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A Game Theory Based Analysis of Decision Making for Green Retrofit under Different Occupancy Types

Xin Liang[1,2], Yi Peng[3], Geoffrey Qiping Shen[2]*

Abstract

Buildings are responsible for almost half of all the energy consumption and greenhouse gas (GHG) emissions in the world. This situation highlights the importance of the green retrofit for existing buildings in reducing the energy consumption and GHG emissions, as emphasized by the academia and improved by the government. Although relevant stakeholders are interested in implementing green retrofit projects, this approach has not been widely pursued by the industry, the reasons of which remain unclear. Therefore, this study aims to reveal the underlying logic by analyzing the behaviors of the building owners and occupiers, who are the direct decision makers in initiating green retrofit at the initial intention phase. Three occupancy scenarios, namely, owner-occupied (baseline scenario), single-occupied, and multi-occupied buildings, are used for the game analysis. The Nash Equilibrium of the game is used to analyze the probable decisions of the owners and occupiers under the last two occupancy scenarios. Results demonstrate that both owners and occupiers are reluctant to retrofit under both scenarios. Nevertheless, the reasons vary under the two scenarios despite the same results obtained. This study clarifies the reasons for the reluctance of the direct decision makers to participate in green retrofit projects. The main reasons include the split incentives between the owners and occupiers, the complex coordination, and the uncertainty of green retrofit. The identified reasons are also beneficial to the policy makers, particularly in their effort to promote green retrofit by considering the requirements of owners and occupiers under the different occupancy types.

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Keywords: Green Retrofit; Decision Making; Game Theory; Owner; Occupier;

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1 Introduction

Buildings are responsible for the majority of the energy consumption and greenhouse gas (GHG) emissions around the world. In the United States (US), buildings consume approximately 50% of the total energy (EIA, 2010), while in Europe, the ratio is approximately 40% (Kashif et al., 2011). In the last few decades, the building energy consumption has continuously increased, particularly in developing countries. In China, the building energy consumption increased by more than 10% annually (Xu et al., 2011). Buildings are also considered responsible for a quarter of the total global carbon dioxide (CO_2) emissions (Hong et al., 2015), which consequently increase the adverse impact on the global environment, healthcare, and economy (Menassa and Baer, 2014). In the life cycle of a building, more than 80% of the energy consumption occurs during the actual occupancy operation stage rather than during the construction stage (UNEP, 2007).

Owing to its essential influence on energy consumption and GHG emission, the green retrofit for existing buildings should be given due attention in relation to sustainable development. "Green retrofit" can be defined as the incremental improvement of the fabric and systems of a building with the primary intention of improving energy efficiency and reducing carbon emissions. It can likewise refer to other terms in literature, such as refurbishment, rehabilitation, modernization, renovation, improvements, adaptation, additions, repairs and renewal on existing buildings (Ali and Rahmat, 2009). However, routine maintenance and cleaning work are excluded (Quah, 1988).

Green retrofit for existing buildings is emphasized by governments all over the world. The US government passed the Energy Policy Act (EPA) of 2005 and the Executive Order 13423, which require retrofitting 15% of the total number of the existing buildings to improve energy efficiency by 2015 compared with the 2003 baseline (EPA, 2005). Approximately 30 billion US dollars are earmarked to conduct green retrofit projects for the existing buildings and facilities. In 2010, the UK government launched the Carbon Reduction Commitment (CRC) Energy Efficiency Scheme to save 1.2 million tons of CO_2 emissions annually by 2020. This scheme motivates the consumers to consider energy efficiency options and to invest in building retrofit projects. Similarly, the Chinese government has introduced various policies.

Chinese 12th Five-Year Plan stipulated that 400 million m^2 residential buildings and 60 million m^2 public buildings are planned to be retrofitted as pilot projects between 2011 and 2015 to improve building energy efficiency.

By contrast, green retrofit projects remain inadequately pursued in the industries. After the 2008 global economic recession, this situation was further exacerbated by the challenge of ensuring the financial support for retrofit activities (Menassa, 2011). Some pilot studies have revealed that the industries are unenthusiastic about green retrofit primarily because of the following aspects: the highly complex design analysis and solution (Davies and Osmani, 2011; Kasivisvanathan et al., 2012; Lapinski et al., 2006), intense interdisciplinary collaboration (Korkmaz et al., 2010; Lapinski et al., 2006), long payback periods (Kasivisvanathan et al., 2012; Menassa, 2011), financial problem (e.g., limited access to capital, high cost, etc.)(Davies and Osmani, 2011; Kasivisvanathan et al., 2012; Xu et al., 2011), lack of retrofit experience (Ali et al., 2008; Kasivisvanathan et al., 2012; Korkmaz et al., 2010), and lack of understanding of the available retrofit technologies (Davies and Osmani, 2011; Miller and Buys, 2008). Most of these research findings were obtained by analyzing the problem from technical, economic, and environmental perspectives. Only a few studies have explored the behaviors of the main stakeholders, who may directly decide whether a building retrofit can be implemented. In practice, the owners and occupiers are the critical direct stakeholders in green retrofit at the initial intention phase. However, these individuals may have varying and conflicting opinions on whether a building should be retrofitted and when and how the retrofit will be implemented. Few studies, if not none, have investigated the decision behaviors of the occupiers and owners under different interaction relationships. Therefore, the logic for reluctance to conduct green retrofit activities in the industry remains unknown.

This study aims to reveal the underlying logic of the industry's reluctance to conduct green retrofit by analyzing the behaviors of owners and occupiers at the initial phase. This study differs from the previous ones because instead of identifying the willingness of the stakeholders or the retrofit-related problems through a survey, it explores the behaviors of the direct decision makers under the current market constraints through a game analysis.

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Modeling the retrofit decision behaviors of the stakeholders under different scenarios with game theory can be an efficient means to properly identify the underlying logic. The rest of the paper is organized into eight sections. Section 2 critically reviews the literature on stakeholders in green retrofit and the relevant motivations and barriers. Section 3 describes the research methodology. Sections 4, 5, and 6 introduce the specific game analysis in the different scenarios of occupancy types. Section 7 comprehensively discusses the analytic results. Section 8 concludes the study and presents recommendations for future research.

2 Literature Review

2.1 Critical stakeholders in green retrofit

The stakeholders in green retrofit are the people who, directly or indirectly, have vested interests in a building and in the outcome of a potential and ongoing green retrofit project (Gucyeter and Gunaydin, 2012). The main stakeholders identified by the literature include the client/owner, occupier/tenant, facilities manager, consultant/designer, contractor, subcontractor, supplier, government, financial institutions, energy service companies, environmental organization, professional association, media, public, labor union, and researcher/educator (Gultekin et al., 2013; Juan et al., 2009; Kaklauskas et al., 2008; Kaklauskas et al., 2004; Miller and Buys, 2008; Yang and Zou, 2014), which are shown in Figure 1. Previous studies asserted that the process of green retrofit projects can normally be divided into five phases, namely, the 1) initial intention or setup, 2) pre-retrofit survey and energy performance assessment, 3) design, 4) site implementation, and 5) validation and verification (Lapinski et al., 2006; Ma et al., 2012). Various stakeholders are involved in green retrofit projects in the different phase (see Figure 1). For example, the energy consultants are normally involved in the pre-retrofit survey and energy performance assessment phase, whereas the designers and contractors participate in the project at the design and implementation phases.

The owners and occupiers play important roles in making green retrofit decisions, particularly at the very early stage, namely, initial intention or setup phase (Liang et al., 2015). In this phase, normally only the owners and occupiers are involved, who propose preliminary retrofit plans and exchange opinions regarding retrofit. These stakeholders can decide whether to launch a retrofit project and to continue to the next steps of energy audit, design, and implementation. The important role of owners in green retrofit can be naturally and easily understood, whereas the role of the occupiers is often underestimated (Karvonen, 2013). Juan et al. (2009) indicated that the influence of the occupiers makes the retrofit more difficult and risky than new buildings because cooperation and participation of occupiers are required in an existing building retrofit (Miller and Buys, 2008). In new buildings, the clients, who will become the building owners after construction, can decide by themselves, whereas in retrofit, the owners have to consider occupiers because of their lease contracts. The satisfaction of the occupiers can directly influence the occupancy rate, rent, and owner reputation in the future. In addition to economic influence, the actions of the occupiers are identified as major determinants of energy consumption (Azar and Menassa, 2012; Azar and Menassa, 2014). The occupiers can affect the energy consumption difference by up to 100% through different behaviors, such as ventilation habits, indoor temperature setting behavior, and after-hour lighting use (Ürge-Vorsatz et al., 2009). Consequently, the occupiers are another essential stakeholders in green retrofit projects. Numerous owners and occupiers intend to carry out green retrofit, but, most of them are interrupted at the beginning because a consensus cannot be reached. Ma et al. (2012) presented that the phase of deciding whether to retrofit buildings, which is before the design phase, is the key phase of a sustainable building retrofit. Thus, answering the question of whether or not to retrofit a building by analyzing the interrelations between the owners and occupiers at the first phase is fundamental.

