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DOI
10.1016/j.enpol.2021.112504

Publication date
2021

Document Version
Final published version

Published in
Energy Policy

Citation (APA)
Jia, L., Qian, Q. K., Meijer, F. M., & Visscher, H. J. (2021). How information stimulates homeowners' cooperation in residential building energy retrofits in China. *Energy Policy*, *157*, Article 112504. https://doi.org/10.1016/j.enpol.2021.112504

Energy Policy 157 (2021) 112504

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

How information stimulates homeowners' cooperation in residential building energy retrofits in China

Ling Jia *, Queena K. Qian, Frits Meijer, Henk Visscher

Faculty of Architecture and the Built Environment, Delft University of Technology, Julianalaan 134, 2628 BL, Delft, the Netherlands

ARTICLE INFO

Keywords:
Building energy retrofitting
Homeowners' cooperation
Retrofitting information
Risk perception
Information source credibility

ABSTRACT

The process of residential energy retrofitting needs to be advanced, especially in the hot summer and cold winter (HSCW) zone of China. Good cooperation from homeowners is the key to the smooth project implementation. Some studies have identified four categories of information as important factors affecting homeowners' decision-making in retrofitting. Such information can improve homeowners' cooperation to some extent. This paper investigates the nature of this influence mechanism of retrofitting information, so as to stimulate homeowners' cooperation. The authors, first, explain how the direct relationship between information and homeowners' level of cooperation is validated. Second, under the mediation role of risk perception, we verify the indirect influence of such information. Third, we analyse the variation in the strength of the relationships between information and homeowners' cooperation under the influence of source credibility. It is concluded that providing information on retrofitting benefits and service is more effective for improving homeowners' cooperation. The integrity of building quality information and the understandability, to the homeowners, of technology information need to be considered. Priority should be given to the sources of expert knowledge and published resources, because they are perceived by homeowners to be relatively credible. Policy suggestions are proposed based on the results.

1. Introduction

Worldwide, the retrofitting of older residential buildings to save energy has been recognized as an important approach to energy conservation and the mitigation of climate change. The GlobalABC Global Roadmap has viewed building retrofitting as one of the key priorities for mitigating the buildings' influence on energy consumption and climate (UNEP, 2016). From 2018, all EU member states were required by the updated Energy Performance of Buildings Directive (EPBD) to carry out long-term retrofitting strategies for the achievement of a highly efficient and fully decarbonized building stock by 2050 (IEA, 2018).

China is no exception and has highlighted residential buildings as a key potential area for energy-savings through energy-efficiency improvement since 2006 (GOSC, 2011; NDRC, 2006). In 2017, residential building retrofitting in both the northern region and the hot summer and cold winter (HSCW) zone also continued to be considered in the latest national plan as one of the main tasks for energy conservation and emissions reduction (MOHURD, 2017). However, there is an unbalanced development of energy retrofits existing between these two regions in China. For example, compared with the retrofitting achievements during the "12th Five-year Plan" period of 990 million m^2 (of floor area) in the northern region, the retrofitting projects that were completed in the HSCW zone, during the same period, were very limited, such that the floor area completed was only 70.9 million m^2. Indeed, more energy consumption is expected for heating in winter and cooling in summer to adjust to people's rising expectations in thermal comfort, especially in the HSCW zone where there is no regional heating (Baldwin et al., 2018). It is, therefore, necessary to speed up the process of energy retrofitting of residential buildings in the HSCW zone of China.

Both the participation of homeowners and also their cooperation are vital to the success of energy retrofits. The multi-owner apartment building is the main form of urban residential buildings in China, and so it is also the main object of energy retrofitting. For buildings with individual private-property rights, each homeowner has the ownership of their own apartment. They can lawfully possess, utilize, profit from and sell house property. All homeowners share ownership of the common parts of a building, but the land is owned by the state. The successful retrofit of these 'multi-dwelling' buildings is necessarily preceded by residents' collective participation and cooperation (Cirman et al., 2011). In China, the level of cooperation of homeowners can be reflected by

* Corresponding author.
E-mail addresses: L.Jia-2@tudelft.nl (L. Jia), k.qian@tudelft.nl (Q.K. Qian), F.M.Meijer@tudelft.nl (F. Meijer), H.J.Visscher@tudelft.nl (H. Visscher).

https://doi.org/10.1016/j.enpol.2021.112504
Received 7 July 2020; Received in revised form 18 June 2021; Accepted 30 July 2021
Available online 12 August 2021

their acceptance of retrofitting plans, their assistance in retrofitting construction, and their facilitation of the maintenance of post-retrofitting buildings, all of which also determines whether energy retrofitting projects can be implemented smoothly.

Energy retrofits in China are generally carried out based on the units of residential quarters, and several apartment buildings make up one residential quarter. The retrofitting priority is given to old residential buildings with poor thermal performance of the building envelope, but with good seismic and structural safety performance (MOHURD, 2013). Laws, regulations and industry standards related to property management were gradually issued after 2003 in China. Property service enterprises are responsible for the maintenance, repair and remediation of management items, such as buildings and equipment, municipal public facilities, greening, sanitation, transportation, public security, and environment in a residential quarter. Most of the older residential quarters built before 2003 rarely introduced professional property managers to maintain the buildings before retrofitting, and so they are heavily dependent on the self-management by the co-owners. The central government has not issued any official documents to specify the share of homeowners' contributions to energy retrofitting. Although the Ministry of Housing and Urban-Rural Development of China in 2008 suggested a contribution of 15%–20%, homeowners contributed less than this percentage (or even only 5%–10%), for the retrofitting projects co-funded by the government and homeowners in practice. In particular, in the HSCW zone, where residential energy retrofitting has not been implemented on a large scale, government finance is still the main, or even the only, funding source. The common retrofitting items in the HSCW zone include lighting, doors, windows, roofs, and external walls.

The cooperation of homeowners is involved in the whole process of energy retrofitting projects. In owner-occupied homes in the US and many European countries, homeowners adopt the role of investors and so their decisions to retrofit are the theoretical premises of building retrofits (Wilson et al., 2015). Their cooperation with contractors in conducting construction work is an important part of homeowners' participation (Suschek-Berger and Ornetzeder, 2010). Similarly, in China, even if homeowners are mostly viewed as beneficiaries, instead of investors, they still need to play an important role in retrofit planning, retrofit implementation and the use of technologies (Liu et al., 2015). Building retrofits rely on a certain degree of participant involvement for the successful achievement of a common goal (Liu et al., 2015). At present, homeowners play a limited role of retrofitting decision-making in China. Their decisions involve: a) the approval of renovating their residential quarters that have been included by the local government in the retrofitting plan; b) their selection of retrofitting technology within the prescribed limits by the local government; and c) the approval of the design scheme that has been made. In the case that homeowners do not bear the expenses of retrofitting, or they only pay a minimal fee, homeowners' requirements are limited within the scope of government's affordability, and of works being in the interests of most homeowners. This scope is based on the financial budget and technical feasibility and is defined by the local government. Homeowners' cooperation also needs to be valued at both the stages of on-site construction and the later usage of retrofit projects, involving: a) cooperating with the contractors to implement the retrofitting schemes that are selected and approved by homeowners themselves; as well as b) at the stage of cooperating with the community or property service company to maintain the residential quarters after retrofitting. However, the divergence of interests among homeowners often leads to the difficulties in reaching a consensus on decision-making, and so affects their intentions to actively cooperate, which is also one of the barriers to the promotion of energy retrofitting in China (Jia et al., 2018a, 2018b; Liang et al., 2016). Uncooperative members, especially at the stage of construction, result in construction delays and budget overruns, and delays in retrofit projects might lead to more disturbance to occupants and existing building operations (Hwang et al., 2015). Moreover, homeowners' cooperation can actually be regarded as family decision-making in China, especially for elderly homeowners. Adults generally provide informal home care and financial support for their aging parents in China (Hu et al., 2020; Ouyang et al., 2018). With the increase in young people's income, the role of the elderly in the family has been significantly weakened, and their consumption decisions mainly rely on the opinions of their adult children (PWC, 2018). Similarly, education is an important factor affecting the power of family decision-making. With the improvement of education quality and higher education expansion, Chinese young adults have access to more educational resources, making their education levels generally higher than that of their parents. Resource theory argues the family member of decision-making power varies with his or her resources (e.g. education) (Blood and Wolfe, 1978). The level of education can determine who is responsible for family decision-making to some extent (Bertocchi et al., 2014; Doss, 2013; Li et al., 2021).

