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A Thematic Review of Elevator Retrofitting in China's Ageing Communities: An Evolutionary Game Theory Approach

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Abstract: China's rapid population ageing collides with a legacy of mid-rise walk-ups built without elevators, creating a persistent mobility barrier and a classic coordination problem within buildings. Using evolutionary game theory (EGT) this thematic review synthesizes evidence on how incentives, rules and learning dynamics shape cooperation over time and advances a proposed cooperative evolutionarily stable strategy (ESS) for elevator retrofitting. This thematic review examines how incentives, rules and learning dynamics shape cooperation over time through reviewing international and Chinese databases (2015–2025), screened studies using pre-specified inclusion/exclusion criteria and extracted variables on players, strategies, payoff construction and policy instruments as findings were synthesized via thematic analysis aligned to EGT constructs (players, strategies, payoff matrices, replicator dynamics and evolutionarily stable strategies). Four themes emerged including (i) asymmetric payoffs by floor position and negative externalities facing lower floors bias outcomes toward stalemate, (ii) calibrated government intervention including subsidy thresholds, majoritarian voting rules and transparent compensation reconfigures payoffs and enables coalition building, (iii) governance and implementation matter as empowered neighborhood committees, staged procedures and pay-per-use financing reduce transaction costs and household risk, (iv) diffusion effects are clear as visible completions raise perceived benefits and lower perceived risks in adjacent estates which accelerates adoption. The reviewed evidence identifies a gap in the monetary valuation of externalities, city-comparable compensation formulas and post-installation governance indicating the need for multi-stage models that extend beyond the vote. Based on identified finding's, recommendations for future policies include bundling instruments rather than rely on a single lever, legislate lifecycle obligations (sinking funds tied to title), publish standard, floor-indexed cost-sharing and compensation schedules grounded in observable impacts, resource community intermediaries to mediate and verify and seed high-visibility demonstration projects to harness social learning making cooperation both attractive and durable.

Keywords: Elevator Retrofitting; Evolutionary Game Theory; Cooperative ESS; Ageing Communities; Urban Governance; Policy Bundles.

1. Introduction

An apparent demographic transition towards a rapidly aging population in China is colliding with a specific feature of its urban legacy according to Li et al., (2024), specifically the vast number of multi-storey residential buildings constructed without elevators during the explosive growth of the 1980s and 1990s. A significant and growing proportion of the nation's elderly especially within established urban centers now inhabit these six-to-seven-story structures, as this combination of demography and architecture presents a stark social challenge where a vertical mobility barrier severely constrains the daily lives of older residents (Zuo et al., 2025). For many, what should be the simple act of leaving home becomes a formidable physical ordeal, effectively rendering them trapped upstairs (Chu & Shu-guang, 2022). Moreover, such a predicament directly reduces the national policy goal of "aging in place" according to the vision centered on facilitating the elderly to live with dignity and independence in their own communities (Zhang et al., 2021). Recognizing the apparent importance of this issue, the Chinese government has responded at the highest levels with key policy documents including the national "Government Work Report" to repeatedly propose the retrofitting of elevators in existing residential buildings as a critical "livelihood project" (Zuo et al., 2025). However, this initiative is framed as far more than a matter of convenience as it is positioned as a key component of the social welfare infrastructure, for which has become vital for enhancing the quality of life for millions and adapting the urban dynamics to an aging society's needs (Lin & Cui, 2021). Therefore, this policy imperative is arguably unambiguous and requires ongoing efforts to effectively bridge the critical gap between the nation's existing built environment and the accessibility requirements of its residents.

2. Current Problems and Challenges

Despite clear policy directives, Guo et al. (2023) contend that implementing elevator retrofitting projects is fraught with conflict, particularly regarding interest balancing and dispute resolution, as observed in Tianjin, China. At its core lies a starkly asymmetrical distribution of costs and benefits, creating a fundamental social dilemma within a single building (Tang & Li, 2022). Upper-floor residents gain significant convenience, eliminate the need for stair climbing and experience enhanced property valuation thereby becoming the primary beneficiaries (Zhang et al., 2024). On the other hand, lower-floor residents experience minimal direct advantages, instead, they often endure tangible burdens like continuous machinery noise, increased shadows from the

structure, heightened corridor traffic and prolonged construction disruption (Çelik et al., 2017). These factors can diminish their property's relative value as this significant disparity rationally reinforces their resistance leading to a classic social dilemma (Larsen & Nyholt, 2024). The collision of individually rational strategies like fervent advocacy from high-floor residents against staunch opposition from ground-floor occupants results in a collectively irrational outcome (Fang et al., 2023; Lim et al., 2025), as no elevators are built and the mobility needs of the elderly remain unaddressed.