The conventional studies related to the stakeholder analysis in green retrofit mainly focused on the owners and designers involved in the energy assessment and design phase (Ali et al., 2008; Stiess and Dunkelberg, 2013). However, a few recent studies have examined the occupiers of existing buildings and their relationship with owners. Stephan and Menassa (2013) proposed an agent-based model to analyze the social network interactions among the stakeholders (i.e., owner, occupier, architect, and contractor) of commercial buildings. In their subsequent study, Stephan and Menassa (2014) emphasized that the network structure and the confidence level of the stakeholders could significantly influence their own alignment toward a unified retrofit objective. This agent-based model originally simulated the dynamic opinions of the stakeholders that were influenced by their interactions to allow the adjustment

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of their values on three dimensions (i.e., cost, energy, and comfort) to an optimal retrofit decision. Fuerst and McAllister (2011) analyzed the rent, cost, and price of the buildings that were influenced by green retrofit and tried to define an appropriate compensation to satisfy both owners and occupiers.

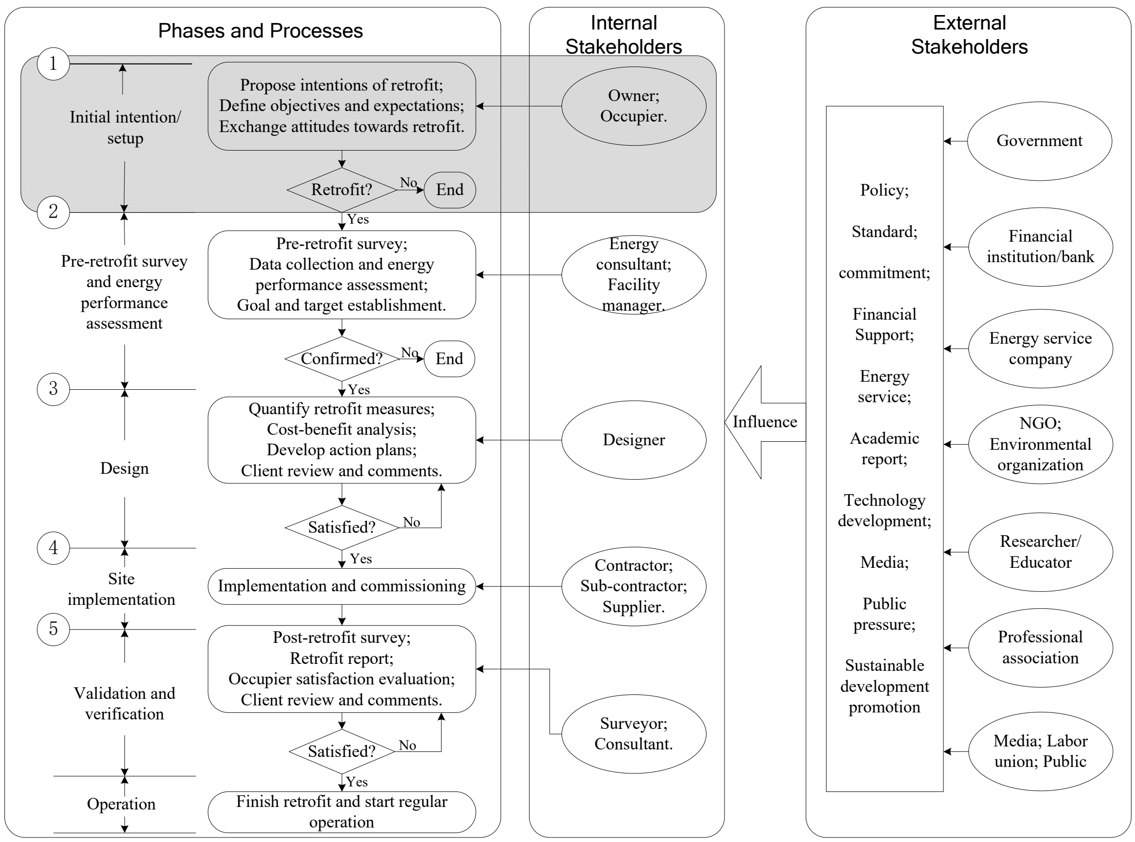

Figure 1 The phases and involved stakeholders in green retrofit projects

2.2 Incentives and drivers for the owners and occupiers

It is important to understand the specific incentives and barriers for the owners and occupiers as they may have varying and conflicting opinions on whether a building should be retrofitted and when and how the retrofit should be implemented. The owners may be motivated to implement retrofit projects by high rent and occupancy rate (Fuerst and McAllister, 2011; Thomas, 2010), tax reduction (Fuerst and McAllister, 2011), and reputation enhancement (Gucyeter and Gunaydin, 2012). Alternatively, the occupiers may be interested in energy cost saving (Ma et al., 2012; Newsham et al., 2009; Rey, 2004), low rent (Menassa and Baer, 2014), and productivity (Fuerst and McAllister, 2011; Thomas, 2010; Xu et al., 2011). Conflicts are probably raised when the owners invest in energy efficiency retrofit, but most direct benefits of energy cost saving are received by the occupiers.

The main incentives for owners and occupiers are identified through the literature review and structured interviews with experts who are experienced in green retrofit projects. The incentives, which can be defined as the potential profits of green retrofit, can be classified into three categories, namely, 1) direct short-term incentives, 2) direct long-term incentives, and 3) indirect incentives. The first category refers to the incentives related to the economic benefits that can be reaped in a short time, such as high rent, low maintenance cost, and tax reduction. The second category also refers to economic benefits, but these ones are gained in the long term (i.e., high occupancy rate, asset value raise, and longevity). The last category includes other incentives related to the social and environmental influence rather than the economic interests. The varying incentives for the owners and occupiers are illustrated in Table 1.

Table 1 The incentives of owners and occupiers in green retrofit

Stakeholders	Direct short-term incentives	Direct long-term incentives	Indirect incentives
Owners	**D_{OW}1:**Higher rent (Fuerst and McAllister, 2011; Thomas, 2010) **D_{OW}2:**Lower maintenance cost (Alanne, 2004; Lapinski et al., 2006; Ouyang et al., 2011; Rey, 2004) **D_{OW}3:**Subsidies/tax reduction (Fuerst and McAllister, 2011; Ouyang et al., 2011) **D_{OW}4:**Return on investment (ROI) (Entrop et al., 2010; Kaklauskas et al., 2004; Miller and Buys, 2008)	**D_{OW}5:**Higher occupancy rate (Fuerst and McAllister, 2011; Ma et al., 2012; Thomas, 2010) **D_{OW}6:**Risks reduction (avoid premature obsolescence, energy cost increasing) (Fuerst and McAllister, 2011) **D_{OW}7:**Longevity (Kaklauskas et al., 2004; Mickaityte et al., 2008) **D_{OW}8:**Asset value raise (Miller and Buys, 2008)	**D_{OW}9:**Reputation enhancement (Gucyeter and Gunaydin, 2012) **D_{OW}10:**Social responsibility (Davies and Osmani, 2011) **D_{OW}11:**Occupiers satisfaction (Thomas, 2010; Xu et al., 2011)
Occupiers	**D_{OC}1:** Lower total cost (including potentially higher	**D_{OC}2:** Productivity improvement (Fuerst and	**D_{OC}3:** Comfort enhancement (Wang et

	rent and lower energy cost) (Caccavelli and Gugerli, 2002; Juan et al., 2010; Newsham et al., 2009; Rey, 2004)	McAllister, 2011; Lapinski et al., 2006; Thomas, 2010; Xu et al., 2011)	al., 2010; Xu et al., 2011) **D_{OC}4:** Social responsibility (Davies and Osmani, 2011)

2.3 Barriers and resistances for the owners and occupiers

Other than the aforementioned split incentives, some barriers (i.e., cost or potential resistances) exist, and they adversely affect the decision making in green retrofit projects. Similar to incentives, the main barriers for the owners and occupiers are identified through the literature review and structured interviews. These barriers are classified into two categories, namely, the 1) direct/economic barriers, and 2) indirect barriers. The first category denotes barriers directly related to the economic problems, such as high retrofit cost, finite capital, and long payback periods. The second category refers to the barriers indirectly related to economy, such as lack of building information, and highly complex design analysis and solution. The specific barriers for the owners and occupiers are shown in Table 2.