One other factor of importance to the level of cooperation of homeowners is their understanding of the whole need and process of retrofitting. This can be a significant information barrier, and is one of the most critical factors hindering homeowners' engagement in energy retrofitting, due to the complexity of the building retrofitting process (Novikova et al., 2011b). Imperfect information is suspected to be the most important failure in the energy efficiency market (Huntington et al., 1994). If homeowners do not understand retrofits, it is difficult to increase their enthusiasm for building energy retrofitting (Novikova et al., 2011a). Meeting homeowners' information needs for their engagement in the retrofitting process can enhance their acceptance of building energy efficiency (Sabet and Easterbrook, 2016). Lack of information is also one of the obstacles of energy retrofitting in China (Liu et al., 2020a). This "Information asymmetry" leads to the scarcity of public awareness of building energy efficiency (Li and Shui, 2015; Zhang and Wang, 2013). In particular, there is a lack of platforms and activities for sharing the retrofitting information, which also results in low public awareness of energy retrofitting (Jia et al., 2018a,b). Recently, pilot projects and public participation activities have been adopted in China, to share the retrofitting information with the public, and to promote building energy retrofitting (Liu et al., 2020a). The Chinese central government has carried out many pilot retrofitting projects (e.g., Sino-German Technical Cooperation (2005–2011)). The public can search for the information on these pilot projects in the network platform to know more about energy retrofitting. Moreover, the community can popularize the knowledge about retrofitting, including through expert consultation and advice in the 'National Energy Conservation Publicity Week' and 'National Low Carbon Day' Activities. However, at present, the central government still seems to ignore the importance of retrofitting information dissemination and energy consumption disclosure, so that the public generally have insufficient knowledge about energy retrofitting, which, in turn, also limits their retrofitting enthusiasm (Liu et al., 2020b). It is necessary for the promotion of energy retrofitting in China to improve the information provided for homeowners to motivate them to cooperate. A deep understanding of the influence mechanism of information on homeowners' cooperative behaviors is thus required to ensure the effectiveness of the provided information.

The information affecting homeowners' enthusiasm for participation and cooperation has been analysed by some researchers (Jakob, 2007; Palmer et al., 2015; Syal et al., 2014; Wilson et al., 2014, 2015), but is mostly related to energy audit, retrofitting costs and benefits and used for investment decision-making. Besides, the existing studies tend to highlight homeowners' participation in the selection of retrofitting technology in order to improve the effectiveness of retrofitting after the completion of the project (Li et al., 2017; Liu et al., 2015; Lo, 2015). Few researchers investigate homeowners' cooperation from the perspective of the whole-process of participation.

To fill this gap, this study investigates how to provide effective information to motivate homeowners towards participation and cooperation in the whole process of energy retrofitting projects in the HSCW zone of China. It achieves this by analysing the influence mechanism of building retrofitting information. Such information effects also consider the roles of risk perception and information source credibility. In China, homeowners tend to have perceptions of high retrofitting risks, especially those at the stages of on-site construction and usage. Indeed, these risks are perceived as being higher by homeowners than perceptions from other stakeholder groups (e.g., the government, designers, and contractors) (Jia et al., 2020). This so-called *amplification of risk perception* is concerned with information transfer and the public's responses to information (Kasperson et al., 1988). Perceptions of high-risks can lead to an increase in the possibility of risk-averse behaviours (Chionis and Karanikas, 2018). Thus, people's participation in actions might be suppressed by their high-risk perception (Bindl and Parker, 2011). In addition to information quantity, information quality is also an important feature of information sharing (Thomas et al., 2009). Information source credibility is a significant factor to measure information quality (Khosrowpour, 2014). As mentioned earlier, homeowners in China can acquire retrofitting information from several sources (e.g., network platforms and experts). In a similar way, homeowners' perceived credibility of these sources acts on information effects, and also needs to be considered in analysing the information affecting homeowners' cooperation.

This paper is organized as follows. First, the hypotheses are set up based on a review of existing theory in the literature to address the relationships among the four key variables: 1) Building retrofitting information; 2) Homeowners' cooperation; 3) Risk perception; and 4) Information source credibility. Second, the samples and measures employed in this study are described. Then, the empirical research results and discussions, based on a questionnaire survey, are also reported to examine the hypotheses. Finally, this paper presents the findings and proposes some policy suggestions for future information provision.

2. Theory and hypotheses

2.1. Four areas of building retrofitting information and homeowners' cooperation

Given the background explained above, the homeowner's decision-making, i.e., the awareness of the need for retrofitting, the choice of retrofitting technology, the implementation of retrofitting measures, and the confirmation of retrofitting effect, runs through the whole process of energy retrofitting (Pettifor et al., 2015; Wilson et al., 2018). Access to relevant information is necessary for the decision-making of retrofitting activities (Stieß and Dunkelberg, 2013). For instance, homeowners' recognition of energy-retrofitting investment is based on the information on productivity (Bardhan et al., 2014); information is also required by homeowners to make optimal choices of retrofitting measures (Palmer et al., 2015). The retrofitting information that is provided for homeowners during the energy retrofitting has been summarized in Table 1.

This retrofitting information can be divided into four categories, including:

Building Information **(BI)** (representing the basic information before retrofitting);
Retrofitting Benefits **(RB)** (reflecting the advantages of energy retrofitting);
Retrofitting Technology **(RT)** (involving the methods of technology installation, usage and maintenance); and
Retrofitting Service **(RS)** (referring to the information on retrofitting service during the construction).

The poor information available to homeowners is the key impediment to the energy retrofitting of residential buildings (Syal et al., 2014). Imperfect information about energy use, technology, and energy savings severely hampers the implementation of housing energy retrofitting (Hrovatin and Zorić, 2018). Homeowners' demand for energy-efficient upgrades is restricted by information imperfections (Bardhan et al., 2014). Golove and Eto (1996) viewed a lack of information on retrofit technology as the main reason for the failure of the energy efficiency market. Moreover, the increased information search costs of homeowners are induced by information asymmetry. The high costs to acquire relevant information limit homeowners' participation in improving building energy efficiency (Bardhan et al., 2014). Lack of targeted information and the induced transaction costs (e.g., search costs and monitoring costs) constitute critical barriers to the development of the energy efficiency market (Howarth and Andersson, 1993). Indeed, successful retrofitting is closely linked to those homeowners who can acquire more information from external sources (Risholt and Berker, 2013). In addition, the provision of effective information is an approach to not only reducing search costs (Ha, 2002), but also achieving pro-environmental behaviours (Catney et al., 2013).

The authors assert that information on building information, retrofitting benefits, and retrofitting technology is relatively neutral, while details on retrofitting services can be provided from both positive and

Table 1
Information on energy retrofitting of residential buildings.

Information category	Information indicators	Reference
Building information (BI)	BI1:building structure	Stieß and Dunkelberg (2013)
	BI2:building physical conditions	de Wilde and Spaargaren (2019); Palmer et al. (2013); Wilson et al. (2014)
	BI3:energy use conditions	de Wilde and Spaargaren (2019); Sabet and Easterbrook (2016); Wilson et al. (2014)
	BI4:energy losses	Palmer et al. (2013); Syal et al. (2014)
Retrofitting benefits (RB)	RB1:preferential policies (e.g., subsidies/government bearing retrofitting costs, and tax benefits)	de Wilde and Spaargaren (2019)
	RB2:energy savings	de Wilde and Spaargaren (2019); Palmer et al. (2013); Syal et al. (2014); Wilson et al. (2014, 2015)
	RB3:financial savings	de Wilde and Spaargaren (2019); Sabet and Easterbrook (2016); Syal et al. (2014); Wilson et al. (2015)
	RB4:effects on health and comfort	de Wilde and Spaargaren (2019); Sabet and Easterbrook (2016); Wilson et al. (2014, 2015)
Retrofitting technology (RT)	RT1:technology characteristics	de Wilde and Spaargaren (2019); Michelsen and Madlener (2016); Syal et al. (2014)
	RT2:technology installation methods	Stieß and Dunkelberg (2013)
	RT3:usage of installed equipment	Stieß and Dunkelberg (2013)
	RT4:equipment maintenance	Owen and Mitchell (2015)
Retrofitting service (RS)	RS1:material quality	de Wilde and Spaargaren (2019); Sabet and Easterbrook (2016); Syal et al. (2014)
	RS2:contractors' competence	de Wilde and Spaargaren (2019); Neuhoff et al. (2011); Syal et al. (2014); Wilson et al. (2014, 2015)
	RS3:installation schedule	Owen and Mitchell (2015)
	RS4:construction tracking	de Wilde and Spaargaren (2019)
	RS5:construction service quality	de Wilde and Spaargaren (2019); Novikova et al. (2011b); Wilson et al. (2014)

negative perspectives. Neutral and positive information contributes to stimulating the consumption of environmentally-preferable products, and particularly positive information can guide consumers towards these products (Leire and Thidell, 2005). Compared to positive information, negative information is less likely to be communicated to help persuade and impact decisions about retrofitting (Siegrist and Cvetkovich, 2001). Consumers' decision-making is probably influenced partially by positive information, but they are unlikely to select the products with negative information (Grankvist et al., 2004). Thus, this paper focuses only on positive information in terms of a retrofitting service. The first hypothesis is proposed as follows.

