\text{high}} + \frac{0.29}{\text{very high}}$$

$$R_{(\mathrm{LO})1} = \frac{0.04}{1} + \frac{0.07}{2} + \frac{0.27}{3} + \frac{0.33}{4} + \frac{0.29}{5}$$

Similarly, the responses on the SI could be expressed in the membership function as follows:

$$R_{(\mathrm{SI})1} = \frac{SI_1}{G_1} + \frac{SI_2}{G_2} + \cdots + \frac{SI_5}{G_5}$$

$$R_{(\mathrm{SI})1} = \frac{0.05}{1} + \frac{0.05}{2} + \frac{0.16}{3} + \frac{0.32}{4} + \frac{0.42}{5}$$

Since the "+" in FSE denotes a notation and not an addition (Ameyaw and Chan, 2015), the equations for the membership functions for both LO and SI can also be expressed as (0.04, 0.07, 0.27, 0.33, 0.29) and (0.05, 0.05, 0.16, 0.32, 0.42), respectively. Subsequently, the LO, SI and MI are calculated using eqn. (1) – (3), respectively:

$$\mathrm{LO_i} = \sum_{i=1}^{5} (G_i \text{ X } R_{(LO)1}) = 1 \text{ X } 0.04 + 2 \text{ X } 0.07 + 3 \text{ X } 0.27 + 4 \text{ X } 0.33 + 5 \text{ X } 0.29 = 3.76$$

$$\mathrm{SI_i} = \sum_{i=1}^{5} (G_i \text{ X } R_{(\mathrm{SI})1}) = 1 \text{ X } 0.05 + 2 \text{ X } 0.05 + 3 \text{ X } 0.16 + 4 \text{ X } 0.32 + 5 \text{ X } 0.42 = 4.06$$

$$\mathrm{MI}_i = \sqrt{\mathrm{LO_i} \text{ X } \mathrm{SI_i}} = \sqrt{3.76 \text{ X } 4.06} = 3.91$$

The membership functions together with the LO, SI and MI of the other risk factors are calculated similarly as in the case of the risk factor 'political continuity risks/change of government'. Table 2 presents the estimated values of each risk factor.

Table 2: LO, SI and MI of Risk Factors (Level 1)

Risk Categories	No.	Risk factors	LO		SI		MI	Rank in Category
			Value	Membership function	Value	Membership function		
Political-Related Risks	PRF01	Political continuity risks/Change in government	3.76	0.04,0.07,0.27,0.33,0.29	4.06	0.05,0.05,0.16,0.32,0.42	3.91	2
	PRF02	Risk associated with land acquisition/land expropriations for housing	4.08	0.00,0.09,0.13,0.39,0.39	4.04	0.00,0.07,0.11,0.53,0.29	4.06	1
	PRF03	Risk associated with opposition to large public-private housing projects	3.37	0.04,0.16,0.28,0.43,0.09	3.35	0.07,0.13,0.27,0.44,0.09	3.35	5
	PRF04	Risk due to policy instability/government commitment to housing project/political opposition to public housing projects	3.72	0.00,0.11,0.24,0.47,0.18	3.84	0.00,0.09,0.22,0.46,0.23	3.78	3
	PRF05	Risk due to delays in project permit approval/delays in obtaining construction permits	3.36	0.06,0.13,0.33,0.35,0.13	3.37	0.09,0.02,0.41,0.30,0.18	3.37	4
Financing-Related Risks	FRF01	Inflation rate volatility (price fluctuation of materials & labour & sustainable technologies)	4.23	0.02,0.03,0.15,0.30,0.50	4.12	0.02,0.05,0.16,0.33,0.44	4.17	4
	FRF02	Fluctuations in exchange rate	4.40	0.00,0.04,0.09,0.30,0.57	4.38	0.00,0.04,0.07,0.36,0.53	4.39	2
	FRF03	Fluctuating cost of finance (interest rates)	4.37	0.00,0.00,0.11,0.41,0.48	4.31	0.00,0.00,0.11,0.47,0.42	4.34	3
	FRF04	Privatization risks (changes from government/public financing to private/market financing strategies)	3.45	0.07,0.02,0.41,0.39,0.11	3.64	0.07,0.04,0.27,0.42,0.20	3.54	7
	FRF05	Poor/inadequate financial market	3.94	0.00,0.02,0.23,0.52,0.23	3.93	0.01,0.02,0.21,0.55,0.21	3.94	6
	FRF06	Increasing tax rates and fees on developers	3.94	0.02,0.02,0.20,0.57,0.20	4.02	0.00,0.00,0.23,0.52,0.25	3.98	5
	FRF07	Delays in payments by governments/clients	4.46	0.00,0.01,0.09,0.33,0.57	4.40	0.00,0.02,0.05,0.44,0.49	4.43	1
	FRF08	Litigations over claims payment	3.74	0.04,0.09,0.22,0.39,0.26	4.03	0.02,0.07,0.15,0.38,0.38	3.88	8
Procurement Risks	CRF01	Corruptions in project procurement	4.04	0.07,0.04,0.04,0.48,0.37	4.00	0.04,0.04,0.16,0.40,0.36	4.02	1
	CRF02	Inadequate competition during project tendering	3.39	0.04,0.22,0.22,0.35,0.17	3.48	0.02,0.16,0.27,0.42,0.13	3.43	3
	CRF03	Errors and omissions in tender documents (i.e. inaccurate cost estimates)/inadequate project design	3.70	0.04,0.07,0.28,0.37,0.24	3.78	0.04,0.02,0.29,0.42,0.23	3.74	2
Design & Construction Risks	DRF01	Construction time overruns	4.00	0.00,0.04,0.20,0.48,0.28	4.08	0.02,0.04,0.20,0.32,0.42	4.04	2
	DRF02	Construction cost overruns	4.14	0.00,0.09,0.11,0.37,0.43	4.19	0.00,0.04,0.20,0.29,0.47	4.16	1
	DRF03	Construction deficiencies/defects (i.e. low quality of work)	3.35	0.09,0.11,0.33,0.30,0.17	3.63	0.09,0.04,0.29,0.31,0.27	3.49	4
	DRF04	Resource unavailability risks (local skill labour & sustainable technologies and materials)	3.08	0.15,0.16,0.30,0.24,0.15	3.35	0.09,0.16,0.24,0.33,0.18	3.21	7
	DRF05	Design and construction variation orders/alteration and rework due to construction variations	3.56	0.02,0.09,0.37,0.35,0.17	3.74	0.02,0.06,0.30,0.41,0.21	3.65	3