Table 2 The barriers of owners and occupiers in green retrofit

Stakeholders	Direct/economic barriers	Indirect barriers
Owners	**B_{OW}1:** High retrofit cost (Lapinski et al., 2006; Menassa, 2011; Xu et al., 2011) **B_{OW}2:** Long payback periods (Kasivisvanathan et al., 2012; Menassa, 2011) **B_{OW}3:** Finite capital (Davies and Osmani, 2011; Kasivisvanathan et al., 2012; Menassa, 2011; Stiess and Dunkelberg, 2013) **B_{OW}4:** Interruptions in operations (Kasivisvanathan et al., 2012; Miller and Buys, 2008) **B_{OW}5:** Risk of retrofits (Menassa, 2011)	**B_{OW}6:** Highly complex design analysis and solution (Davies and Osmani, 2011; Kasivisvanathan et al., 2012; Lapinski et al., 2006) **B_{OW}7:** Lack of building information (Davies and Osmani, 2011; Kasivisvanathan et al., 2012; Menassa, 2011) **B_{OW}8:** Lack of retrofit experience (Ali et al., 2008; Korkmaz et al., 2010)
Occupiers	**B_{OC}1:** Higher rent (Fuerst and McAllister, 2011; Thomas, 2010) **B_{OC}2:** Interruptions in operations (Kasivisvanathan et al., 2012; Miller and	**B_{OC}4:** Lack of understanding or interest about environment (Davies and Osmani, 2011) **B_{OC}5:** Lack of information(Davies and

	Buys, 2008)	Osmani, 2011; Kasivisvanathan et al., 2012; Menassa, 2011)
	B_{OC}3: Risk of retrofits (energy may not be saved by retrofit) (Menassa, 2011)	**B_{OC}6:**Possibility of relocation(occupiers may not bear interruptions or higher rent) (Fuerst and McAllister, 2011)

2.4 Summary of the review

The abovementioned studies (Fuerst and McAllister, 2011; Stephan and Menassa, 2014; Stephan and Menassa, 2013) are helpful in understanding the important roles of the owners and occupiers and their varying interests in green retrofit. However, understanding alone is not sufficient to reveal the underlying logic of the industry's reluctance to conduct green retrofit. The shortcomings of the existing studies are explained in the succeeding paragraphs.

First, the existing studies generally overlooked the role of the owners and occupiers in green retrofit at the initial phase. Many green retrofit plans were canceled at the beginning stage because of controversies among the owners and occupiers. Therefore, the behaviors of the owners and occupiers at the initial phase must be re-examined to clearly identify the underlying reasons. Focusing on one phase of green retrofit can also help decompose and simplify the decision-making problems as well as achieve relatively accurate results.

Second, the existing studies disregarded the complicated behaviors of the owners and occupiers under different interaction relationships, or different occupancy types. Unlike the case of new buildings, the occupiers are the main stakeholders in the green retrofit for existing buildings, which can be classified into three categories according to occupancy type, namely, owner-occupied, single-occupied (not by owner), and multi-occupied (Rhoads, 2010). These occupancy types can influence the position and power of the stakeholders, benefit distribution, transaction cost, and other factors in decision making. In the case of owner-occupied buildings the owners can make decisions completely by themselves. The single-occupied buildings are rented to a single tenant, probably a company or institute in a relatively large scale. The single tenants significantly influence the profit of the building owners and therefore have relatively high negotiation capabilities. A retrofit decision must be agreed to by the single occupier, otherwise, the decision becomes difficult to implement. The multi-occupied buildings are occupied by numerous tenants who are commonly in a small scale. Every occupier only rents a small part of the building, and the rent from an individual occupier is not sufficient to influence the profit of owners. In this case, the owner dominates the decision-making process, as such, if small occupiers do not agree with the owner, they can only choose to "vote with their feet," that is, to terminate the contract and move out. Based on the above analysis, the influences of occupancy types on the green retrofit decisions at the initial phase must not be overlooked.

Finally, existing studies mainly focused on the effects of cost, energy saving, and comfort on green retrofit (Stephan and Menassa, 2014). However, some other factors likewise play important roles in green retrofit decisions, such as reputation enhancement, risk reduction, and transaction costs. In particular, some large-scale companies attach significant importance to reputation and risk. According to our interview, public influence and reputation enhancement are assigned the highest priority in the green retrofit project of China Recourse Headquarter in Hong Kong, which was completed in 2012.

The abovementioned limitations present difficulties in understanding why the existing identified reasons would result in the reluctance to implement green retrofit in the industry. To mitigate such deficiency, this study aims to reveal the underlying logic of industry's reluctance to conduct green retrofit by analyzing the behaviors of owners and occupiers at the initial phase. This study differs from the previous ones in that it explores the behaviors of the direct decision makers under current market constraints through game analysis, rather than identifying the willingness of the stakeholders or retrofit-related problems through survey. The factors affecting the behaviors of these decision makers, including economic, environmental, and social factors, in the short and long terms are systemically analyzed and selected based on the literature review. Game theory is used to model the behaviors of the owners and occupiers under different occupancy types. The results of this study are critical to the analysis of the feasibility of a building retrofit and may serve as a foundation for formulating more energy efficiency strategies and policies.

3 Methodology

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3.1 Research design

To fulfill the research aim, this study is conducted with four procedures, which are demonstrated in Figure 2.

First, this study identifies the research problem and research gap through the literature review. The relevant literature asserts that, a key problem in promoting green retrofit is the low motivation and engagement of people even under incentive policies. To determine the reasons underlying this problem, this study limits the research scope to the owners and occupiers at the initial phase. The behaviors of these decision makers are specified in Sections 1 and 2.

Second, this study analyzes the main possible influential factors of green retrofit decisions by conducting literature review and expert interview. A series of semi-structured interviews are conducted with 19 experts from Hong Kong and Mainland China, who have participated in green retrofit projects as project manager, designer, facility manager, contract manager, contractor, and third-party consultant authorized by the government to audit projects. The analysis results are discussed in Section 2.

Third, the identified problem in reality is mapped to a theoretical model by game theory. Most owners and occupiers prefer to show their positive attitudes rather than reluctance towards green retrofit to the public. This condition explains why the major cases in the existing studies are successful retrofit projects. Constrained by such realities, we adopt game theory to investigate the research question using theoretical model and logical deduction rather than an empirical study. The data for the game analysis are primarily obtained from the existing studies and interviews about real cases. This process is useful in overcoming the shortages of limited data as a relative value rather than absolute value that is needed in the game analysis. The probable decisions of the owners and occupiers under the three occupancy types are discussed in Sections 4 to 6.

Finally, the result interpretations and uncertainty discussion are presented in Section 7. The conclusions and limitations of this study are emphasized in Section 8.