This challenging scenario filled with competing interests of stakeholders makes retrofitting an ideal subject for game theory analysis, as the official approach to resolving this issue has significantly evolved which mirrors broader shifts in China's urban governance philosophy (Kochan, 2015). Earlier rigid policies which often required near-unanimous resident consent, effectively granted any single dissenting household veto power (He et al., 2023) and this predictably led to widespread project paralysis and growing frustration. Moreover, this failure also prompted a major policy re-evaluation as cities such as Shanghai and Beijing began to remove these impediments by reducing voting thresholds to more practical majorities, like the "double two-thirds" rule. Beijing's innovative "three-step" method also exemplifies this transition towards a more pragmatic, facilitative state role (Zhang, 2002; Zhao et al., 2021). This represents a substantially more dynamic challenge than simply procedural adjustment as it signifies a fundamental re-engineering of the government's function in community disputes whereby the state is shifting from a top-down enforcer of an unworkable ideal, such as unanimity, to a strategic facilitator. Through establishing new "rules of the game" via mechanisms like majority voting, financial subsidies and supportive legal frameworks, it empowers communities to overcome the "tyranny of the minority" and in this context, the elevator dilemma has become a critical proving ground for a new, more responsive model of grassroots governance.

3. Research Rationale and Structure

This systematic review aims to critically synthesize and evaluate the academic literature that applies evolutionary game theory (EGT) to the persistent social dilemma of elevator retrofitting in China. Given the challenging context where these projects often face paralysis due to disputes among residents with conflicting interests, EGT offers an ideal theoretical framework for comprehending the strategic interactions that evolve over time. Consequently, the primary objective of this study is to investigate how existing EGT models elucidate the dynamics of cooperation, conflict and negotiation. Through this examination, the review seeks to gain deeper insights and a comprehensive understanding of the factors that either facilitate or impede successful outcomes, ultimately pinpointing the policy levers most effective at resolving negotiation impasses. To achieve this, the report will logically guide the reader through an inquiry that begins by establishing the theoretical framework, justifying the selection of EGT and reviewing its application in comparable social contexts. Subsequently, we will detail the systematic review protocol that underpins our analysis, specifying the research questions, search strategy and criteria for literature selection. The core of the paper will then present a synthesis of the findings organized into key themes and will outline the key elements of these game-theoretic models including the players, their payoffs and the significant impact of various policy interventions. In the conclusion, we will summarize the most valuable insights and propose a suite of evidence-based policy recommendations designed to inform future governance strategies.

4. Literature Review

4.1. Evolutionary Game Theory (EGT) on Urban Governance

This review employs evolutionary game theory as its foundational analytical framework to comprehensively model the highly dynamic and multi-stakeholder negotiations inherent in elevator retrofitting projects. EGT offers a distinct advantage over classical game theory by relaxing the assumption of perfect rationality, instead, it is predicated on the principle of bounded rationality asserting that individuals make decisions based on incomplete information, learn from past experiences and imitate the successful strategies of others (Camerer, 2025). This methodological approach is particularly well-suited for contexts involving community governance where decisions do not arise from isolated, static interactions but rather emerge through a dynamic, iterative process characterized by negotiation, social learning and continuous adaptation over time (Hakiman & Sheely, 2023). Most importantly, a core tenet of EGT is its emphasis on the dynamic evolution of strategies within a population rather than seeking a singular Nash equilibrium, EGT models how the prevalence of various strategies shifts across successive rounds of interaction (Yue et al., 2023). Strategies yielding higher returns tend to proliferate while those with diminished efficacy gradually decline as this dynamic evolutionary process is mathematically articulated by replicator dynamics, furnishing a robust framework for simulating the progression of an interacting agent system towards a stable state (Lim & Capraro, 2021). This population-level, learning-oriented perspective accurately reflects real-world scenarios where residents' perspectives are shaped by ongoing dialogues, the outcomes of analogous projects in other communities and evolving governmental policies.