	DRF06	Technical complexity risk associated with project	3.49	0.05,0.07,0.33,0.44,0.11	3.62	0.02,0.04,0.40,0.38,0.16	3.55	5
	DRF07	Force majeure events	3.14	0.09,0.24,0.26,0.26,0.15	3.37	0.07,0.21,0.18,0.36,0.18	3.25	6
	DRF08	Construction accidents and injuries	3.19	0.01,0.26,0.33,0.33,0.07	3.17	0.04,0.20,0.38,0.31,0.07	3.18	8
Operation & Maintenance Risks	ORF01	Fluctuating market demand or preference/low social acceptability	3.62	0.04,0.04,0.33,0.44,0.15	3.76	0.04,0.05,0.25,0.43,0.23	3.69	1
	ORF02	Socio-spatial segregation	3.46	0.02,0.22,0.20,0.40,0.16	3.50	0.02,0.16,0.23,0.48,0.11	3.48	4
	ORF03	Operation/maintenance cost overruns	3.37	0.07,0.11,0.31,0.40,0.11	3.26	0.05,0.16,0.36,0.34,0.09	3.32	5
	ORF04	Utilities supply risks/supporting utilities/infrastructure risk	3.54	0.02,0.15,0.30,0.33,0.20	3.60	0.04,0.13,0.27,0.31,0.25	3.57	3
	ORF05	Congestion on existing amenities/infrastructure due to new households	3.00	0.11,0.26,0.24,0.30,0.09	3.13	0.07,0.19,0.37,0.28,0.09	3.06	6
	ORF06	Privatization risk (privatization of existing public rental stock)	3.62	0.04,0.11,0.26,0.37,0.22	3.53	0.06,0.09,0.38,0.20,0.27	3.57	2

To evaluate the membership functions of each risk category, the LO and SI weights of each risk factor were first calculated using eqn. (4) and eqn. (5) (as shown in Table 3). For instance, the LO weight of the risk factor 'political continuity risks/change in government' which is among the five risk factors (n = 5) within the risk category named 'political-related risks' is calculated as follows:

$$W_{LOi} = \frac{\mathrm{LO_i}}{\sum_{i=1}^{n} \mathrm{LO_i}} = \frac{3.76}{3.76+4.08+3.37+3.72+3.36} = \frac{3.76}{18.29} = 0.21$$

Similarly, the SI weigh of risk factor 'political continuity risks/change in government' can be calculated as follows

$$W_{SIc} = \frac{\mathrm{SI_c}}{\sum_{i=1}^{n} \mathrm{SI_i}} = \frac{4.06}{4.06+4.04+3.35+3.84+3.37} = \frac{4.06}{18.66} = 0.22$$

Table 3 reports upon the estimated W_{LOi} and W_{SIc} of each risk factor and category. Using the estimated LO and SI weights of each risk factor within a category, the LO and SI membership function of a risk category were calculated using eqns. (6) – (8) (as shown in Table 4). For example, the LO membership function for the risk category named 'political-related risks' can be calculated as follows:

$$\mathrm{D_{LOc}} = \sum_{i=1}^{n} (W_i \,\mathrm{X}\, R_{(LO)i}) = [0.21, 0.22, 0.18, 0.20, 0.18] \;\mathrm{X}\; \begin{bmatrix} 0.04 & 0.07 & 0.27 & 0.33 & 0.29 \\ 0.00 & 0.09 & 0.13 & 0.39 & 0.39 \\ 0.04 & 0.16 & 0.28 & 0.43 & 0.09 \\ 0.00 & 0.11 & 0.24 & 0.47 & 0.18 \\ 0.06 & 0.13 & 0.33 & 0.35 & 0.13 \end{bmatrix}$$

$$= (0.19, 0.19, 0.20, 0.19, 0.19)$$

Similarly, the SI membership function for the risk category 'political-related risks' can be calculated as follows:

$$\mathrm{D_{SIc}} = \sum_{i=1}^{n} (W_i \;\mathrm{X}\; R_{(\mathrm{SI})i}) = [0.22, 0.22, 0.18, 0.21, 0.18] \;\mathrm{X}\; \begin{bmatrix} 0.05 & 0.05 & 0.16 & 0.32 & 0.42 \\ 0.00 & 0.07 & 0.11 & 0.53 & 0.29 \\ 0.07 & 0.13 & 0.27 & 0.44 & 0.09 \\ 0.00 & 0.09 & 0.22 & 0.46 & 0.23 \\ 0.09 & 0.02 & 0.41 & 0.30 & 0.18 \end{bmatrix}$$

$$= (0.19, 0.20, 0.20, 0.20, 0.19)$$

Based on the $\mathrm{D_{LOc}}$ and $\mathrm{D_{SIc}}$ values, the $\mathrm{LO_C}$, the $\mathrm{SI_C}$ and the $\mathrm{MI_C}$ of each risk category are estimated as shown in Table 4. For example, using the risk category 'political-related risks', the values are estimated as follows:

$$\mathrm{LO_c} = \sum_{i=1}^{5} (G_i \,\mathrm{X}\, \mathrm{D_{LOC}}) = 1 \,\mathrm{X}\, 0.19 + 2 \,\mathrm{X}\, 0.19 + 3 \,\mathrm{X}\, 0.20 + 4 \,\mathrm{X}\, 0.19 + 5 \,\mathrm{X}\, 0.19 = 2.88$$

$$\mathrm{SI_C} = \sum_{i=1}^{5} (G_i \;\mathrm{X}\; \mathrm{D_{SIc}}) = 1 \,\mathrm{X}\, 0.19 + 2 \,\mathrm{X}\, 0.20 + 3 \,\mathrm{X}\, 0.20 + 4 \,\mathrm{X}\, 0.20 + 5 \,\mathrm{X}\, 0.19 = 2.94$$

$$\mathrm{MI_c} = \sqrt{\mathrm{LO_c} \;\mathrm{X}\; \mathrm{SI_C}} = \sqrt{2.88 \;\mathrm{X}\; 2.94} = \sqrt{8.47} = 2.91$$

Table 3: LO and SI of Each Risk Category (Level 2)