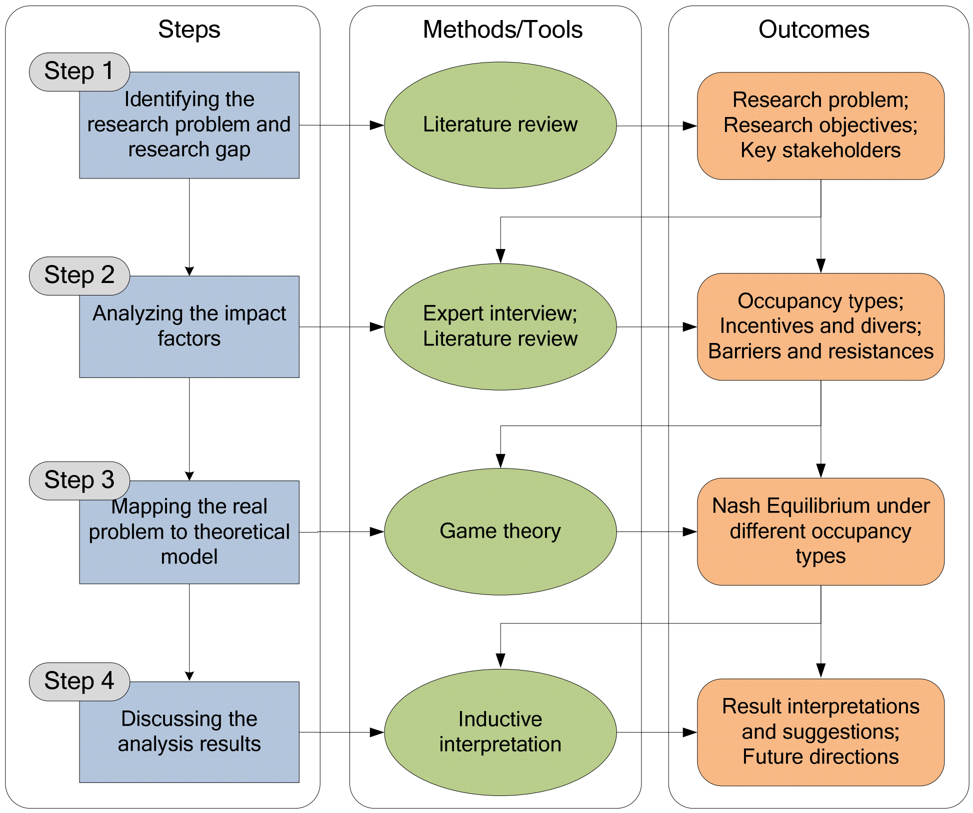

Figure 2 Schematic of research process

3.2 Game theory

Game theory is used to model the decision behaviors of owners and occupiers in green retrofit. Previous studies have determined that many owners and occupiers intend to implement green retrofit, but only a few can reach a consensus and continue its implementation. Although other methods can be used to identify the reasons behind the actions, game theory focuses on players' different actions influenced by the actions of other players. In the beginning of green retrofit, owners and occupiers, as key decision makers, are interdependent and have different interests on the issue. For example, when the owners intend to administer green retrofit to improve their social reputation or to reduce maintenance cost, they have to consider the rent contracts with occupiers. On the contrary, when the occupiers want to implement green retrofit to save energy cost, they have to consider the attitudes of the owners. Thus, the final green retrofit decision depends on the actions of both the owners and occupiers. In this case, game theory can be adopted to analyze the strategies of both parties.

The results of the game theory analysis presented in this paper can provide causal and solid proof for green retrofit decisions.

Game theory was established to identify the optimal solutions for economic behaviors (Von Neumann and Morgenstern, 1945). Nash (1950) developed a definition of an "optimum" strategy for multiplayer games. This strategy, which is well-known as the "Nash Equilibrium", indicates that every player cannot obtain a benefit by changing his or her own action; thus, the equilibrium is stable (Healy, 2006). Nash equilibrium, which is a type of game theory, is generally used to analyze the competition or collaboration problems between two decision makers, such as the prisoner's dilemma (Fudenberg and Tirole, 1991). Three basic elements exist in game theory (i.e., player, strategy, and payoff). A player, who assumes absolutely rational self-interest, is an individual participant in the decision-making of strategic choices. Strategy is the choice or action of a player, that can either be a pure or mixed strategy in certain probabilities. Payoff is the interest that a player accrues by adopting a strategy (Peng et al., 2014). Payoffs, which are quantitative, are normally described by a payoff matrix to illustrate the interest of a player based on all decisions.

Game theory is widely used in research related to sustainable development and green building, particularly with regard to the relationship among the stakeholders and their decision making. Gu et al. (2009) analyzed the strategies for energy-efficient housing developments with game theory by integrating four players, namely, the administration, the developers, the architects, and the inhabitants. The study identified several crucial issues in energy-efficient building development and indicated that achieving the energy efficiency objective is difficult if the actions of all the players are based on their respective rational self-interest (Gu et al., 2009). However, this conclusion is relatively general and is not based on a concrete analysis of relationships and interests. Some studies have specified and quantified the interest of the players in games (Li et al., 2011; Mohsenian-Rad et al., 2010). Li et al. (2011) proposed a game theory model to analyze the energy-saving building market in China through a game of customers and developers, whose interests were calculated quantitatively. Game theory has also been used to evaluate and simulate energy consumption (Mohsenian-Rad et al., 2010; Soliman and Leon-Garcia, 2014). However, the existing studies based on game theory are primarily for new energy efficiency building rather than for green retrofit. To elaborate the use of game theory in this study, the research problem definition are presented in the following sub-section.

3.3 Problem definition

The problem of developing a strategy on green retrofit is defined as a non-cooperative game between the owners and occupiers of the existing buildings. The critical elements for the game analysis are specified below.

1) Players: Two players are involved in the game, namely, the owner and the occupier, as elaborated in Section 2.1.

2) Strategies: In general, the owner is the entity who establishes the initiative to retrofit and provides the initial retrofit plans. However, the occupiers have become increasingly active in green retrofit projects in recent years. Given that numerous buildings have been retrofitted over the past few years, the successful experiences have attracted the occupiers because of the learning effect. In 2015, 81 occupiers actively raised 16 million CNY to finish the green retrofit project in the International Trade Center of Shenzhen, China (Xiao, 2015). Therefore, both the owner and occupier in this game have two strategies, namely, "initiative to retrofit" and "reluctant to retrofit." The former strategy is initiative to conduct green retrofit, whereas the latter is the resistance to the implementation of green retrofit but keeps regular operation.

3) Payoffs: The payoffs of owners and occupiers depend on their respective strategies, which are shown in the payoff matrix in Figure 3. $B_{ow11}, B_{ow12}, B_{ow21}$, and B_{ow22} represent the benefits of an owner under different strategies, whereas $B_{oc11}, B_{oc12}, B_{oc21}$, and B_{oc22} represent the benefits of an occupier.

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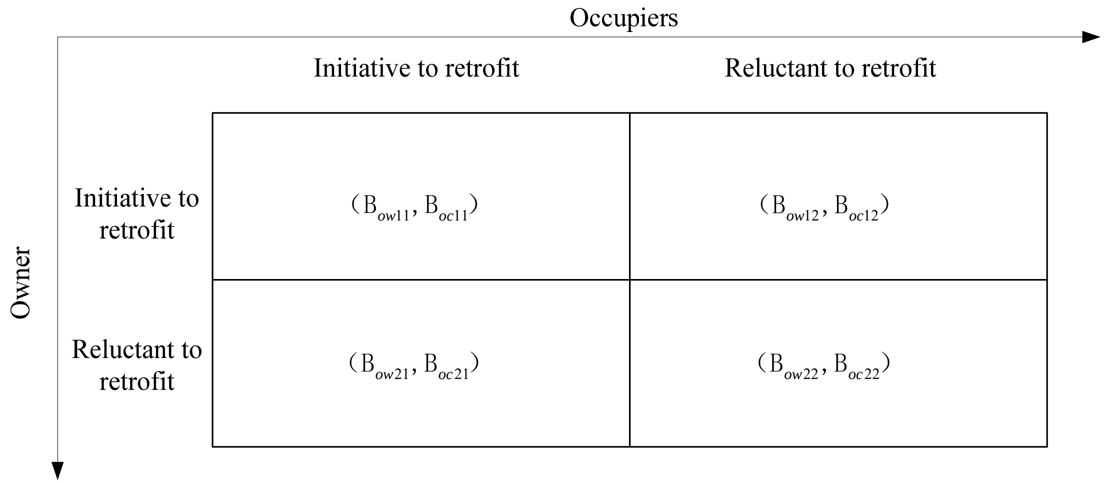

Figure 3 The payoff matrix of retrofit strategy for owner and occupier

4 Retrofit decision for owner-occupied building

The owner-occupied building is first discussed, because it is the simplest occupancy type and can be used as a baseline. In this type of building, the occupiers also own the building, and they can make retrofit decisions by themselves without negotiation. The income of the owners comes from the energy cost saving, maintenance cost saving, building value increase, and public impact. The costs are the retrofit investment and operation disturbance. The rent, occupancy rate, and turnover rate are not considered in this owner-occupied situation. These variables are described in Table 3. The column of "Driver/Barrier" shows the corresponding relation between the variables and the drivers or barriers illustrated in Tables 1 and 2. This study assumes that the decision to retrofit depends on the benefits that the decision makers can reap from retrofit. Therefore, non-economic factors, such as the lack of building information (BOW6) and lack of retrofit experience (BOW7), are not considered in this analysis. The subsidies and tax reduction (DOW3) are not included in the variables, because the model focuses on the retrofit decisions without market interventions. In fact, the Chinese government only provides incentive funds for the energy-efficiency retrofit of the residential buildings in the northern heating area of China (Zhou et al., 2010) and of the public buildings in a few pilot cities. Most areas are not funded by government, a condition that is consistent with this model. The risks of retrofits (DOW5/BOW6) are likewise not considered in this analysis, which are discussed in Section 7.3.