H1. Information has a positive influence on the level of homeowners' cooperation, such that increased information can improve homeowners' cooperation in energy retrofitting projects.

2.2. Risk perception as a mediator of the relationship between information and homeowners' cooperation

Risk perception is a kind of subjective assessment of risks by individuals (Pidgeon, 1998). The presentation of the relevant information is one of the factors causing individuals' differences in risk perception (Van der Pligt, 1996). Information is necessary for people to assess the risks, and people's exposure to information can shape their risk perception (Lindell and Perry, 2012). In fact, high levels of people's concern about risks can be considered to result from inadequate provision of information (Williams and Noyes, 2007). The information in the risky situation is more important to new consumers than to existing customers, and the results of information search contribute to the decrease in their overall risk perception (Ha, 2002). In particular, positive information on a specific object is likely to be conducive to a decrease in perceived risks about this object (Nedungadi et al., 2001).

People tend to respond and react subjectively to risks perceived, and their risk perception affects their behaviours and actions (Bauer, 1960). Risks in the building context are characterized by uncertainty (including uncertain events and uncertain impacts) (Chia, 2006). Uncertainty avoidance is a key principle of people's behaviours (Ketokivi and Mahoney, 2016). People usually take actions to avoid risks that are perceived by them to be serious (Mañez et al., 2016). As a result of risk aversion, high levels of risk perception can limit people's involvement in energy retrofitting. Measures that reduce homeowners' perception of risks are thus considered to contribute to the improvement of homeowners' participation and cooperation (Jia et al., 2020).

The existing studies in other fields have identified the relationships of the three factors of information, risk perception, and people's involvement. Williams and Noyes (2007) pointed out that risk perception is dependent on information sufficiency and is also an inherent factor influencing people's decision-making. From another context, Seabra et al. (2014) thought that information about terrorism has direct impacts on tourists' risk perception and affects their involvement in trip planning. Selma et al. (2014) found out that risk perception is an important influential variable for public acceptance of carbon capture and storage and is also affected by information to some extent. Therefore, this paper presents the second hypothesis as follows.

H2. Information has a positive influence on the level of homeowners' cooperation through risk perception, such that increased information lowers risk perception and decreased risk perception further improves homeowners' cooperation.

2.3. Information source credibility as a moderator of the strength of the relationship between information and homeowners' cooperation

The intention of information receivers to use information is affected by their perceived credibility of information sources (Bannister, 1986). Information source credibility refers to the judgments of information receivers on the believability of information sources (Pornpitakpan, 2004). It determines how people view the information acquired from these sources as being believable (Baggett et al., 2006). Source expertise is an important element of source credibility and refers to the perceived competence of information providers (Pallavicini et al., 2017). When the information sources are perceived to be competent and trustworthy, the information is less challenged or doubted (McNie, 2007). Those deferring to information sources generally pay less attention to information content, and scrutinize the content only when the source is viewed as lacking in expertise (Gass, 2015). The credibility of information sources has an influence on the way people process information (Petty and Cacioppo, 1996), and highly credible sources are likely to boost the degree to which the information is processed (Trumbo and McComas, 2003). When source credibility is perceived to be high, information receivers are more likely to change their opinions in the direction guided by the information (Hovland and Weiss, 1951). Syal et al. (2014) divided the retrofitting information sources into two categories based on earlier work by the researchers: published information and expert knowledge. In the Chinese context, homeowners have opportunities to access experts for consultation and are also provided with professional retrofitting knowledge through the National Energy Conservation Publicity Week and National Low Carbon Day Activities. Meanwhile, they can, not only seek the professionals from the local pilot retrofitting projects for more information, but also, acquire the information about pilot projects on the public network platforms. Some professional websites about building energy efficiency also provide the information relevant to energy retrofitting. Besides, Hrovatin and Zorić (2018) thought that the informal information sources (e.g., personal contacts and social media) are also important in energy retrofitting projects. Likewise, homeowners in China can also collect the relevant information from their family, friends and neighbours in their own social network.

Pornpitakpan (2004) reviewed the studies on source credibility, and pointed out that information sources with high credibility were more persuasive than ones with low credibility, in terms of changing perceptions and attitudes as well as gaining behavioural compliance. Credibility and trustworthiness of information sources are identified by Petty et al. (1994) as the determinants of whether people accept information or not. Trust is one of the credibility dimensions and is commonly considered interchangeable with credibility (Jungermann et al., 1996). By encouraging people to accept information, trust increases the role of information in risk perception (Langford, 2002). Trust is an important determinant of public risk perception, and the success of risk communication is dependent on the trust in the people providing information (Smith and Brooks, 2013). The lack of consensus on risk perception is also concerned with a lack of trust in information sources (Poortinga and Pidgeon, 2003). Similarly, homeowners' distrust in information sources also limits the trustworthiness and effectiveness of information in energy retrofitting (Gram-Hanssen et al., 2007). Homeowners' involvement and cooperation are reliant on the acquirement of trusted information (Sabet and Easterbrook, 2016). Distrust in information about what retrofits are, why they are beneficial, and how to implement them is viewed as one of the main reasons for less support for energy retrofitting (Syal et al., 2014). Therefore, this paper proposed the third hypothesis that is defined as H3. The strength of information's role moderated by source credibility in H3 includes the strength of information's direct and indirect effects as mentioned in H1 and H2, and the following H3a and H3b describe the moderation roles of source credibility in these two effects of information, respectively.

H3. Information source credibility moderates the strength of the influence of information on the level of homeowners' cooperation, such that information has a stronger positive effect on homeowners' cooperation when source credibility is perceived to be high.

H3a. High source credibility strengthens the positive direct effect of information on the level of homeowners' cooperation, such that increased information is more able to improve homeowners' cooperation in the case of high source credibility.

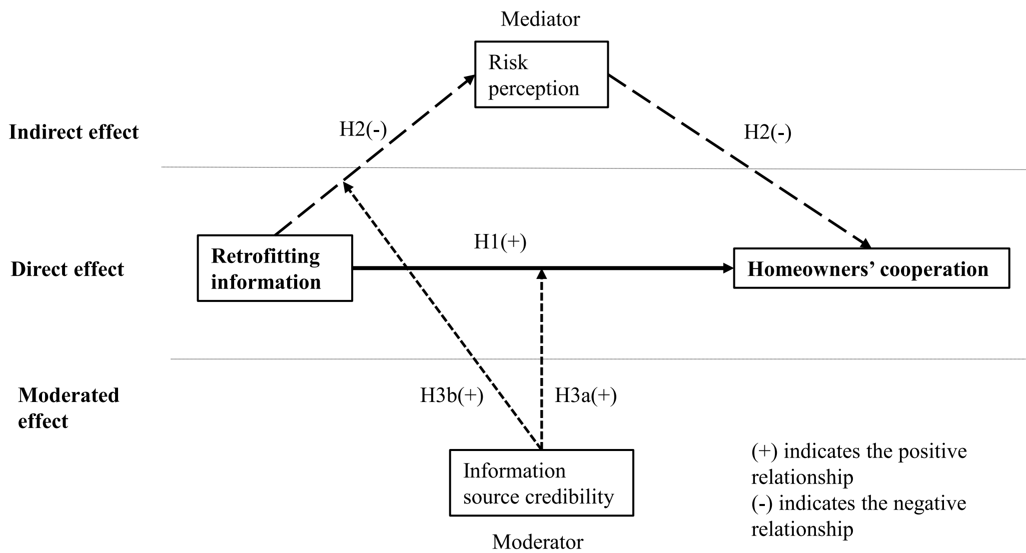

Fig. 1. A conceptual framework for hypotheses measurements.