Risk Categories	No.	LO				SI			
		Value	Total weight	Factor Weight	Group Weight	Value	Total weight	Factor Weight	Group Weight
Political-Related Risks	PRF01	3.76	18.29	0.21	0.17	4.06	18.66	0.22	0.17
	PRF02	4.08		0.22		4.04		0.22	
	PRF03	3.37		0.18		3.35		0.18	
	PRF04	3.72		0.20		3.84		0.21	
	PRF05	3.36		0.18		3.37		0.18	
Financing-Related Risks	FRF01	4.23	32.53	0.13	0.29	4.12	32.83	0.13	0.29
	FRF02	4.40		0.14		4.38		0.13	
	FRF03	4.37		0.13		4.31		0.13	
	FRF04	3.45		0.11		3.64		0.11	
	FRF05	3.94		0.12		3.93		0.12	
	FRF06	3.94		0.12		4.02		0.12	
	FRF07	4.46		0.14		4.40		0.13	
	FRF08	3.74		0.12		4.03		0.12	
Procurement-Related Risks	CRF01	4.04	11.13	0.36	0.10	4.00	11.26	0.36	0.10
	CRF02	3.39		0.30		3.48		0.31	
	CRF03	3.70		0.33		3.78		0.34	
Design & Construction Risks	DRF01	4.00	27.95	0.14	0.25	4.08	29.15	0.14	0.26
	DRF02	4.14		0.15		4.19		0.14	
	DRF03	3.35		0.12		3.63		0.12	
	DRF04	3.08		0.11		3.35		0.11	
	DRF05	3.56		0.13		3.74		0.13	
	DRF06	3.49		0.13		3.62		0.12	
	DRF07	3.14		0.11		3.37		0.12	
	DRF08	3.19		0.11		3.17		0.11	
Operation & Maintenance Risks	ORF01	3.62	20.61	0.18	0.19	3.76	20.78	0.18	0.18
	ORF02	3.46		0.17		3.50		0.17	
	ORF03	3.37		0.16		3.26		0.16	
	ORF04	3.54		0.17		3.60		0.17	
	ORF05	3.00		0.15		3.13		0.15	
	ORF06	3.62		0.18		3.53		0.17	
Summation of total weights			110.51				112.68		

The LO and SI membership function of the risk category were deployed for assessing the overall risk level by first calculating the LO and SI weights of each risk category (refer to Table 4). The number of risk categories is five (k= 5). Using the risk category 'political-related risks', for example, the LO and SI weights are calculated as follows:

$$W_{LOc} = \frac{\mathrm{LO_c}}{\sum_{c=1}^{k} \mathrm{LO_c}} = \frac{2.88}{2.88+4.12+3.66+3.59+3.46} = \frac{2.85}{17.68} = 0.16$$

$$W_{SIc} = \frac{\mathrm{SI_c}}{\sum_{c=1}^{k} \mathrm{SI_c}} = \frac{3.00}{3.00+4.01+3.73+3.79+3.45} = \frac{3.00}{17.98} = 0.17$$

Then, the overall membership functions of LO and SI represented as $\mathrm{D_{LOoverall}}$ and $\mathrm{D_{SIoverall}}$, respectively, are calculated as follows:

$$\mathrm{D_{LOoverall}} = \sum_{c=1}^{k} (\mathrm{W_{LOc}} \text{ X } \mathrm{R_{(LO)c}})$$

$$= [0.16, 0.23, 0.21, 0.20, 0.20] \text{ X } \begin{bmatrix} 0.19 & 0.19 & 0.20 & 0.19 & 0.19 \\ 0.02 & 0.03 & 0.18 & 0.40 & 0.38 \\ 0.05 & 0.10 & 0.17 & 0.40 & 0.26 \\ 0.05 & 0.13 & 0.27 & 0.35 & 0.20 \\ 0.05 & 0.15 & 0.28 & 0.38 & 0.16 \end{bmatrix}$$

$$= (0.07, 0.18, 0.22, 0.35, 0.24)$$

Similarly, the overall membership function of $\mathrm{D_{LOoverall}}$ for all the risk categories is calculated as follows:

$$\mathrm{D_{SIoverall}} = \sum_{c=1}^{k} (\mathrm{W_{SIc}} \text{ X } R_{\mathrm{(SI)c}})$$

$$= [0.16, 0.23, 0.21, 0.20, 0.19] \text{ X } \begin{bmatrix} 0.19 & 0.20 & 0.20 & 0.20 & 0.19 \\ 0.01 & 0.03 & 0.15 & 0.43 & 0.37 \\ 0.03 & 0.07 & 0.24 & 0.42 & 0.25 \\ 0.04 & 0.09 & 0.27 & 0.34 & 0.25 \\ 0.05 & 0.13 & 0.31 & 0.34 & 0.18 \end{bmatrix}$$

$$= (0.06, 0.10, 0.23, 0.35, 0.25)$$

Using the grade point alternatives, G_i, with the $\mathrm{D_{LOoverall}}$ and $\mathrm{D_{SIoverall}}$, the overall likelihood of risk occurrence ($\mathrm{LO_{overall}}$), overall severity of risk impact ($\mathrm{SI_{overall}}$) and overall magnitude of risk impact ($\mathrm{MI_{overall}}$) (refer to Table 4) could be estimated as

$$\mathrm{LO_{overall}} = \sum_{i=1}^{5} (G_i \text{ X } \mathrm{D_{LOoverall}}) = 1 \text{ X } 0.07 + 2 \text{ X } 0.18 + 3 \text{ X } 0.22 + 4 \text{ X } 0.35 + 5 \text{ X } 0.24$$

$$\mathrm{LO_{overall}} = 3.69$$

$$\mathrm{SI_{overall}} = \sum_{i=1}^{5} (G_i \text{ X } \mathrm{D_{SIoveral}}) = 1 \text{ X } 0.06 + 2 \text{ X } 0.10 + 3 \text{ X } 0.23 + 4 \text{ X } 0.35 + 5 \text{ X } 0.25$$

$$\mathrm{SI_{overall}} = 3.60$$

$$\mathrm{MI_{overall}} = \sqrt{\mathrm{LO_{overall}} \text{ X } \mathrm{SI_{overall}}} = \sqrt{3.69 \text{ X } 3.60} = \sqrt{13.28} = 3.64$$

The interpretations of the LO, SI and MI of the risk categories and overall risk level are shown in Table 4 and Fig. 3.