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Table 3 The variables of decision in owner-occupied building

Stakeholder	Variable	Definition	Driver/Barrier
Owner	B_{ow}	benefit of a building owner	$D_{OW}1/4$
	S_e	energy saving through green retrofit	$D_{OW}4$
	S_o	operation saving through green retrofit	$D_{OW}2$
	ΔV	building value increase through green retrofit	$D_{OW}7/8$
	ΔP	public impact through retrofit	$D_{OW}9/10/11$
	I	investment of building retrofit	$B_{OW}1/2/3$
	D	disturbance of business during retrofit	$B_{OW}4$

B_{ow}^{oo} can then be calculated with the following formula, where the superscript "oo" represents the owner-occupied condition:

$$B_{ow}^{oo} = S_e^{oo} + S_o^{oo} + \Delta V^{oo} + \Delta P^{oo} - I^{oo} - D^{oo} \quad (1)$$

All variables represent the life cycle value, which is an efficient method in conducting an economic analysis of the building retrofit issues (Ouyang et al., 2011). Various factors may influence the decision making of retrofit in different levels. The factors related to the direct economical profit, such as I^{oo}, D^{oo} and S_e^{oo}, may be considered as the high priority; otherwise, they are regarded as the relatively low priority (e.g., ΔP^{oo}). The difference among these factors depends on specific projects and on the evaluation of the owners. When $B_{ow}^{oo} > 0$ in this owner-occupied scenario, the owners can benefit from the green retrofit and will choose it as the strategy. Otherwise, the green retrofit will not be implemented. The building owners and occupiers in this scenario have no game, because the decision is made only by the owners.

5 Retrofit decision for single-occupied building

In the scenario of a single-occupied building, two players, namely, the owner and the single occupier, are in the game for green retrofit decision making. The advantages and disadvantages of the green retrofit for the owner are the economic aspects and social influences of the process. The economic aspects include the operation cost saving from green retrofit, building value increasing, and investment. The social influences pertain to the reputation of a company, enterprise social responsibility, environmental impact, and other factors related to the society. To confirm the preliminary proposal and decide on the implementation, the owner and the occupier must communicate and negotiate with each other, which may cost time, money, and human resource. In addition to the factors illustrated in Section 4, the increasing rent and coordination costs are the influencing factors for owners in this scenario.

For single occupiers, the advantages and disadvantages of green retrofit pertain primarily to the economic aspects and social influences. Economic aspects include energy cost saving from green retrofit, rent increase, and disturbance of business during the retrofitting. Social influences are the same as the social factors of the owners. Different from the scenario of an owner-occupied building, the rent and disturbance of the business during the retrofitting is accrued to the occupiers rather than to the owners. These variables are described in Table 4. The non-economic factors, such as comfort enhancement ($D_{OC}3$), lack of understanding or interest about environment ($B_{OC}4$) and lack of information ($B_{OC}5$), are not considered.

Table 4 The variables of decision in single-occupied building

Stakeholder	Variable	Definition	Driver/Barrier
Owner	ΔR	increased rent by retrofit	$D_{OW}1/5$
	C_c	coordination cost for retrofit	$B_{OW}1$
Occupier	B_{oc}	benefit of building occupier	$D_{OC}1/2$
	S_e	energy saving through green retrofit	$D_{OC}1$
	ΔR	increased rent through retrofit	$B_{OC}1$
	D	disturbance of business during retrofit	$B_{OC}2$
	ΔP	public impact through retrofit	$D_{OC}4$

The payoff matrix for the owners and occupiers in a single-occupied building is shown in Figure 4, where the superscript "so" represents the single-occupied condition.

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Owner \ Occupier	Initiative to retrofit	Reluctant to retrofit
Initiative to retrofit	$B^{so}_{ow11}=S^{so}_{o11}+\Delta V^{so}_{11}+\Delta R^{so}_{ow11}+\Delta P^{so}_{11}-I^{so}_{11}-C^{so}_{11}$ $B^{so}_{oc11}=S^{so}_{e11}+\Delta P^{so}_{11}-D^{so}_{11}-\Delta R^{so}_{oc11}$	$B^{so}_{ow12}=S^{so}_{o12}+\Delta V^{so}_{12}+\Delta P^{so}_{12}-I^{so}_{12}-C^{so}_{c12}$ $B^{so}_{oc12}=S^{so}_{e12}+\Delta P^{so}_{12}-D^{so}_{12}$
Reluctant to retrofit	$B^{so}_{ow21}=S^{so}_{o21}+\Delta V^{so}_{21}+\Delta P^{so}_{21}$ $B^{so}_{oc21}=S^{so}_{e21}+\Delta P^{so}_{21}-D^{so}_{21}-I^{so}_{21}$	$B^{so}_{ow22}=0$ $B^{so}_{oc22}=0$

Figure 4 The payoff matrix for owner and occupier in single-occupied building

Based on this adapted matrix, the following scenarios are investigated to identify the Nash Equilibrium under the single-occupied condition.

The action of the occupier when the owner has the initiative to retrofit

Green retrofit can be implemented smoothly when the owner has the initiative to implement the approach and the occupier is also interested in it. The occupier should be willing to pay additional rent to the owner to compensate for additional costs of implementing green retrofit (Fuerst and McAllister, 2011). This scenario occurs mostly in government and large private organizations, where sustainable development is considered an essential factor in building selection (Miller and Buys, 2008). The occupier tends to pay additional rent ΔR^{so}_{oc11}. In cases where the owner decides to implement green retrofit but the occupier is reluctant, green retrofit can still be implemented because the owner is the main decision-maker. The reluctant occupier, as a large organization, cannot move out because of the long rental contract and high relocation cost, but could take the position of non-cooperation. Given the strong influence of the owner's income and profit, the single occupier will have relatively high negotiation capacity and will not pay additional rent ΔR or other alternative compensations to the owner when he/she does not want to cooperate in green retrofit during the contract period. To sum up, regardless of the initiative of the occupier to implement green retrofit, green retrofit is implemented only if the owner wants to.

The benefit and cost of green retrofit are similar in two conditions, but the difference is whether an increment exists in rent after retrofit. According to previous case studies, rent, price, and occupancy rate of a building are positively related to its green feature, as shown in Table 5. Therefore, this study assumes that green retrofit could raise building value (Miller and Buys, 2008), occupancy rate, and rent (Thomas, 2010). The key information can be summarized as follows:

$$S_{e11}^{so} + \Delta P_{11}^{so} - D_{11}^{so} \approx S_{e12}^{so} + \Delta P_{12}^{so} - D_{12}^{so} \quad , \quad \Delta R_{oc11}^{so} \geq 0 \tag{2}$$

Referring these data to the formula in the Figure 4, the matrix reveals that:

$$S_{e11}^{so} + \Delta P_{11}^{so} - D_{11}^{so} - \Delta R_{oc11}^{so} \leq S_{e12}^{so} + \Delta P_{12}^{so} - D_{12}^{so}, \tag{3}$$

$$\text{or } B_{oc11}^{so} \leq B_{oc12}^{so} \tag{4}$$

Table 5 The premium of rent, value and occupancy rate in green buildings

Literature	Rental Premium	Value Premium	Occupancy Rate Premium
Miller et al. (2008)	9%	No Premium	2-4%
Eichholtz et al. (2010)	3.3%	1.9%	NA
Pivo and Fisher (2010)	2.7%	8.5%	NA
Wiley et al. (2010)	7-17%	NA	10-18%
Fuerst and McAllister (2011)	4-5%	25-26%	1-3%

According to Formula (4), the occupier should choose “reluctant to retrofit” or non-operation if the owner has the initiative to implement green retrofit.