H3b. High source credibility amplifies the positive indirect effect of information on the level of homeowners' cooperation, such that increased information is more able to reduce risk perception in the case of high source credibility and further to enhance homeowners' cooperation.

Fig. 1 integrates the above hypotheses to show the conceptual relationships among information, source credibility, risk perception, and homeowners' cooperation.

3. Methods

3.1. Sample and procedure

The empirical survey was conducted in Anhui Province in China. Anhui is one of the provinces where residential energy retrofitting has been carried out relatively early in the HSCW zone. The province has started the promotion and implementation of residential energy retrofitting since 2013 and has encouraged the province-wide retrofitting since 2016. In 2000, at the national level, the Ministry of Housing and Urban-Rural Development of China issued the first regulations on energy conservation in civil buildings. Many provinces in the HSCW zone, including Anhui, have viewed residential quarters built before 2000 as the key targets of renovation at this stage. Meanwhile, considering that the design standard for energy efficiency of residential buildings in the HSCW zone was released in 2010, the authors of this study limited the survey targets to owners of residential buildings built before 2010. Among the completed retrofitting projects, most are the residential quarters built in the 1980s and 1990s, and those built after 2000 are concentrated on buildings of 2001–2005. The residential buildings built during these periods have poor performance in energy efficiency, but have the potential to continue to be used for the next few decades rather than to be demolished. The empirical survey was conducted in six cities in Anhui, and two residential quarters that were built in the 1980s–1990s and in the years between 2001 and 2005, respectively, were selected in each city. Each residential quarter contains 150 to 230 households. Residential buildings in the twelve residential quarters were low-rise concrete-masonry buildings (1-3 storeys) or multi-story concrete-masonry buildings (4-6 storeys). These buildings were designed and constructed using materials with low performance and without any energy efficiency measures (e.g., thermal insulation and ventilation system), and are thus the potential targets of energy retrofitting.

The questionnaires were sent out online. With the popularity of mobile social applications in China, many residential quarters have established their own chat groups in such applications. Basically, every household has at least one representative to join this group to communicate within the residential quarter. All homeowners in the target residential quarters can be contacted via these chat groups. The questionnaire link sent as a message to the chat groups where the twelve residential quarters are located, could be shared by all group members. The questionnaire is open to the homeowners in all age groups and with different education backgrounds. These respondents were instructed to measure four kinds of variables (including information on retrofitting, information source credibility, risk perception, and homeowners' cooperation). Overall, 708 people completed the online questionnaire within a period of one month (survey date: Spring, 2020).

This survey was conducted under some control measures to reduce selection bias. The questionnaire in this study was distributed directly to the target population in order to avoid under-coverage. The questionnaire included a preselecting question which asked respondents to only take part in the survey if they are the owners, instead of tenants or family members of owners. It is also possible that two and over members in one chat group are from one household, and thus some owners did not open the questionnaire when their family members have already filled it out. Meanwhile, the questionnaire link was sent as a message to these chat groups, and some people may have missed it unintentionally. The response rate cannot be accurately determined in this study, but non-response does not necessarily imply a self-selection bias when its reasons are diverse (Amecke, 2012).

This research study conducted the following pre-selection procedure, prior to the analysis to ensure the quality and accuracy of the questionnaires. First, the survey gave an opening question to control over whether respondents are the owners in the target residential quarters. Both tenants and family members of the owners were screened out. Second, this study tested the completed surveys for random response patterns (straight lines) to exclude the respondents who chose the same answer choice over and over again. Third, the respondents who gave mutually conflicting responses were also excluded. For instance, some respondents had no knowledge about building information but thought that building information they received from all sources were totally credible. Finally, 413 were responses remaining for data analysis. The authors regard the sample size of 413 observations to be sufficient for empirical analysis on public engagement in China. For example, Qi et al. (2020) obtained 364 valid questionnaires to analyse the influence of public communication on public acceptance of nuclear energy; and Gong et al. (2020) used 324 samples to explore the factors influencing public acceptance of clean heating.

Table 2
Basic information on participants.

Variables		Frequency	Percent
Gender	Male	223	54%
	Female	190	46%
Age	18–45	376	91%
	46–69	32	8%
	Above 69	5	1%
Education	High school or lower	79	19%
	Junior college	243	59%
	Bachelor	81	20%
	Master or above	10	2%
Year	Before 2000	242	59%
	2001–2010	171	41%
Total		413	100%

Table 2 shows the demographic data of the survey sample. The majority of the respondents are from the young and highly-educated group (aged under 45 and educated in a college or university), which is also different from the expectation of this survey. Based on the further inquiry with several elderly homeowners, there might be three reasons for the unbalanced distribution of respondents' ages as follows: (1) compared with the elderly, young people spend more time on the Internet using mobile phones, which makes it more likely for them to notice the questionnaire link sent as a message; (2) residential energy retrofitting is an emerging topic in China so that elderly people might have little knowledge about retrofitting; and (3) the elderly tend to ask their adult children for help with household decision-making in China, which might also be the case with filling out questionnaires. In fact, the high percentage of respondents with a good educational background in the sample is also related to the ages (under 45) of most respondents. The educational attainment of the survey sample is different compared to those from the distribution in the international context, but is in line with China's stage of educational development. Attributing to University Enrolment Expansion,[1] more people have been able to enter a university after graduating from high school since 1999. The admission rate of the college entrance exams has exceeded 50% since 2001, and now it has reached over 90%. This educational policy has also significantly increased the proportion of people under the age of 45 obtaining higher education in China. Nonetheless, the results based on this sample can be generalized due to the important roles of young and highly-educated people in Chinese family decision-making, as mentioned before.

3.2. Measurement

3.2.1. Information on retrofitting

A self-report survey is made to measure the information. This method is a kind of subjective measurement and is used to ask the participants direct questions concerning perceptions, attitudes, or intended actions (Christensen and Knezek, 2008). It is also used to measure other variables including information source credibility, risk perception, and homeowners' cooperation. The participants were first asked to self-evaluate the extent to which they possessed information on retrofitting. For example, the participants were asked directly "How knowledgeable are you about building structure". The information level is measured on a five-point scale from 1 to 5 indicating from 'not knowledgeable at all' to 'very knowledgeable'.

3.2.2. Information source credibility

The credibility of information source (IS) was rated by the participants in terms of three kinds of information sources, including:

- social contacts with laypeople (e.g., family, colleagues, and neighbours) (IS1);
- expert knowledge/expert advice (e.g., contractors, designers, energy service experts, and government officials) (IS2); and
- resources published on a public platform (e.g., pilot projects information on a public network platform and databases of energy use) (IS3).

The participants rated the credibility of four categories of information from three types of sources. For example, they were asked, "How credible do you think the building information is, that you received from your social contacts with laypeople". The credibility level is rated on a five-point scale from 1 to 5, indicating from 'not credible at all' to 'very credible'.

Table 3
Risk perception items adapted from Jia et al. (2020).

Risk No.	Items	Risk perception No.
R1	Unqualified building materials	RP1
R2	Lack of construction skills	RP2
R3	Moral hazard	RP3
R4	Poor quality of old residential buildings themselves	RP4
R5	Poor safety management	RP5
R6	Inadequate maintenance	RP6
R7	Difficulties in post-retrofit repair	

3.2.3. Risk perception

A six-item scale was used to measure homeowners' risk perception (RP) in energy retrofitting, as shown in Table 3. Jia et al. (2020) identified seven risks perceived highly by homeowners who have experienced the energy retrofitting. They did this by measuring the level of their concern about each risk. This study integrated the last two risks related to post-retrofitting maintenance into one question and asked participants' concerns about retrofitting risks based on six questions to measure participants' risk perception. All the items were measured on a five-point scale from 1 to 5, with 1 indicating 'not concerned at all' and 5 indicating 'very concerned'.