Table 4: Overall LO, SI and MI of All Risk Categories (Level 3)

Risk Categories	LO			SI			MI	Rank
	Weight	Value	Membership function	Weight	Value	Membership function		
Political-Related Risks	0.16	2.88	(0.19,0.19,0.20,0.19,0.19)	0.16	2.94	(0.19,0.20,0.20,0.20,0.19)	2.91	5
Financing-Related Risks	0.23	4.12	(0.02,0.03,0.18,0.40,0.38)	0.23	4.09	(0.01,0.03,0.15,0.43,0.37)	4.10	1
Procurement-Related Risks	0.21	3.66	(0.05,0.10,0.17,0.40,0.26)	0.21	3.82	(0.03,0.07,0.24,0.42,0.25)	3.74	2
Design & Construction Risks	0.20	3.52	(0.05,0.13,0.27,0.35,0.20)	0.20	3.64	(0.04,0.09,0.27,0.34,0.25)	3.58	3
Operation & Maintenance Risks	0.20	3.51	(0.05,0.15,0.28,0.38,0.16)	0.19	3.50	(0.05,0.13,0.31,0.34,0.18)	3.50	4
Overall Risk Level (ORL)		3.69	(0.07,0.18,0.22,0.35,0.24)		3.60	(0.06,0.10,0.23,0.35,0.25)	3.64	

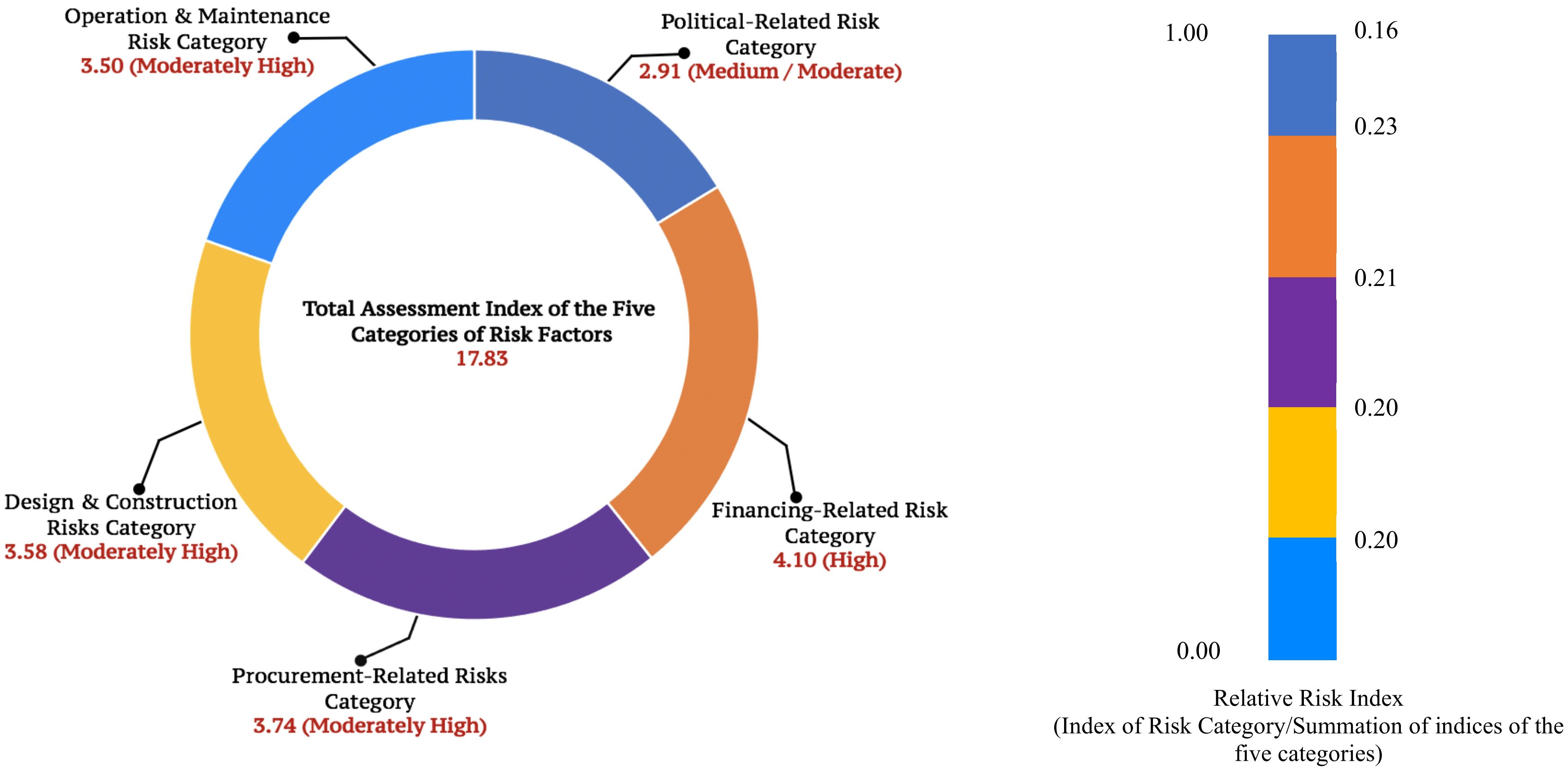

Fig. 3: Assessment Indices of the Five Categories of Risk Factors

5. Discussion of Findings in the Ghanaian Context

5.1 Risk Category 1 – Political-Related Risks

Political-related risks rank fifth with a moderate risk level of 2.91. Its LO and SI indices are both moderate values of 2.88 and 2.94, respectively (refer to Table 4 and Fig. 3). This category contains five risk factors of which 'risk associated with land acquisition/land expropriations for housing' has high risk impact of 4.06; 'political continuity risks/change of government' and 'risk due to policy instability/political opposition to public housing projects' are ranked moderately high with MI of 3.91 and 3.78, respectively.

Lands in Ghana are mostly owned by customary institutions such as stools (which represents the authority of chiefs in southern Ghana); skin (which represents the authority of chiefs in northern Ghana); clans and families. However, through the invocation of eminent domain, the state can acquire land for public purpose (Larbi, 2008, p.21). Yet, governments' access to land/land expropriations is a major problem in Ghana as evinced in its high risk value (4.06). This concurs with findings of Larbi (2008) and Gillespie (2018) that land expropriation is a critical risk factor that has led to unresolved issues such as: unpaid compensation on acquired land; encroachment on acquired land; problems of intergenerational equity; and divestiture of state-owned enterprises to private enterprises. These have culminated in lack of trust between the state and customary landowners and have undermined tenure security on acquired land. Consequently, the state faces a herculean task to acquire land for public private partnership for low-cost housing facilities in major cities and towns. Regards intergenerational equity, projects are stalled due to protest from families, clan and community on expropriated land in the past. Some families and clan believe that, even if compensations were paid to the earlier generation, the compensations are inadequate (Larbi, 2008). Similarly, private developers and households encounter project delays due to multiple sales of land to multiple owners which often result in dilatory court proceeding. Such incidents deter potential small-scale developers from investing in rental facilities.