The action of the occupier when the owner is reluctant to retrofit

If both the owner and the occupier are reluctant, the building operates without the innovation. Thus, neither cost nor profit exists according to green retrofit, that is, $B_{oc22}^{so} = 0$. In the situation where the owner is reluctant and does not want to invest, but the occupier is active in sustainable development, the occupier can choose to invest in the retrofit project. The single occupier is mainly a large organization that has high economic strength to support green retrofit (Miller and Buys, 2008). In addition to economic strength, the single occupier generally has a long rental contract, which makes possible for reaping returns on investment to cover the retrofit cost. However, the costs of retrofit, which are investment I_{21}^{so} and disturbance of business during retrofit D_{21}^{so}, are short term and definite, whereas the profits of retrofit, which are energy cost saving S_{e21}^{so}, and public impact ΔP_{21}^{so}, are long term and uncertain. In addition, energy saving S_{e21}^{so} is not reliable because of the contract period. Rent contract may be terminated in several years, which means the occupier can only obtain S_{e21}^{so} for several years rather than for the whole life cycle of a building. Specifically, the duration of reaping profit may be shorter than payback time. Given that most investors are often reluctant to take challenges (Rhoads, 2010), they tend to assign more weight to certain cost in the short term than to uncertain profit in the long term. The key information can be summarized as follows:

$$S_{e21}^{so} + \Delta P_{21}^{so} - D_{21}^{so} - I_{21}^{so} \leq 0, \quad B_{oc22}^{so} = 0 \tag{5}$$

namely, $B_{oc21}^{so} \leq B_{oc22}^{so}$ (6)

According to Formula (6), the occupier should choose “reluctant to retrofit” when the owner is reluctant to green retrofit because of the risk in payback period.

Based on Formulas (4) and (6), the best interests of the occupier are served by the “reluctant to retrofit” action regardless of the action the owner takes, which means “reluctant to retrofit” is the dominant strategy for the occupier(Myerson, 2013). Therefore, the action of the owner is discussed in the following section based on the situation where the occupier is reluctant to retrofit.

The action of the owner when the occupier is reluctant to retrofit

As mentioned earlier, if the owner and the occupier are reluctant to green retrofit, then green retrofit is not implemented, and the owner obtains neither cost nor profit, such that $B_{ow22}^{so} = 0$. If the occupier is not interested in green retrofit but the owner has the initiative in the approach, then it can be implemented without the cooperation of the occupier, as discussed in the previous section. Under this condition, the owner cannot reap certain and direct payback from increased rent ΔR, but can only obtain uncertain, long-term, and indirect profit from green retrofit, such as operation cost saving S_{o12}^{so}, building value increase ΔV_{12}^{so}, and public impact ΔP_{12}^{so}. By contrast, investment I_{12}^{so} and coordination cost C_{c12}^{so} are certain, short-term and direct, and are thus considered important by the owner because of the risk-adverse characteristic (Rhoads, 2010). The key information can be summarized as follows:

$$\mathrm{S}_{o12}^{so}+\Delta V_{12}^{so}+\Delta P_{12}^{so}-\mathrm{I}_{12}^{so}-C_{c12}^{so} \leq 0, \quad \mathrm{B}_{oc22}^{so}=0 \tag{7}$$

namely, $\mathrm{B}_{ow12}^{so} \leq \mathrm{B}_{ow22}^{so}$ (8)

According to Formula (8), the owner should choose “reluctant to retrofit” when the occupier is reluctant to green retrofit.

The preceding analysis in Formula (8) reveals that, in a single-occupied building, the occupier chooses “reluctant to retrofit” regardless of what the owner chooses, and the owner is reluctant to retrofit to guarantee his or her interests. Hence, the Nash Equilibrium for the owner and the single occupier is “reluctant to retrofit,” and “reluctant to retrofit,” respectively. Given that a multi-occupied building is another common occupancy type, a comparative study is discussed in the next section.

6 Retrofit decision for multi-occupied building

Given that each occupier is an independent economic entity in this scenario, the owner must play games with each occupier individually. The occupiers have similar scales, costs, and benefits, and thus their decisions should not be significantly different. Therefore, occupiers are considered homogeneous in the game. The game can be abstracted with two players, namely, owner and homogeneous occupiers. This study does not focus on the differences of occupiers, and the cooperation and games among occupiers are not included as well.

Different from single-occupied condition, numerous occupiers exist in a multi-occupied building. In this condition, occupancy is relatively small scale and has a high turnover rate. Therefore, the owner is dominant in the relationship. Occupiers are powerless in negotiation

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and can only choose to "vote with their feet," which means relocating to another building. Relocation raises additional costs for occupiers and owner in terms of relocation cost and turnover cost respectively. Table 6 describes these additional costs.

Table 6 The variables of decision in multi-occupied building

Stakeholder	Variable	Definition	Driver/Barrier
Owner	C_t	turnover cost of owner	$B_{OW}1/4$
Occupier	C_r	relocation cost of occupier	$B_{OC}6$

Other advantages and disadvantages of green retrofit are similar to those of the condition of single-occupied building. The payoff matrix for owners and occupiers in multi-occupied buildings is shown in Figure 5, where the superscript "mo" represents the multi-occupied condition:

Owner \ Occupiers	Initiative to retrofit	Reluctant to retrofit
Initiative to retrofit	$B^{mo}_{ow11}=S^{mo}_{o11}+\Delta V^{mo}_{11}+\Delta R^{mo}_{ow11}+\Delta P^{mo}_{11}-I^{mo}_{11}-C^{mo}_{c11}$ $B^{mo}_{oc11}=S^{mo}_{e11}-D^{mo}_{11}-\Delta R^{mo}_{oc11}$	$B^{mo}_{ow12}=S^{mo}_{o12}+\Delta V^{mo}_{12}+\Delta R^{mo}_{ow12}+\Delta P^{mo}_{12}-I^{mo}_{12}-C^{mo}_{t12}-C^{mo}_{c11}$ $B^{mo}_{oc12}=-C^{mo}_{r12}$
Reluctant to retrofit	$B^{mo}_{ow21}=-C^{mo}_{t21}$ $B^{mo}_{oc21}=-C^{mo}_{r21}$	$B^{mo}_{ow22}=0$ $B^{mo}_{oc22}=0$

Figure 5 The payoff matrix for owner and occupier in multi-occupied building

Based on this adapted matrix, the following scenarios can be investigated to identify the Nash Equilibrium under the multi-occupied condition.

The action of the owner when the occupier has the initiative to retrofit

In a situation where the owner does not want to invest on retrofit, but the occupiers want to, a single occupier does not have enough economic capabilities or influential power to implement the approach. Therefore, if the active occupiers cannot reach consensus with the reluctant owner and cannot implement retrofit by themselves, they can only choose to "vote with their feet," which raises the turnover cost for the owner C_{t21}^{mo}. However, this turnover cost does not increase significantly because small companies consider cost and location as the dominant factors for building selection (Rhoads, 2010). If occupiers are interested in green retrofit, they will support it and pay additional rent to the owner to compensate for the additional costs (Fuerst and McAllister, 2011). Under this condition, the owner can reap a direct payback from the increased rent ΔR_{ow11}^{mo} as compensation for the investment. However, the owner must pay the coordination cost to raise the rent. Coordination cost C_{c11}^{mo} is proportional to the number of occupiers. The cost is very high when numerous occupiers, various contracts, and different rental periods exist (Rhoads, 2010), namely, $\mathrm{C}_{c11}^{mo} >> 0$. The key information can be summarized as follows:

$$\mathrm{S}_{o11}^{mo} + \Delta V_{11}^{mo} + \Delta R_{ow11}^{mo} + \Delta P_{11}^{mo} - \mathrm{I}_{11}^{mo} - \mathrm{C}_{c11}^{mo} \le 0\,, \quad -\mathrm{C}_{t21}^{mo} \approx 0 \tag{9}$$

$$\text{namely,} \quad \mathrm{B}_{ow11}^{mo} \le \mathrm{B}_{ow21}^{mo} \tag{10}$$

According to Formula (10), the owner should choose "reluctant to retrofit" when the initiative of the occupiers is to engage in green retrofit.

The action of the owner when the occupier is reluctant to retrofit

If both owner and occupiers are reluctant to green retrofit, then it is not implemented. The owner obtains neither cost nor profit, such that $\mathrm{B}_{ow22}^{mo} = 0$. When the occupier is not active in green retrofit but the owner is, the approach can be implemented without the cooperation of some reluctant occupiers. If some occupiers cannot reach consensus with the owner, they will move out, which results in turnover cost C_{t12}^{mo} for the owner. Generally, occupancy rate and rent per unit increase after green retrofit (Ma et al., 2012; Thomas, 2010). Thus, even though some occupiers move out because of retrofit, the owner can reap increased rent ΔR_{ow12}^{mo} from the new occupiers. However, high occupancy rate in the future and high rent from a new occupier is an indirect and long-term benefit for the owner. Other profits of retrofit, including operation cost saving S_{o12}^{mo}, increased building value ΔV_{12}^{mo}, and public impact ΔP_{12}^{mo}, are long term and uncertain. By contrast, the costs of retrofit are short term and definite. The risk-adverse investor does not want to take challenges to compare uncertain interests with specific costs. The key information can be summarized as follows:

$$S_{o12}^{mo} + \Delta V_{12}^{mo} + \Delta R_{ow12}^{mo} + \Delta P_{12}^{mo} - I_{12}^{mo} - C_{t12}^{mo} - C_{c12}^{mo} \leq 0, \quad B_{ow22}^{mo} = 0 \tag{11}$$

$$\text{namely,} \quad B_{oc12}^{mo} \leq B_{oc22}^{mo} \tag{12}$$

According to Formula (12), the owner should choose “reluctant to retrofit” when the occupier is reluctant to green retrofit.