3.2.4. Homeowners' cooperation

As shown in Table 4, the level of homeowners' cooperation (HC) was measured by five items. According to the field survey, this study summarized the homeowners' rights and obligations in energy retrofitting. Five items of homeowners' cooperative behaviours originate from these homeowners' roles listed in Table 4. Participants were asked the likelihood that they would take these actions if their homes were planned by the government to be renovated. A five-point scale from 1 to 5 was used to measure homeowners' cooperative behaviours, indicating from 'totally unlikely' to 'very likely'.

3.3. Data analysis

First, this study conducted descriptive and correlation analysis using all the variables to confirm that there were sufficient variations of variables and if certain variables were correlated. Moreover, descriptive analysis was used to show the average levels of information, risk perception, and homeowners' cooperation.

Second, structural equation modelling (SEM) was used with AMOS 23.0 to verify hypotheses 1 and 2. Six latent variables (including BI, RB, RT, RS, RP, and HC) are involved in hypotheses 1 and 2, and this paper examined the direct and indirect effects among these variables. Compared with other multivariate analysis methods, SEM is more useful to deal with the variables that cannot be measured directly and to estimate multiple inter-dependent relationships among these variables (Kline, 2015). There are two components in SEM: measurement model,

[1] University Enrolment Expansion refers to, the educational reform policy for expanding continuously the enrolment of general colleges and universities based on economic and employment issues since 1999 in the People's Republic of China (i.e., Mainland China).

Table 4
Items for measuring the level of homeowners' cooperation.

Homeowners' rights and obligations in energy retrofitting	Items of homeowners' cooperation
Homeowners can decide whether to approve the energy retrofit of their home, and most homeowners' approval (more than 2/3) is required.	HC1: Approve the energy retrofitting of their homes.
Homeowners can first give some opinions about retrofit items to the government staff. Then, when retrofit items are posted, they can also put forward some advice. During the period of posting the retrofit schemes, homeowners can give feedback to the government staff.	HC2: Accept all the renovation plans arranged by the government, including doors and windows, external walls, roofs and so on.
Homeowners need to cooperate with the government staff to clean the spot before the on-site construction.	HC3: Cooperate with the government and other project personnel to remove the obstacles in the construction site, including the illegal construction in the community and on the roof, etc.
Homeowners can supervise contractors' work and can also give some advice about retrofit construction.	
Homeowners need to cooperate with contractors in construction work.	HC4: Cooperate with the construction personnel and follow their schedule, plan, site planning, and material placement arrangements.
Homeowners can participate in the checking and acceptance of retrofit projects.	
Homeowners need to maintain the renovated buildings to keep the good performance of installed retrofit technologies.	HC5: Maintain the post-retrofitting residential quarters under the arrangement of the government and property management enterprises.

and structural model. Each measurement model is used to elaborate one latent variable by employing several observable variables, while the structural model conveys the interrelated dependence relationships among the latent variables. A large sample size is necessary for SEM. Kline (2015) gave a minimum sample size of 200, while Raykov and Marcoulides (2012) suggested at least 10 observations per indicator variable in the model. The number of samples in this study is 413 and there are 14.75 cases per indicator variable, which is considered to be sufficient data points.

Third, linear multiple regression methods with SPSS 23.0 were used to test hypothesis 3. RP and HC were linked to four information variables (BI, RB, RT, and RS) respectively to form four independent models, and three variables of IS credibility related to each information variable were imported into the corresponding information model in sequence. This paper centred the variables of information and IS credibility before constructing interactive items so as to reduce multi-collinearity. The multiple linear regressions were employed to examine the moderating effect of information source credibility on the strength of direct relationships between information and HC. HC was the dependent variable, and there were three independent variables including information, IS credibility, and the interaction parameter between information and IS credibility. Then, the moderation roles of IS credibility on the strength of the indirect effect between information and HC via RP were tested by the PROCESS procedure written by Hayes (2017), in which a 5000 resampling bootstrap was adopted. In the procedure, the model number was first set to 8. HC, information, RP, and IS credibility were moved to this procedure as outcome variable, independent variable, mediation variable, and moderation variable, respectively.

4. Results

4.1. Descriptive analysis

Descriptive statistics and correlations of all variables are shown in Appendix A. The participants were generally less informed of all types of information (mean < 3) and also had some concern about retrofitting risks (mean $= 3.6$). These participants expressed a relatively positive attitude towards cooperation (mean $= 3.51$). No matter what kinds of information they received, the participants viewed expert knowledge and published resources (mean > 3 and even 3.5) as more credible information sources than social contacts with laypeople (mean < 3). *Risk perception* was positively correlated with *building information* but negatively correlated with *information on retrofitting service*. *Homeowners' cooperation* was positively correlated with information on *retrofitting benefits* and *retrofitting service*, but negatively correlated with *risk perception*.

4.2. Structural equation model specification

According to the theoretical expectation, the structural equation model was generated. The resulting model is shown in Fig. 2, which presents the path coefficients ranging from 0.57 to 0.85 for the effects of observed variables on latent variables. It is suggested that the observed indicators can represent the latent constructs.

The overall model fit was evaluated and the test results are given in Table 5. The coefficient of χ^2/degree of freedom is 2.137, which is lower than the criteria. Based on the outputs of AMOS 23.0, Table 5 also presents the values of five main indexes recommended by Hu and Bentler (1998) and lists the corresponding traditional cut-off values suggested by Marsh et al. (2004). As shown in Table 5, the fit between the theoretical model and data is acceptable, and thus, the overall model for relationships between information, risk perception, and homeowners' cooperation is supported.

In order to assess the internal reliability of latent variables, Composite Reliability (CR) values and Average Variance Extracted (AVE) values are provided in Table 6. CR measures the consistency of a set of latent construct indicators in the measurement, and the values above 0.8 can be considered adequate for the reliable construct (Koufteros, 1999). AVE detects the true representativeness of latent construct variables and is a supplementary measure for construct reliability (Koufteros, 1999). AVE values are suggested to be more than 0.5 for any construct (Bagozzi and Yi, 1988). Table 6 presents six latent variables with CR being over 0.8 and AVE being over 0.5, which indicates good internal consistencies of all latent variables.

The parameter estimates of direct paths derived from the structural equation model are shown in Table 7. *Information on building* and *retrofitting service* has significant impacts on *risk perception*. Risk perception is negatively correlated with *homeowners' cooperation*. Meanwhile, H1, the direct effect of information on homeowners' cooperative behaviours, is also examined. *Homeowners' cooperation* is positively contributed by *information on retrofitting benefits* and *retrofitting service*.

Table 8 provides the bias-corrected bootstrapping results to examine H2 of the mediating role of risk perception. A 5000 resampling bootstrap was used to support the mediating role of *risk perception* between *building information* and *homeowners' cooperation* and between *positive information on retrofitting service* and *homeowners' cooperation*.

4.3. Testing the moderating role of information source credibility on direct relationships between information and homeowners' cooperation

The moderation testing of information source credibility was performed in the case of different sources and different kinds of information. The testing results are used to verify H3a and are shown in Table 9.

As shown in Table 9, the credibility of both *expert knowledge* and *published resources* moderates significantly the strength of the relationship between *retrofitting benefits* and *homeowners' cooperation*. Fig. 3 and Fig. 4 provide the slope test further to support the moderation effect of the credibility of these two sources. The direct relationships between *retrofitting benefits* and *homeowners' cooperation* are significant only under the high credibility of the sources.