'Political continuity risks/change of government' and 'risk due to policy instability/political opposition to public housing projects' are critical risk factors to sustainable housing supply in Ghana. Similarly, Twumasi-Ampofo et al. (2014) concluded that 'change of government' and 'negative politics by governments' are among the reasons for abandoned public housing projects. This problem could be attributed to 'lack of institutional structure' for ensuring the continuation of projects. Moreover, the procurement of public or state housing facilities through foreign companies could engender policy instability/political opposition – depending upon project size and its impact on domestic real estate developers/investors. Large-scale public-private housing projects to be procured through a partnership with foreign companies could lead to excessive exposure of domestic real estate developers to financially stronger foreign competition. A study by Frimpong and Marbuah (2010) suggested that exposing GREDA and other indigenous real estate developers, whose housing facilities are non-exportable, to foreign competition could significantly reduce domestic developers' investment by 1.76%. Consequently, real estate developers and their political allies could oppose such projects e.g. the cancelation of the STX projects (cf. Awanyo et al., 2016).

To mitigate land expropriation risk, a partnership agreement between landowners and government or developers is essential, where lump sum payments from governments as compensations could be discouraged in favour of a portion of the lump sum. Under future agreements, landowners could be apportioned a number of housing units while the government allocate the remaining housing units to low- and middle-income families. This innovative strategy will not only reduce the Government's lump sum financial burden but also mitigate problems related to intergenerational equity. For developers and landowners, policies that encourage such partnerships could alleviate land disputes and the initial high expenses that developers incur in land acquisition and promote smart growth/compact development through redevelopment of underutilized land in urban areas. To prevent conflicting claims to land ownership due to multiple sales, land allocations by chiefs, clans and family heads must be state regulated through the Land Use and Spatial Planning Authority (LUSPA). This could be achieved if the LUSPA are adequately resourced with both human and fiscal resources.

Housing projects abandonment is attributed to various reasons (cf. Twumasi-Ampofo et al., 2014). For example, a political party that assumes incumbency focuses solely on its campaign promises, leaving initiated projects commissioned by past political parties neglected or abandoned. Furthermore, contractors are mostly awarded contracts based upon political affiliation as opposed to competency, which partly contributes to low quality construction due to a contractor's ineptitude. In addition, a paucity of institutional or regulatory structure prevents successive governments from effectively monitoring project completion rates during or following government transition. To alleviate these risk factors, projects must be awarded based on competence using transparent tendering procedures that are devoid of manipulations. Furthermore, an independent regulatory structure is needed to ensure continuation of housing projects post government transition. This could be attained through the allocation of project budget to an independent body following detailed and meticulous estimation of project cost (Adabre et al., 2020).

5.2 Risk Category 2 - Financing-Related Risks

This risk category has the highest risk level of 4.10 and its LO and SI indices are both high with 4.12 and 4.09, respectively (refer to Tables 4 and Fig. 3). It consists of eight risk variables (refer to Table 2) but the top five risk factors include: 'delays in payments by governments/clients'; 'fluctuation in exchange rate'; 'fluctuating cost of finance (interest rates)'; 'inflation rate volatility (price inflation of materials/labour and sustainable technologies)'; and 'increasing tax rates and fees on developers'. These risk factors have a negative impact on projects' cash flow, funding and profitability (Ameyaw and Chan, 2015; Tetteh et al., 2020) and impede the attainment of sustainable development goals in housing projects/facilities.

Delay payments by government officials has been highlighted as a critical risk in public housing and other public construction projects (cf. Twumasi-Ampofo et al., 2014; Fugar and Agyakwah-Baah, 2010; Famiyeh et al., 2017). Without adequate risk mitigation measures, other risk factors may be triggered viz: cost and time overruns; and deficient construction quality. To curb delay payments, contractual schemes such as a payment bond could be utilised so that contractors can evoke the bond for payment of certified work if the clients or government officials fail to pay after a stipulated number of days.

Moreover, 'fluctuating cost of finance' (due to loan default) in Ghana is not viable for sustainability attainment in public or private affordable housing. This risk is also caused by weakness in the Ghanaian financial system including rising commercial bank prime lending rates recorded as 23.60% and 23.83% in 2015 and 2017, respectively (Owusu-Ansah et al., 2018; Ameyaw and Chan, 2015; Adabre and Chan, 2021). High prime rates imply the government could attract money from lenders by promising them high interest rates (higher than the prime rates) using treasury bills. Similarly, the interest rates of private financial instruments (i.e. fixed deposits) have to be higher than the prevailing treasury bill rates for financial institutions to attract portfolio investment/deposits from investors. Though this form of competition between treasury bill rates and fixed deposit rates may be unhealthy for banks, it is not uncommon in Ghana. Financial institutions, in turn, lend to private developers at high interest rates. Interest rates on housing microfinance loans range from 36 - 48% while that for mortgages range from 25-37% per annum in Ghana (Ghana Housing Profile- UN-Habitat 2011). Consequently, about 72.7% of the sources of finance among developers is self-finance. Thus, comparing these lending rates against an estimated 12% return on investing in rental facilities, private developers or landowners might not be interested in providing rental facilities through mortgage financing. Even among the few developers (about 18%) who use mortgage financing for housing projects, developers may charge high rents or sell at high prices, thus making these houses unaffordable to low- and middle-income earners.

Aside influencing investment in new housing projects, these financing risk factors could affect sustainable development in existing facilities among low- and middle-income households. Ensuring sustainable housing of existing facilities is more of a financial vis-à-vis technical issue in Ghana. The country's energy crisis effectuates the frugal use of available energy (Brew-Hammond, 2010; Owusu-Manu et al., 2021). Strategies to alleviate this crisis could include contractors retrofitting of existing housing stock using energy efficient technologies or installing stand-alone green energy generation (e.g. renewables such as solar) using balloon payments met by residents saving in energy consumed. In Ghana, such contracts could be socially inclusive for low- and middle-income households and provide financial institutions with security that final payment is contained within the asset's capital value if default is made when payment is due. If properties are connected to the mains, then surplus energy can then be sold back to the grid, to offset fluctuating interest rates that can increase the cost of loans secured – such has historically prevented the use of largely imported energy saving technologies. However, Lee et al. (2015) found that 'increase in installation costs', which could partly be attributed to instabilities of macroeconomic variables, was among the critical risk factors in energy performance contracting (EPC). Thus, finding viable solutions in that regard is key to realising sustainable housing objectives.