According to Formulas (10) and (12), the best interests of the owner are served by the “reluctant to retrofit” action regardless of the action occupiers take; thus, “reluctant to retrofit” is the dominant strategy for the owner(Myerson, 2013). Therefore, the action of the occupiers is only discussed in the following section based on the situation where the owner is reluctant to retrofit.

The action of the occupier when the owner is reluctant to retrofit

If both owner and occupier are reluctant to green retrofit, the building is operated without green retrofit. Thus, neither cost nor profit exists according to green retrofit, such that $B_{oc22}^{mo} = 0$. As mentioned previously, if occupiers want to implement green retrofit but the owner does not, the approach is not implemented, and the active occupiers move out, which incurs relocation fee C_{r21}^{mo}. The key information can be summarized as follows:

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$$\mathrm{S}_{e21}^{so} + \Delta P_{21}^{so} - D_{21}^{so} - I_{21}^{so} \leq 0\,,\ \ \mathrm{B}_{oc22}^{mo} = 0 \tag{13}$$

namely, $\mathrm{B}_{oc21}^{so} \leq \mathrm{B}_{oc22}^{so}$ (14)

According to Formula (14), the occupier should choose “reluctant to retrofit” when the owner is reluctant to green retrofit.

Based on the above analysis, the Nash Equilibrium for the owner and the occupiers is “reluctant to retrofit” and “reluctant to retrofit,” respectively, under the multi-occupied condition. This conclusion is consistent with two cases in China, which were studied through interviews conducted in October 2014. One case is the Jin Bin Teng Yue Building, an office building in Guangzhou, China. The building is occupied by about 400 tenants. The owner had the initiative to implement energy-efficient lighting in public areas. The negotiation with the tenant committee and tenants with opposite opinions took almost half a year. The facility managers complained that despite the small-scale of this green retrofit project, coordinating required from them a considerable amount of time. The other case is the Electronic Technology Building in Shenzhen, China, which is a commercial building used for the wholesale selling of electronic products. The building has more than 1000 tenants, many of whom occupy areas less than 10 m^2. This building has yet to be green retrofitted. The facility managers stated they had considered green retrofit, but they had to give up the idea because coordinating more than 1000 tenants was extremely difficult.

7 Discussion

Under the owner-occupied condition, owners can decide by themselves based on Formula (1). However, under the single and multi-occupied conditions, the Nash Equilibrium is “reluctant to retrofit” and “reluctant to retrofit” owing to the interaction between the owners and occupiers at the initial phase. Such reluctances explain the lack of enthusiasm for green retrofit in the industry. Figure 6 illustrates the mechanism of game theory analysis under three different occupancy types. The major reasons and issues are discussed below.

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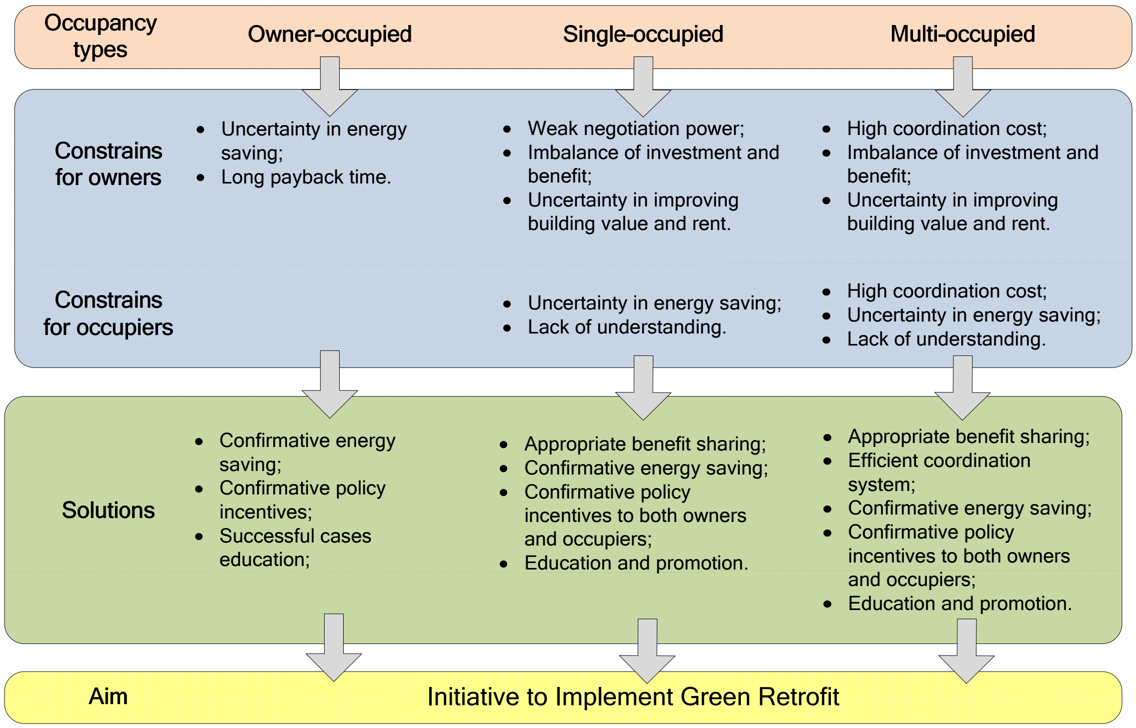

Figure 6 The mechanism of game theory analysis under three different occupancy types

7.1 Differences among occupancy types

The difficulty level of green retrofit is strongly related to the occupancy type of a building. First, the compensation of investment on green retrofit varies according to different occupancy types. In owner-occupied buildings, owners can obtain benefits directly from the green retrofit through low energy consumption. However, in single or multi-occupied buildings, investment of owners in green retrofit will not guarantee direct energy savings. In these conditions, the owners may be rewarded primarily in three other ways, namely, higher rents, lower holding costs and lower risk (Fuerst and McAllister, 2011), compared to owner-occupied buildings. Retrofit benefits are transferred via the first way from tenants to owners. In other words, the green retrofit projects are partly and indirectly funded by the occupiers. The second way, lower holding costs, refers to lower maintenance cost and longer operation time until the next retrofit. The last way involves avoiding premature obsolescence, policy changing, and risk associated with the future increase in energy cost. Among these three rewarding ways, higher rents may be the most direct and promising way to cover costs and earn profits. Risk is difficult to quantify. Low holding cost may not be realized due to new technologies and human maintenance behaviors during long operation periods. Thus, if owners cannot obtain direct energy saving benefits, then they will pursue higher rents or other kinds of direct economic compensation from occupants. In single-occupied buildings, the single occupier is generally a large organization that has a long rental contract. If the occupier is reluctant to retrofit, raising rent ΔR_{ow}^{so} in the short term after retrofit will be difficult. In multi-occupied buildings, the occupiers are in relatively small scale and have short contracts with owners. Hence owners can raise rent ΔR_{ow}^{mo} to compensate for the retrofit cost in the short term.

Second, the coordination cost of green retrofit relies on occupancy type. Coordinating with occupiers about the green retrofit decision takes time and incurs labor and economic costs on the part of the owners. Coordination cost C_c is positively related to the number of occupiers N_{oc}, that is, $C_c \propto N_{oc}$. In owner-occupied buildings, owners do not need to coordinate with occupiers; thus $C_c = 0$. In single-occupied buildings, negotiations are conducted with only one occupier. Therefore, the coordination cost is low, that is, $C_c \approx 0$. In multi-occupied buildings however, coordination cost is high enough to be emphasized, that is, $C_c >> 0$, because there are numerous occupiers with various contracts, which increases the difficulty of negotiating.