According to the results of the moderation effect in Table 9, the

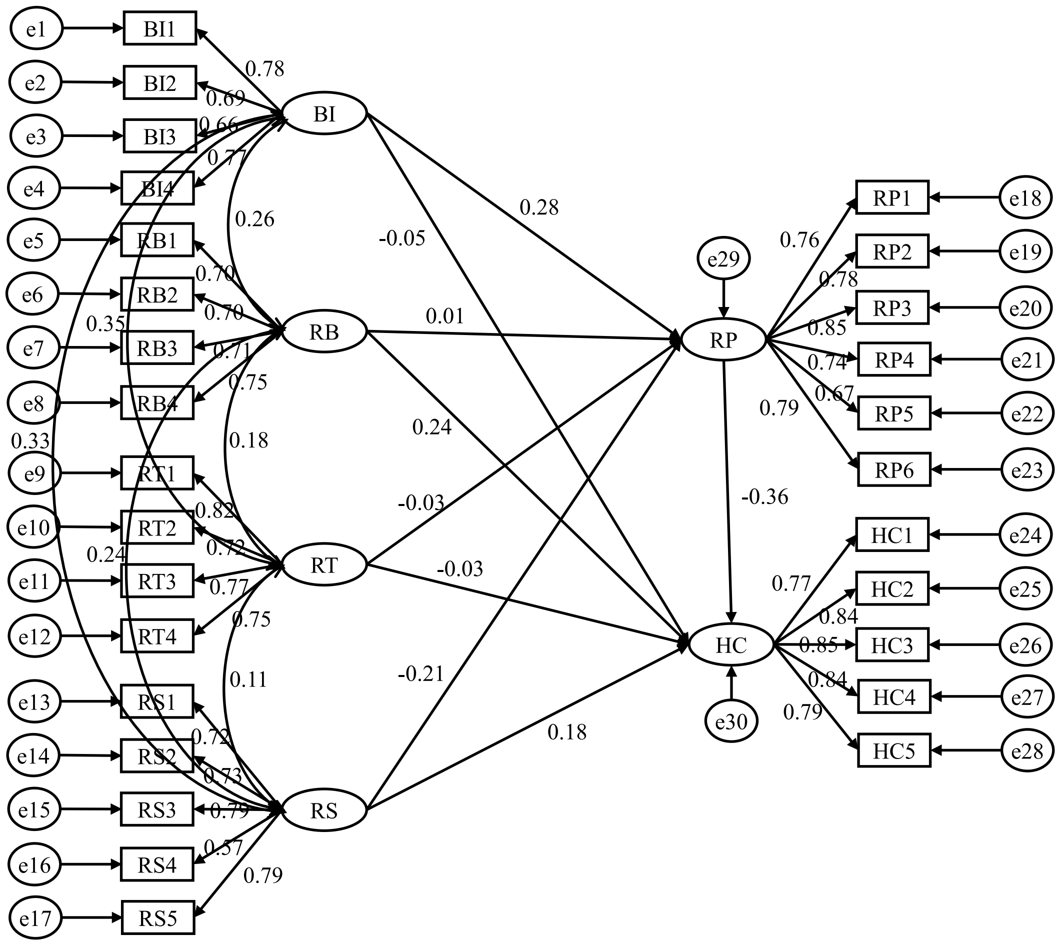

Fig. 2. Derived structural equation model.

Table 5
Goodness-of-fit (GOF) indexes.

Fit index	χ^2/degree	CFI	IFI	TLI	RMSEA	SRMR
Value	2.137	0.932	0.933	0.924	0.053	0.0468
Criteria	<3	>0.9	>0.9	>0.9	<0.08	<0.05

Note: CFI = comparative fit index; IFI = incremental index of fit; TLI = Tucker-Lewis index; RMSEA = root mean square of approximation; SRMR = standardized root mean square residual.

Table 6
Composite reliability and average variance extracted.

Dimension	CR	AVE
BI	0.813	0.522
RB	0.807	0.512
RT	0.850	0.587
RS	0.843	0.522
RP	0.895	0.589
HC	0.910	0.669

Note: BI=Building information; RB = Retrofitting benefits; RT = Retrofitting technology; RS = Retrofitting service; RP = Risk perception; HC=Homeowners' cooperation.

interactive effect of the credibility of *social contacts with laypeople* and *information on retrofitting technology* significantly influences *homeowners' cooperation*. Fig. 5 provides further support for the interactive effect: increased *information on retrofitting technology* has a more significantly negative impact on *homeowners' cooperation* in the case of high

Table 7
Regression weights of the direct path.

Path	Standardized Estimate	S.E.	C.R.	P
BI→RP	0.281	0.072	4.111	***
RB→RP	0.013	0.078	0.208	0.835
RT→RP	−0.030	0.071	−0.497	0.619
RS→RP	−0.214	0.083	−3.471	***
RP→HC	−0.362	0.048	−6.469	***
BI→HC	−0.046	0.058	−0.722	0.470
RB→HC	0.241	0.064	4.143	***
RT→HC	−0.032	0.055	−0.576	0.565
RS→HC	0.176	0.067	3.034	0.002

Note: "***" indicates $P < 0.001$; BI=Building information; RB = Retrofitting benefits; RT = Retrofitting technology; RS = Retrofitting service; RP = Risk perception; HC=Homeowners' cooperation.

Table 8
Bootstrap testing of the mediating role of risk perception.

Path	Standardized Estimate	SE	Bias-corrected 95%CI		
			Lower	Upper	P
BI→RP→HC	−0.102	0.025	−0.158	−0.059	0.000
RB→RP→HC	−0.005	0.022	−0.048	0.039	0.836
RT→RP→HC	0.011	0.021	−0.031	0.054	0.560
RS→RP→HC	0.077	0.023	0.036	0.127	0.000

Note: BI=Building information; RB = Retrofitting benefits; RT = Retrofitting technology; RS = Retrofitting service; RP = Risk perception; HC=Homeowners' cooperation.

Table 9
Moderating results in direct paths.

	Path	IS1	IS2	IS3
Main effect	BI→HC	−0.027	−0.023	−0.016
	RB→HC	0.196**	0.190**	0.217**
	RT→HC	−0.017	−0.018	−0.003
	RS→HC	0.233**	0.223**	0.222**
Moderation effect	BI*IS→HC	−0.052	−0.056	0.051
	RB*IS→HC	0.075	0.113*	0.156**
	RT*IS→HC	−0.164**	−0.038	−0.074
	RS*IS→HC	0.074	−0.072	0.030

Note: "**" and "*" indicate $p < 0.01$ and $p < 0.05$, respectively; BI=Building information; RB = Retrofitting benefits; RT = Retrofitting technology; RS = Retrofitting service; HC=Homeowners' cooperation; IS=Information source; IS1=Social contacts with laypeople; IS2 = Expert knowledge/expert advice; IS3=Resources published on a public platform.

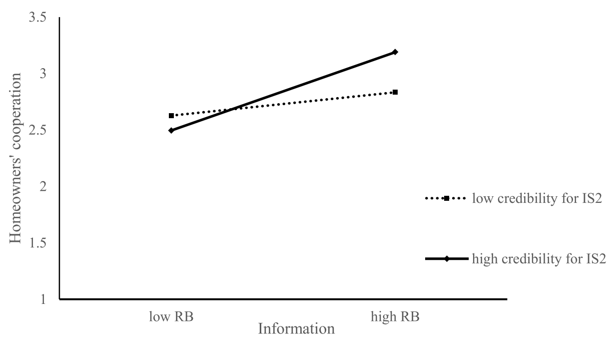

Fig. 3. Interactive effect of RB and IS2 credibility on HC.

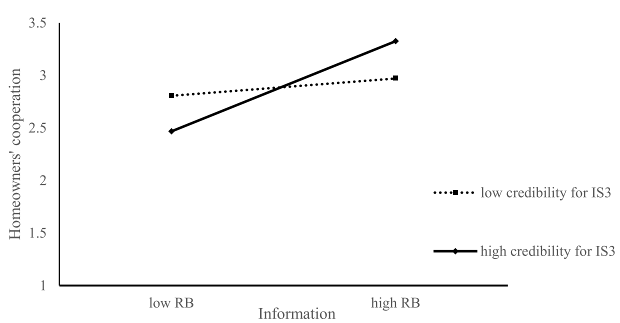

Fig. 4. Interactive effect of RB and IS3 credibility on HC.

credibility of *social contacts with laypeople*.

4.4. Testing the moderating role of information source credibility on indirect relationships between information and homeowners' cooperation via risk perception

Based on a 5000 re-sampling bootstrap in PROCESS, the moderating role of information source credibility in the mediating effect of risk perception is examined to validate H3b. The testing results are shown in Table 10.

Table 10 provides the support for the moderating role of source credibility in the indirect influence of *building information* on *homeowners' cooperation*. The mediation effect of *risk perception* is moderated by the credibility of both *social contacts with laypeople* and *expert knowledge* significantly. The mediation effects of *risk perception* are significant only in the case of high credibility (+1 SD from the mean) of *social contacts with laypeople* and *expert knowledge*.