The effects of 'fluctuating cost of finance' and 'fluctuating inflation rate' could be mitigated through draconian regulations that restrict treasury bill rates and fixed deposit rates (Frimpong and Marbuah, 2010). The government could achieve this by regulating the use of short-term financing and instead deploy long-term funding such as bonds and stocks to reduce the rate of inflation. Besides, low interest rates could discourage excessive portfolio investments such as fixed deposits while promoting real investment such as housing supply among developers and improve access to bank loans among self-builders for housing supply. At low interest rates, it is expected that the rate of default loan could be mitigated. Therefore, low financing cost and other additional incentives (i.e. improved tax law on rental income, improved rent control laws and planning regulations on rental facilities) could motivate adequate supply of rental facilities. This could provide shelter for 40.5% of all urban households who depend on rental facilities for accommodation.

5.3 Risk Category 3 - Procurement-Related Risks

Procurement-related risks category ranks second with a moderately high MI (3.74), moderately high LO (index =3.66) and moderately high SI indices (index = 3.82). This risk category underlies three main risk factors among which 'bribery and corruptions in project procurement' has a high magnitude of impact of 4.02 and 'errors and omissions in tender documents (i.e. inaccurate cost estimates)' has a moderately high magnitude of impact of 3.74, respectively (refer to Table 4).

The high MI (4.02) of 'bribery and corruption in project procurement' confirms the findings of Ameyaw et al. (2017). Corruption in the Ghanaian construction industry is still an importunate issue though the Public Procurement Act 2003 has been enacted to ensure transparent procurement and corrupt-free practices in public procurement. It is often caused by political connections, tenuous regulatory structure and dubious sole sourcing of projects. Corruption is mostly manifested in various forms such as kickbacks (extortion), collusion and tender rigging, bribery, conflict of interest and fraud (ibid). Contractors mostly pay 10-20% of the tender sum to obtain construction contracts (Ameer, 2015). Therefore, winning contractors may either inflate the contract sum to cover for the 10-20% payment and/or cut corners to recoup the 10-20% payment. Consultants may also contribute to the corrupt practices by reducing the number of bidders at the tendering stage, certifying shoddy works and overvaluing works at the contract stage in exchange for monetary or personal gains. Thus, project costs are inflated, quality reduced and project environmental safeguards ignored. Consequently, corruption could stifle economic, social and environmental sustainability attainment in public housing projects (Ameyaw et al., 2017; Manu et al., 2019). Bribery and corruptions also affect private developers and households in housing development. High transaction costs such as delays in statutory approval (i.e. land registration and permit approval on land development) have led to non-bankable land among most households. Most developers and households who can obtain these statutory approvals do so at high cost because of extra corrupt charges (Ghana Housing Profile, UN-Habitat, 2011). Without effective policies to streamline land registration or permit approval, potential developers could be discouraged by the high transaction cost (i.e. corrupt charges) and delays in statutory approvals.

To achieve sustainable housing, it is not surprising that target 16.5 and target 16.6 of the UN's Sustainable Development Goals demand a substantial reduction in bribery and corruption while simultaneously, ensuring effective, transparent and accountable institutions. In a project, consultants owe clients/governments a fiduciary duty by ensuring ethical behaviour and strict adherence to this duty which would prevent overvaluing of contractor's work. High ethical standards and associated training seminars run by professional bodies such as Ghana Institution of Surveyors (GhIS), Ghana Institution of Architects (GIA) and Ghana Institute of Construction (GIOC) are essential for regulating members' behaviour as are enforcement sanctions (such as blacklisting) for non-compliant members. Consultants could be subject to similar measures and regular auditing by independent consultants to ensure that contractors are paid for works executed. Moreover, effective implementation of e-procurement could lessen corrupt practices and misuse of power by limiting human involvement to engender greater transparency at all stages of the development process (Sohail and Cavill, 2008).

'Errors and omissions in tender documents (i.e. inaccurate cost estimates)' is also ranked moderately high (> 3.50) as a CRF, and it is attributed to the limited tenure of office of governments and public officials. Public projects in Ghana are often initiated when elections are approaching to canvas public votes. Consequently, consultants produce project designs and cost estimates at short notice which can lead to limited specifications in project design and inaccurate cost estimates for complex public housing projects (Twumasi-Ampofo et al., 2014). These circumstances provide fertile grounds for: underestimation of cost, quality or programme contractual obligations; inadequacy of environmental sustainability measures implemented; and error or omission propagation. However, the growing trend of construction digitization (such as industry 4.0 cf. Newman et al., 2020; Sepasgozar et al., 2021), incentives to enable consultants and contractors to adapt quickly to these technologies could improve project cost estimates and reduce this risk factor.

5.4 Risk Category 4 - Design & Construction Risks

With a moderately high risk level of 3.58, moderately high LO index (3.52) and moderately high SI index (3.64), 'design & construction risk category' ranks third. It entails eight risk factors (refer to Table 2) but the top four risk factors include: 'construction cost overruns'; 'construction time overruns'; 'design and construction variation orders/alteration and rework due to variations'; and 'technical complexity/risk associated with project'.

Public housing projects often grind to a halt because of cost overruns and, design and construction variations orders (Fugar and Agyakwah-Baah, 2010). These risk factors invariably decrease housing quality, affect the implementation of sustainable technologies and decrease productivity through lost revenue or additional expenses incurred. Though cost and time overruns are related (cf. Ameyaw and Chan, 2015), their antecedent causes are different. In the Ghanaian construction industry, Famiyeh et al. (2017) revealed that cost overruns were caused by clients' financial difficulties; delays in payments to contractors; and design variations. However, time overruns are caused by: financial challenges; unrealistic estimation of project duration; and poorly defined project scope (ibid). The Danish construction industry experienced similar causes (cf. Larsen et al., 2016). To control them, there should be adequate planning of housing projects to accurately ascertain the cost, time and technical complexities of the project before the detailed design and construction. Contractual schemes such as liquidated and ascertained damages (LAD) could be reinforced to control time overruns caused by contractors. For an effective execution of LADs, contracts for public housing should be strictly 'fixed-date'.