Third, the occupancy rate, turnover cost of the owner, and relocation cost of the occupier are different among occupancy types. In the owner-occupied condition, owners do not need to consider the occupancy rate and turnover cost, that is, $C_t = 0$. In the single-occupied condition, the single occupier affects the occupancy rate considerably. If the single occupier moves out, the turnover cost should be high to the owner and the relocation cost should be high to the occupier, that is, $C_t >> 0, C_r >> 0$. Therefore, the single occupier has a strong negotiating power and will not choose to terminate the contract even if the opinion differs with that of the owner. In the multi-occupied condition, turnover and relocation costs are much lower than those in the single-occupied condition. From the long-term perspective, the occupancy rate can be improved by green retrofit (Fuerst and McAllister, 2011), which will likewise raise the rent.

7.2 Split incentives between owners and occupiers

Owners and occupiers are most likely to have conflicting opinions on green retrofit decisions because the former usually invests in green retrofit projects but various benefits (e.g., energy saving, health, and productivity improvement, etc.) will be reaped by the latter. This imbalance between investment and benefit, which will hinder cooperation between owners and occupiers, is an essential problem in green retrofit decisions.

Green retrofit projects can be invested in three ways, namely, 1) owner funded, 2) occupier funded, and 3) third-party financing (Rhoads, 2010). The third situation is related to external influence, which is not considered in this study. Occupiers may not stay in one building for a long time, which makes investments in green retrofit projects risky. Hence, owner funding is the primary financing type in practical green retrofit projects, except when the occupier has enough economic capability and long rental contract.

Green retrofit is supposed to improve energy efficiency and save energy cost. Who benefits from saving cost is related to the type of rental contract. "Net rental contract" indicates that tenants pay the energy bill and will benefit from energy savings. "Gross rental contract" indicates that owners pay the energy bill and will benefit directly from energy savings. The former is more common than the latter because it can result in low operating costs (Fuerst and McAllister, 2011). Clearly, based on net rental contracts, the primary beneficiary of green retrofit is the occupier who pays the energy bills. When a building is not owner-occupied, this benefit, however, cannot provide direct incentives that could motivate an owner to invest in green retrofit projects.

Several cases have demonstrated that owners and occupiers stand at different points with split incentives and interest conflicts. Menassa and Baer (2014) conducted a case study of a bachelor quarters building at Naval Station Great Lakes in the US. Their results indicated that the priorities of the retrofit requirements are significantly different between owners and occupiers. The difference rate is from -36% to 76%. Table 7 summarizes the most different requirements. Given these split incentives, an appropriate investment and return distribution system is highly needed for green retrofit promotion (Fuerst and McAllister, 2011).

Table 7 The most different requirements between tenants and owners

Requirements	Rating of tenants	Rating of owners	Difference
Reduce costs of carbon offset	3	1.7	76%
Leverage business platforms	3.8	2.2	73%
Improve occupant health	4.3	3	43%
Improve occupant attendance	4.2	3	40%
Avoid costs due to opposition	2.8	2	40%
Lower project capital costs	2.7	4.2	-36%

Source:Menassa and Baer (2014)

7.3 Uncertainty of green retrofit

Another essential issue for green retrofit is uncertainty, which can be analyzed from the following perspectives. First, although numerous studies have emphasized that green retrofit will improve energy efficiency (Caccavelli and Gugerli, 2002; Mickaityte et al., 2008; Rey, 2004), others have put forward opposing opinions. Newsham et al. (2009) indicated that 28%–35% of energy-certified buildings use more energy than their conventional counterparts. Scofield (2009) likewise found that the energy savings of certified buildings are not significantly different from those of comparable buildings. Thus, after green retrofit, and even with certification as LEED, realizing energy savings in operation remains uncertain, such that S_e-D-I<0.This finding implies that owners and occupiers may not obtain direct benefit from retrofit.

Second, other researchers have questioned the opinion that green retrofit will increase building value (Miller and Buys, 2008) and occupancy rate (Fuerst and McAllister, 2011). Many organizations lack understanding of or interest in the environment (Davies and Osmani, 2011), especially small organizations that consider location and cost as the most dominant factors in building selection rather than sustainable factors. Based on the former analysis, green retrofit may result in a higher rent, which may reduce the occupancy rate. Thus, realizing higher building value and occupancy rate after green retrofit is uncertain. Although green retrofit can achieve positive results in relation to building value and occupancy rate, calculating the results quantitatively is difficult because of various influencing factors (Rhoads, 2010).

Third, most owners and occupiers lack experience and understanding of green retrofit (Davies and Osmani, 2011; Kasivisvanathan et al., 2012), including the processes (Ali et al., 2008), the available technologies (Miller and Buys, 2008) and the information on existing buildings (Menassa, 2011). Additionally, green retrofit involves more complex design analysis, more intense interdisciplinary collaboration (Lapinski et al., 2006) and more stakeholders (Davies and Osmani, 2011) than regular retrofit. These factors may intensify uncertainty in decision making for green retrofit.

Last, the payback period of green retrofit is relatively long (Kasivisvanathan et al., 2012; Menassa, 2011). In a long payback period, numerous uncertain factors may affect the success of green retrofit, such as related polices, interest rate, technology progress, and environmental change. These uncertain factors may cause decision makers to be more cautious and bring negative influences on green retrofit.

8 Conclusions

Although green retrofit has been emphasized by the academia and improved by the government for more than a decade, such approach has yet to be pursued widely in industries. Inspired by this phenomenon, this research analyzed green retrofit from the perspective of a game between owners and occupiers, who are the key decision makers on whether to retrofit or not during the initial phase. Occupancy types were classified into three categories, namely, owner-occupied, single-occupied (not by owner), and multi-occupied. After comparing the costs and benefits of green retrofit for owners and occupiers, the payoff function was proposed under owner-occupied condition, and payoff matrixes were proposed under single and multi-occupied conditions. Green retrofit decisions in owner-occupied buildings are relatively easy to make, whereas implementing green retrofit under the other two conditions is difficult, because the Nash Equilibrium is “reluctant to retrofit” and “reluctant to retrofit” for owners and occupiers, respectively.

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This research contributes to the understanding of the reluctance of industries implement green retrofit despite their interest in the approach. The main reasons and issues of this problem are occupancy types, split incentives, and uncertainty of green retrofit. Green retrofit is mainly invested in by owners, but the direct benefit of energy cost saving is reaped by occupiers. Hence, this outcome negatively affects the motivation of owners. Owners can obtain investment compensations from high rent and other benefits from increased occupancy rate, building value, and reputation because of green retrofit. However, the long payback period of green retrofit suggests that benefits to owners are indirect and uncertain.

This research can help policymakers in understanding the reasons for this problem and in finding appropriate solutions. For example, to overcome split incentives, some profits, such as redistributed mechanisms, can be adopted to improve the implementation of green retrofit. Energy-saving profit can be redistributed through some form of compensations between owners and occupiers, as well as among other stakeholders, such as energy service companies. However, balancing profits is difficult for stakeholders who have conflicting interests. To relieve uncertainty, the government can launch incentive policies, such as subsidies and tax reduction to strengthen profit and shorten payback time. This can guarantee positive benefits from green retrofit. Other methods, such as training and experience sharing, can likewise reduce uncertainty because these methods can enhance the understanding of green retrofit. Compared with new green buildings, green retrofit in occupied buildings is much more difficult due to the higher level of risk and uncertainty derived from occupiers. Occupiers are the direct decision makers, and their behavior can significantly influence energy consumption (Desmedt et al., 2009; Liang et al., 2016). However, most current policies focus on owners rather than on occupiers, which highlights the need for future policies that can pay due attention to occupiers.

Nonetheless, this study has some limitations. This study is mainly a theoretical study with logical deduction rather than empirical study. This is caused by lack of effective data and real cases to model the reluctance behavior of owners and occupiers at the initial phase. Several case studies were conducted to verify the conceptual model in this study. Future studies may focus on applications in industry, using surveys to identify and compare the willingness of owners and occupiers to initiate green retrofit under different occupancy types. Based on the willingness investigations and implications of this study, appropriate policy mechanisms could be designed for industry application. Future studies can also implement simulations to verify the theoretical decision behaviors of owners and occupiers. In addition, it should be noticed that this study assumes a static game analysis, which is useful to understand the underlying logic and most likely decisions. However, green retrofit is undertaken in a dynamic world. Therefore, future studies should use a dynamic game analysis to model the decision behaviors of owners and occupiers, which may further deepen our understanding.

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