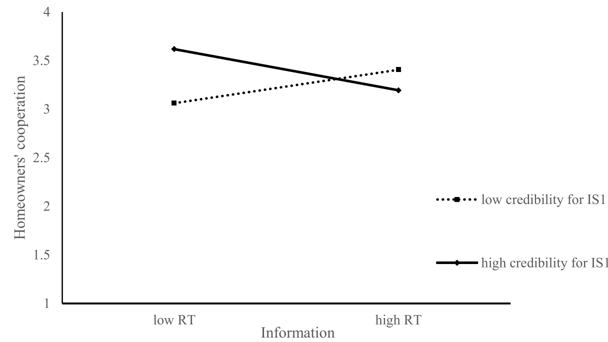

Fig. 5. Interactive effect of RT and IS1 credibility on HC.

The moderating role of source credibility in the indirect effect of *retrofitting technology information* can also be supported by the results shown in Table 10. The credibility of *social contacts with laypeople* can moderate the mediation effect of *risk perception* between *information on retrofitting technology* and *homeowners' cooperation* significantly. The mediation effect of *risk perception* is significant only when the credibility of *social contacts with laypeople* is high.

Table 10 supports the moderating role of source credibility in the indirect influence of *positive information about retrofitting service* on *homeowners' cooperation*. The moderating roles of the credibility of all three information sources, namely *social contacts with laypeople*, *expert knowledge*, and *published resources*, in the mediation effect of *risk perception* are significant. The indirect effects between *positive information about retrofitting service* and *homeowners' cooperation* via *risk perception* are significant only when the source credibility is high.

5. Discussion

5.1. Limited role of building and technology information under the current environment of energy efficiency

The findings of this paper show that there is no significant direct relationship between building information and homeowners' cooperation. Currently, there is no reasonable and uniform standard for the energy consumption of old residential buildings in China, especially those that were built before 2000. Even if household energy consumption is very considerable, these homeowners might have no consciousness about the necessity of energy retrofitting due to the lack of the baseline of building energy consumption. Moreover, the average household electric power price in China was only $0.084 per kilowatt-hour, a price that was much lower than some developed countries such as Germany, Italy, the UK, and Japan, with electricity prices of over $0.2 per kilowatt-hour, based on 2016 data. The usage of electricity with low prices is considered by homeowners in the HSCW zone to be able to compensate for poor building thermal insulation systems to ensure a sense of living comfort. These situations in China are consistent with the study results of Palmer et al. (2013) in two respects: (1) energy spending does not put much pressure on household finances due to low energy prices; and (2) information on the energy performance of homes alone is insufficient to drive homeowners to renovate their homes.

It is found out that the provision of retrofitting technology information does not contribute significantly to homeowners' cooperation. Such insignificant influence is probably due to the limitations of selection on retrofitting technology in China. In general, technology options provided for homeowners are standardised retrofit packages and are

Table 10
Moderated mediation results.

Mediation path	Moderator		Effect	SE	BootLLCL	BootULCL
BI→RP→HC	IS1		−0.043	0.018	−0.083	−0.009
		High(+1 standard deviation)	−0.112	0.029	−0.177	−0.062
		Low(-1 standard deviation)	−0.018	0.026	−0.070	0.032
	IS2		−0.061	0.018	−0.099	−0.030
		High(+1 standard deviation)	−0.127	0.030	−0.195	−0.077
		Low(-1 standard deviation)	0.006	0.023	−0.040	0.056
	IS3		−0.024	0.019	−0.066	0.012
RB→RP→HC	IS1		0.026	0.019	−0.010	0.064
	IS2		0.013	0.019	−0.022	0.052
	IS3		0.018	0.020	−0.022	0.059
RT→RP→HC	IS1		−0.067	0.021	−0.111	−0.030
		High(+1 standard deviation)	−0.078	0.027	−0.134	−0.030
		Low(-1 standard deviation)	0.045	0.027	−0.006	0.101
	IS2		−0.036	0.022	−0.080	0.007
	IS3		0.004	0.020	−0.036	0.046
RS→RP→HC	IS1		0.042	0.018	0.011	0.081
		High(+1 standard deviation)	0.102	0.028	0.053	0.165
		Low(-1 standard deviation)	0.017	0.027	−0.038	0.070
	IS2		0.048	0.019	0.015	0.088
		High(+1 standard deviation)	0.110	0.031	0.055	0.175
		Low(-1 standard deviation)	0.010	0.028	−0.046	0.065
	IS3		0.050	0.026	0.003	0.106
		High(+1 standard deviation)	0.095	0.031	0.042	0.164
		Low(-1 standard deviation)	0.016	0.028	−0.039	0.072

Note: BI=Building information; RB = Retrofitting benefits; RT = Retrofitting technology; RS = Retrofitting service; RP = Risk perception; HC=Homeowners' cooperation; IS1=Social contacts with laypeople; IS2 = Expert knowledge/ expert advice; IS3=Resources published on a public platform.

limited within a scope set by the local government and designers in advance in China. It is likely, that these standardised retrofitting technologies are not what homeowners need (Lo, 2015). As a result, the information relevant to these technologies cannot motivate homeowners to be involved actively in retrofitting projects. This problem results from the current retrofitting financing mode in China. In the case that governments cover all the expenses, the boundaries of retrofit packages are determined by the available government financial support (de Feijter et al., 2019).

5.2. Impetus of homeowners' cooperation: benefits and good service

It is confirmed that increased information on retrofitting benefits can facilitate directly homeowners' cooperation. At present, the local government is the main investor of energy retrofitting of residential buildings in China. The reduced household spending without any capital input is still attractive to homeowners. Direct economic benefits underwritten by the government are necessary for the homeowners to accept the retrofitting solutions (Li et al., 2013). Moreover, with the improvement of living standards, homeowners tend to focus more on living comfort, which can explain the rapid growth in building power consumption in recent years in China but is, in turn, also a great motivator of participating in energy retrofitting to homeowners. Even in the study of Pettifor et al. (2015), the maintenance of a level of comfort was viewed to be more relevant to homeowners than financial motivators. Similarly, Gram-Hanssen (2014) also supported that increased knowledge of all energy efficiency benefits could motivate homeowners to improve the energy efficiency of their homes.

Our survey confirms that, increased positive information about retrofitting service is conducive to the improvement of homeowners' cooperation, both directly and indirectly. The information on retrofitting service in this study covers some practical issues, mainly involving contractors' construction service and homeowners' control over construction. In China, homeowners are rarely involved in the search for contractors, material procurement, and construction planning. Positive information enables homeowners to realize the high reliability of contractors and the high feasibility of supervising the construction work, further reducing their perceived uncertainty due to their low involvement in retrofitting construction. Our result is actually in line with the finding of Christensen et al. (2014) that homeowners consider the practical issues concerning homeowners' ability to cope with retrofitting and the reliability of tradespersons as the main concern for retrofitting or not. Meanwhile, the information covering practical issues also contributes to the decrease in homeowners' worries and anxieties (Zundel and Stieß, 2011).

5.3. Barriers to homeowners' cooperation: safety concern and hard-to-understand technology information

The indirect effect of building information on homeowners' cooperation is significant but is negative due to its amplification effect on risk perception. This might be attributed to the common reality of the poor structural quality of old residential buildings. Poor design and construction is indeed a common problem of building stock in China (Baldwin et al., 2018). In particular, housing commercialization in the 1980s and 1990s led to a nationwide boom of urban residential buildings in China, but there was no requirement for housing quality, due to the lack of laws and standards. For example, the "Construction Law", the highest-level law regulating the quality of housing construction in China, was issued in 1997, and "Regulations on the Quality Management of Construction Projects" was officially approved and implemented by the State Council in January 2000. The majority of survey participants in this study are from the residential quarters built before 2000 (i.e., in the 1980s and 1990s). The reality of this information leads homeowners to doubt the stability of the building structure in the retrofitting process. People's exposure to information on the risky situation can trigger higher levels of their risk perception (Lindell and Hwang, 2008; Lindell and Perry, 2012).

Negative effects of technology information on homeowners' cooperation directly and indirectly are increased significantly under the influence of the high credibility of social contacts. It can come down to the features of technology information, namely, their complexity and them being difficult to understand. Much of the information about technology and equipment of building energy efficiency involves complicated terminologies and is thus poorly understood by homeowners (Syal et al., 2014). Similarly, the knowledge of the laypeople in homeowners' social networks is also influenced, which leads to their misunderstanding of technology to some extent. The information from social networks is viewed as a complement to specific technical information and plays a decisive impact on homeowners' decisions (Bartiaux et al., 2014). Inaccurate or biased information from social networks leads homeowners to have more concern about risks about retrofitting technology and also prevents homeowners from accepting retrofitting.