5.5 Risk Category 5 - Operation & Maintenance Risks

This risk category ranked fourth with a moderately high risk level of 3.50 and LO and SI indices are both moderately high values of 3.51 and 3.50, respectively. 'Operation & maintenance risk category' entails six risk factors (refer to Table 2). Within this risk category, 'fluctuating market demand or preference/low social acceptability of housing facilities', 'privatization risk' and 'utilities/infrastructural supply risks' are key risk factors that are ranked moderately high.

'Fluctuating market demand or preference/low social acceptability of housing facilities' is among the risk factors that could affect public and private housing facilities. Public housing projects are speculative in nature because decisions on land acquisition, design and construction are mostly made without a specific customer in mind (Ahadzie et al., 2008). Sustainability measures such as high-rise public and private apartments and compact development are often encouraged to: improve housing supply; reduce urban sprawl; and ensure optimum utilization of land. Although urban areas require more affordable housing, surprisingly, problems of low social acceptability or take up rates could persist among most middle-income earners (especially family households) due to: a lack of communal space to pound Ghanaian's traditional delicacy of *fufu* (cf. Agyemang et al., 2018); and the geographical position of public housing facilities on the peripheral of cities which incurs additional transportation costs (cf. Grant et al., 2019; Croese et al., 2016). Low social acceptability of high-rise housing facilities could be controlled through community co-designing and co-production at the design stage so that potential households share resources (including knowledge) and legitimacy (including power/authority) to co-design and co-produce suitable habitation (cf. Laitinen et al., 2018; Lee, 2008). Essentially, co-design and co-production ensure empathy between the design team and potential households, and prevent information asymmetry occurring between them to promote households' satisfaction and stakeholder's satisfaction – such initiatives instigate social sustainability attainment in public and private housing projects and improve sales of housing facilities and market performance of housing projects (Chan and Adabre, 2019; Hamdan et al., 2021). Incidental benefits of this approach include opportunities to reduce low social acceptability/take-up rates and reduce the occurrence of abandoned projects.

Public housing privatization risk could occur due to the sale of public rental housing units to sitting tenants or other potential households (Ho, 2004). Though the motive underpinning this form of privatization seeks to improve housing ownership, this is often far from altruistic reasons and could impose risks and barriers to sustainable housing. Privatization of public housing could lead to upgrading of public housing facilities, rent increases, displacement of middle-income households in urban areas and re-selling to wealthier households (Kitzmann, 2017; Fields and Uffer, 2014). Consequently, housing is treated as a commodity for accumulating wealth and as a security for hedging against inflation but not for shelter. For instance, following the privatization of some SSNIT rental facilities, detailed reports revealed 'how sitting tenants, including parliamentarians, bought SSNIT properties and resold them without occupation' (Ghana Housing Profile, UN-Habitat, 2011, p.29). Privatization leads to inadequate rental facilities, which could contribute to the increasing inequality and poor living conditions in urban areas (Suleman et al., 2019; Lu et al., 2021). To mitigate this risk, privatisation of state-owned rental facilities in Ghana could be minimised by quota. Moreover, current and successive governments could focus more on the supply of public rental facilities (vis-à-vis owner-occupied facilities) to increase the availability of rental facilities and therefore, reduce high advance rental charges by private landlords (Arku et al., 2012; Akaaabre et al., 2018). Such a strategy could improve accessibility among the many households (> 40) that depend on rental facilities in most urban areas.

Holistic sustainable development in housing requires complementary infrastructure/utilities. However, public housing facilities in Ghana are often developed at the peripheral of cities and towns where complementary facilities (e.g. basic educational facilities, healthcare, retail or transportation facilities) are lacking or inadequate due to prodigious financial resources required to supply such facilities. Inadequate access to these facilities hinder environmental sustainability attainment because increasing commuting distance to these facilities further exacerbates vehicular emissions and increases fuel costs for households (Croese et al., 2016). Besides, intermittent supply of utilities such as potable water and electricity is a major problem among households (Ameyaw and Chan, 2015). Thus, although public housing facilities could be provided at affordable prices or rent, inflated living cost due to a lack of local complementary facilities or utilities increases the risk of low take up.

5.6 General Discussion and Broader Implication of the Findings

Notwithstanding the laudable goal of the United Nation's policy for sustainable housing by 2030, attaining this goal could be hindered by risk factors. Globally, studies have revealed the effects of risk factors on housing, although many prior studies are qualitative (cf. Ho, 2004; Fields and Uffer, 2016; Susilawati, 2009) and are prone to subjectivity in their findings. Attributed to the problem of subjectivity, the fuzzy synthetic evaluation (FSE) technique has been employed in this study to establish an objective and quantitative assessment of risks impact. Although some of the risk are specific to housing projects, other risk factors pertain to most scopes of construction projects (cf. Ameyaw and Chan, 2015; Zhao et al., 2016; Hwang et al., 2017). Therefore, both specific risks to housing and general construction project risks were considered to comprehensively identify risk that could affect sustainable housing development from the views of professionals. This study is among the few studies to employ the FSE for assessing the impact of risk factors towards making recommendations for achieving sustainable housing development.

Findings from the FSE analysis revealed that the 'financial-related risk category' was the highest rank among the five categories of risk factors while the 'political-related risk category' was moderately ranked. The findings imply that 'financial-related risk category' have the highest impact or effect on sustainable housing. Similar FSE analysis of risk categories by Ameyaw & Chan (2015) revealed that the financial/commercial risk category is the most critical risk with regard to impact or effects while the 'legal and socio-political risk category' ranks relatively low. However, in prior quantitative studies (cf. Adabre et al., 2021; Mosannenzadeh et al., 2017), the 'political-related risk category' is determined as the origin of the other risk categories. Yet, the seemly contrasting findings of this present study and the findings of a prior study (cf. Adabre et al., 2021) are but complementary. Although the 'political-related risk category' has a moderate impact from the FSE analysis as revealed in this study, it can originate other risk categories of higher impact or effect. This assertion is confirmed in the work of Mosannenzadeh et al. (2017) in which the 'political-related risk category' has a higher causal influence but not necessarily higher impact or effect. Rather, the financial-related factors were determined as critical or higher impact factors. Thus, the 'political-related risk category' could originate 'financial-related risk factors' of much higher impact or effect than the 'political-related risks category'.

Therefore, comparing the findings of previous studies on causal influence of risk categories (cf. Adabre et al., 2021) and findings on risks impact or effect (risk criticalities) as revealed in this study and the study of Ameyaw & Chan (2015), it can be concluded that: risk factors that have causal influence (i.e. political-related risks) may not necessarily be the most critical risks concerning impact or effect, as evinced in this study. On the other hand, the most critical risk factors (i.e. risk factors that have the highest impact) may not necessarily have the most causal influences on other risk factors, as evinced in Adabre et al. (2021). In general, risk factors/categories of low impact could originate other risk factors/categories of higher impact. A theoretical and practical implication of this statement is that for adequate mitigation of risk factors by policymakers and practitioners, both the impact(s) and causal influence of risk factors should be assessed individually yet complementarily. This present study has complemented an existing study (cf. Adabre et al., 2021) on causal influence by proffering the impacts of risk categories. Besides, the study provides numerical values on risk impacts which are lacking in prior qualitative studies (cf. Twumasi-Ampofo et al., 2014; Owusu-Manu et al., 2020) that could be prone to subjectivity in risk impact evaluation.

Relating the study's findings to the broader scope could reveal other interesting pointers to policymakers at the national and international levels. For instance, in some Asian countries such as Singapore and Hong Kong, there is a relatively high preference for high-rise residential facilities. However, high-rise residential facilities in Ghana and in most sub-Saharan African countries could be affected by the risk of low social acceptability or low-take up among family households (cf. Agyemang et al., 2018). Furthermore, in developed economies such as USA and UK where interest rates and inflation rates are relatively low and stable, financial-related risks in that regard could be relatively low in such countries. This is in contrast in the case of Ghana and other sub-Saharan African countries where financial-related risks are high and have affected development of mortgage institutions/banks. Moreover, 'corruption risks' and 'challenges on land access' are highly ranked risk factors in Ghana. The former risk factor could be common among developing economies whose institutional system is poorly developed and not adequately digitized, while the latter risk factor could be common in economies that have poor institutions/regulatory system concerning ownership right and development right on land. Although differences may exist on the criticalities of the risk factors/categories among countries, a common risk factor regards housing supply from the formal sector or regulated institutions could be low acceptability or low-residential take up by the target households. Typical cases are evinced in Malaysia (cf. Teck-Hong, 2012); United Kingdom (cf. Mulliner et al., 2013); China (cf. Yuan et al., 2018) and Ghana (cf. Agyemang et al., 2018). This risk could be attributed to the fact that housing supply from the formal sector, especially from the governments, are mostly supplied as speculative facilities, without the views of the potential households at the onset of housing development. The problem is that the facilities do not often meet the expectation of the households. This mostly leads to low-residential satisfaction and low social acceptability/ low tale-up rate at worse, which could contribute to the uncertainty problem – to build or not to build – among policymakers and real estate developers. This problem could partly be controlled through co-production and co-designing of housing facilities with the potential households for optimum economic, social and environmental benefits.

6. Conclusion

This study aimed to identify and evaluate the criticalities/impact of risk factors for sustainable housing in Ghana. A comprehensive literature review was first conducted to identify the potential CRFs and questionnaire survey data collected was analysed using the FSE technique. Data analysis revealed that the following critical risk factors hinder sustainable housing viz: 'delays in payment by governments/clients', 'fluctuations in exchange rate', 'fluctuating cost of finance (interest rates)', 'construction cost overruns', 'inflation rate volatility (price fluctuation of materials, labour and sustainable technologies)', 'risk associated with land acquisition/land expropriations for housing'; 'corruption in project procurement' and 'construction time overruns'. Further analysis on the MI of the risk categories revealed that 'financial-related risk category' is the most critical and that risk factors within this category have the greatest MI on housing supplies. It also affects retrofitting of existing housing facilities to sustainability standards.

Notwithstanding the relevance of the findings presented, several limitations are apparent. For example, the study did not include responses from households or potential households and the sample size is relatively small. Therefore, future studies could employ a larger sample size and/or conduct a comparative study between respondents from the formal sector and the informal sector (i.e. households or self-builders) on CRFs that hinder sustainability attainment in affordable housing. Besides, statistical analysis could be conducted using large sample size of normally distributed data to assess if there are significant differences in the ranking of the risk categories.

Despite the study's limitations, its findings have practical implications for sustainable housing to meet housing deficits in Ghana' urban conurbations. Such a dearth in supply has inadvertently created high advance rental charges and increasing slums, and so this research provides compelling evidence for policymakers and practitioners to augment housing supply for sustainable development. To realise this objective, a renewed focus on risk factors is needed because understanding these represents the starting point for tackling the issues involved. The high ranking of 'financing-related risk factors' implies risk factors in this category could undermine sustainable housing supplies and energy efficient retrofitting of existing housing facilities. 'Fluctuating/high cost of finance (interest rate)' implies that banks and governments attract lenders by promising them high rates of return on fixed-deposits and treasury bills, respectively. The financial institutions in turn, lend to developers at a higher rate. This could influence portfolio investment and thus, discourage real investment such as increasing supply/construction of housing facilities for rent or for sale. This scenario substantially effects the country's inflation rate. To mitigate the financing-related risk factors, the government could ensure stable macroeconomic policies are continued by successive governments. This could be achieved if governments further reduce base rates and prime rates in addition to reducing short-term borrowing (treasury bills). Long-term funding (i.e. bonds and shares) could rather be deployed for financing projects including public housing.

The high ranking of 'land expropriation risk' could be an indication that landowners are mostly not adequately compensated which often leads to delays on site possession and obstruction on the flow of project tasks/activities. Therefore, adequate packages for compensation (such as monetary compensation and infrastructure supply) could incentivize landowners to make land available for public low-cost housing projects. This could partly reduce 'time overruns' and 'cost overruns' on public housing projects. Besides, policies that encourage developer-landowner partnership could ensure smart/compact development through redevelopment of underutilized land in cities. Regarding risk factors related to 'operation and management of housing projects', promoting co-production and co-designing in public housing facilities could reduce low-residential satisfaction and 'low acceptability rate' of housing facilities and ensure social sustainability attainment through household's and neighbourhood's satisfaction. Furthermore, privatisation of existing public rental housing facilities for homeownership should be minimised. Government could focus more on rental facilities supply in most cities with adequate security measures for the safety of households. Such rental facilities could serve as a buffer and could reduce the exorbitant advance rental charges from private landlords/developers. Theoretically, future study could investigate the causal relationships among the individual risk factors.

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