5.4. Thoughts on differences of information sources

The findings support that, high credibility of information sources is a prerequisite to the significant direct or indirect effect of retrofitting information on homeowners' cooperation. Still, the moderating effect of source credibility, such as published resources providing building information and social contacts providing retrofitting benefits, cannot be reflected in survey results in some cases, due to the limitation of the availability of information. The importance of the Internet as an information source is dependent on the available online building analysis tools (Novikova et al., 2011b). However, informative online instruments, such as a building energy consumption database and energy performance certificates, are rarely found in China. In this case, it is difficult for homeowners to extract the particular building information they need from published resources.

Similarly, few retrofitting benefits can be perceived by laypeople especially in the HSCW zone of China. Homeowners who have benefitted from retrofitting in this region are limited due to the slow development of residential energy retrofitting. Moreover, as mentioned by Matschoss et al. (2013), apartment owners rarely monitor their energy consumption and expenditure. In other words, few homeowners, even those who have experienced energy retrofitting, are familiar with retrofitting benefits like energy and financial savings. As a result, potential consumers of energy retrofitting can only receive very limited information on retrofitting benefits from their social contacts with laypeople, even if Bartiaux et al. (2014) considered information transferring through social networks as a characteristic of retrofitting.

6. Conclusions and policy implications

There is an increased attention to energy retrofits of residential buildings especially in the HSCW zone in China. Homeowners' cooperation is the key to the smooth implementation of retrofitting projects in order to speed up the retrofitting process. This paper contributes to the body of knowledge by considering information provision into as an approach to improving homeowner' cooperation in the whole process of retrofitting projects. This study determines the direct relationships between four kinds of retrofitting information and homeowners' cooperation, the indirect relationships via risk perception and the influences of information source credibility as a moderator on these relationships.

The results show the important roles of both retrofitting benefits and positive information about retrofitting service in motivating homeowners to cooperate. The government should value the diffusion of information on retrofitting benefits and service of information in the general public domain. In consideration of the importance of high source credibility and homeowners' general recognition of expert knowledge and published resources, the government must make pilot retrofitting projects more transparent. More retrofitting benefits are disseminated at public platforms in the way of achievements demonstration. Meanwhile, the communication and exchanges between pilot projects and the local community should be strengthened to make retrofitting service information accessible to homeowners.

The objective information on some quality problems in the building itself leads to the increase in homeowners' concern about the safety during the retrofitting, thereby reducing their enthusiasm for cooperation. The government should make more detailed and strict provisions of quality and structure of the potential renovated buildings to ensure retrofitting safety. This positive information about building quality (e.g., the potential to reinforce the buildings or to deal with cracks and water seepage) should be correspondingly stressed in the published retrofitting plans to reduce homeowners' risk perception. Furthermore, some local governments have facilitated the adoption of energy consumption databases of public buildings, but databases for residential buildings are seldom mentioned. The government should pay more attention to the establishment of energy consumption databases of residential buildings, and make them available to the public.

The technology information on the standardised retrofitting packages has a minimal influence on homeowners' cooperative behaviours, but homeowners' cooperation is significantly hindered by the increase of technology information under the high credibility of social contacts with laypeople. The government should encourage appropriately personalized retrofitting projects. It requires a good understanding of the context of homeowners' everyday life so that the government can carry out retrofitting projects based on homeowners' actual needs within the financial limits. However, the fundamental solution is that the government needs to diversify the channels of retrofitting investment and social capital. It is also suggested that the government should provide technical information in a form that can be easily understood by homeowners. In other words, the provided technical information needs to be adapted to homeowners' state of knowledge to make sure of their proper understanding.

This study has shown that homeowners' cooperation is closely influenced by risk perception and retrofitting information. Still, other factors affecting homeowners' cooperation were overlooked, such as homeowners' reputation among the neighbours (Zundel and Stieß, 2011), and personal norms referring to the feelings of moral obligations (Kastner and Stern, 2015). These factors about personal values can be incorporated into the model of homeowners' participation in future. Besides, given the unique government-led retrofitting model in China, this paper does not consider financial constraints to homeowners' cooperation that has been mentioned generally in the international context (Biekša et al., 2011; Caputo and Pasetti, 2015; Dahlhausen et al., 2015). Considering that homeowners' investment is the key to maintaining the continuous development of energy retrofitting, future research can focus on how to develop effective economic measures (e.g., loans and subsidies) to attract more funds from homeowners, instead of relying solely on government finance.

CRediT authorship contribution statement

Ling Jia: Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft, Writing – review & editing. **Queena K. Qian:** Writing – original draft, Writing – review & editing. **Frits Meijer:** Writing – review & editing. **Henk Visscher:** Writing – review & editing.

Declaration of competing interest

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

Acknowledgments

This work is supported by the China Scholarship Council and Department of Management in the Built Environment, Delft University of Technology. The authors would also like to acknowledge the editing by Dr. Paul W. Fox of an earlier draft of this paper.

Appendix A. Means, Standard Deviations, and Correlations among Variables

	Variables	M	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	BI	2.44	0.81																	
2	RB	2.34	0.69	0.22**																
3	RT	2.56	0.72	0.28**	0.14**															
4	RS	2.27	0.66	0.30**	0.20**	0.09														
5	RP	3.60	0.76	0.16**	0.03	0.05	−0.11*													
6	HC	3.51	0.81	−0.02	0.21**	−0.02	0.22**	−0.35**												
7	BI-IS1	2.70	1.08	0.01	0.04	0.08	−0.08	−0.10*	0.06											
8	BI-IS2	3.16	1.10	0.00	0.17**	0.09	−0.01	−0.13**	0.13**	0.69**										
9	BI-IS3	3.39	1.01	−0.03	0.13**	−0.02	−0.08	−0.17**	0.07	0.63**	0.64**									
10	RB-IS1	2.87	1.21	0.11*	0.12*	0.07	0.04	−0.14**	0.11*	0.17**	0.24**	0.21**								
11	RB-IS2	3.38	1.09	0.09	0.13**	−0.01	0.10*	−0.14**	0.10*	0.11*	0.24**	0.16**	0.61**							
12	RB-IS3	3.61	1.02	0.06	0.06	0.08	0.02	−0.10*	0.02	0.13*	0.24**	0.19**	0.59**	0.63**						
13	RT-IS1	2.85	0.92	0.09	−0.05	−0.00	0.02	−0.03	0.10*	0.21**	0.20**	0.14**	0.15**	0.09	0.00					
14	RT-IS2	3.38	0.98	0.03	−0.06	−0.02	−0.02	0.04	0.03	0.22**	0.18**	0.19**	0.15**	0.05	−0.06	0.68**				
15	RT-IS3	3.36	0.94	0.06	0.02	−0.12*	0.04	0.05	0.10*	0.21**	0.19**	0.12*	0.08	0.00	−0.08	0.58**	0.62**			
16	RS-IS1	2.68	1.03	−0.03	−0.06	−0.03	−0.09	−0.22**	−0.01	0.23**	0.18**	0.26**	0.06	0.03	−0.09	0.25**	0.27**	0.16**		
17	RS-IS2	3.35	1.04	0.14**	−0.12*	0.02	−0.08	−0.20**	−0.10	0.15**	0.07	0.15**	0.20**	0.15**	0.03	0.21**	0.24**	0.14**	0.59**	
18	RS-IS3	3.15	0.80	−0.08	−0.14**	0.01	−0.11*	−0.14**	−0.06	0.16**	0.06	0.16**	0.11*	0.06	−0.01	0.23**	0.27**	0.10*	0.61**	0.59**

Note: N = 413. *$p < 0.05$, **$p < 0.01$; Two-tailed test. M = Mean; SD= Standard Deviation; BI=Building information; RB = Retrofitting benefits; RT = Retrofitting technology; RS = Retrofitting service; RP = Risk perception; HC=Homeowners' cooperation; IS1=Social contacts with laypeople; IS2 = Expert knowledge/expert advice; IS3=Resources published on a public platform.

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