4.2. Empirical EGT Applications and Relevance

A growing body of empirical studies confirms that evolutionary game theory provides a suitable analytical framework for understanding multi-stakeholder challenges within China's urban development and construction sectors (Li et al., 2025; Su & Zhang, 2025; Wang et al., 2023). While these investigations do not explicitly focus on elevator retrofitting, they nevertheless clarify analogous coordination difficulties among public authorities, private enterprises and end-users. Furthermore, they clarify how incentive structures, monitoring mechanisms and learning dynamics collectively shape the trajectory towards collaborative outcomes (Yu & Huang, 2019). Cumulatively, these studies offer both methodological precedents and pragmatic insights pertinent to dissecting the "elevator dilemma" as research examining promotion models for green buildings identified clear strategic interactions occurring among governmental entities, developers and households (Zhao et al., 2025). A consistent pattern observed across diverse contexts reveals that when reward and sanction frameworks are credible and appropriately calibrated, developers tend to adopt higher standards and consumers exhibit a greater willingness to incur associated costs (Zhao et al., 2025). In essence, public policy

recalibrates the landscape of potential outcomes as cooperative behaviors proliferate once the anticipated benefits of compliance demonstrably outweigh those of non-compliance (Zhao et al., 2025). The direct applicability of this principle to elevator retrofitting is clear as financial inducements such as subsidies, rebates and targeted support can influence decisions towards installation and acceptance. Moreover, studies on supervision within construction safety introduce a cautionary perspective as tripartite models involving government agencies, general contractors and supervision engineers suggest that overly prescriptive intervention may inadvertently diminish the autonomy and accountability of other participants (Qin & Zheng, 2024).

Additionally, effectiveness is enhanced when oversight is rigorous but proportionate, thereby preserving scope for professional monitoring and localized problem-solving, as for elevator retrofits, this implies that public authorities should delineate clear regulations and allocate resources, while concurrently avoiding the suppression of building-level negotiations and self-governance initiatives (Chever & Klien, 2017). Thus, work related to the recycling of construction and demolition waste addresses a classic free-rider predicament between entities involved in material production and recovery. In this domain, two primary levers are found to be most influential including the extent of financial subsidies and the perceived probability of regulatory enforcement. When both factors are established at meaningful thresholds, non-compliance becomes economically disadvantageous, thereby stabilizing cooperative recycling norms (Su et al., 2020). This analogy extends to multi-owner buildings with mixed interests where certain residents may disproportionately benefit from the contributions of others, whereby in such scenarios it is required to carefully designed incentives can secure participation or offer compensation to those who perceive fewer direct private gains (Hua et al., 2023). Finally, analyses of the elevator insurance market which encompass government, insurers and operational units suggest that both subsidies and penalties exert influence on supply and demand, steering outcomes towards stable participation equilibria (Bo et al., 2023). This research stream demonstrates that policy instruments possess the capacity to organize behavior at the point of initial installation as well as across the entire operational ecosystem of elevators (Langer & Lemoine, 2022). The aforementioned research consensus conveys a consistent message for retrofitting initiatives as it is key to align payoffs through credible incentives and judicious oversight, as well as to preserve the integral roles of intermediate stakeholders and to anticipate the emergence of cooperation when the long-term advantages of collective action are both salient and enforceable.

4.3. Key Theoretical Constructs for the Review

To ensure coherence in the analysis this review integrates fundamental constructs from evolutionary game theory, firstly, 'players' are defined as the autonomous decision-making entities and within the scope of elevator retrofitting, these encompass residents residing on both higher and lower floors, municipal authorities and when applicable, elevator service providers or property management companies. Secondly, 'strategies' represent the array of choices accessible to each participant for instance residents are commonly presented with a dichotomous decision between collective action and resistance, whereas governmental bodies might opt for subsidization or abstention, or implement regulation versus non-intervention, similarly, firms have the option to invest or decline. Thirdly, the 'payoff matrix' systematically quantifies the outcomes of these strategic interactions by allocating costs and benefits to every permutation of available strategies. This aspect is particularly important as it demonstrates the underlying incentive structures and consequently predicts how behavioral patterns might evolve in response to shifts in policy variables. The fourth component 'replicator dynamics,' models the temporal evolution of strategy prevalence, illustrating how agents adjust their approaches based on comparative payoffs such as strategies demonstrating superior performance relative to the average are likely to proliferate while underperforming strategies gradually diminish. Finally, the notion of an 'evolutionarily stable strategy' signifies a state of equilibrium, characterized by a behavioral configuration that resists displacement by minor deviations, thus constituting a robust and practical steady-state outcome. Through integrating and synthesizing these theoretical constructs, this review frames elevator retrofitting as a multi-player game where policy mechanisms and socio-cultural factors determine payoffs, as these payoffs in turn impel adaptation, which subsequently produces outcomes ranging from sustained deadlock to successful implementation with subsequent feedback influencing future decision cycles as shown in the proposed conceptual framework for this study in figure 1.

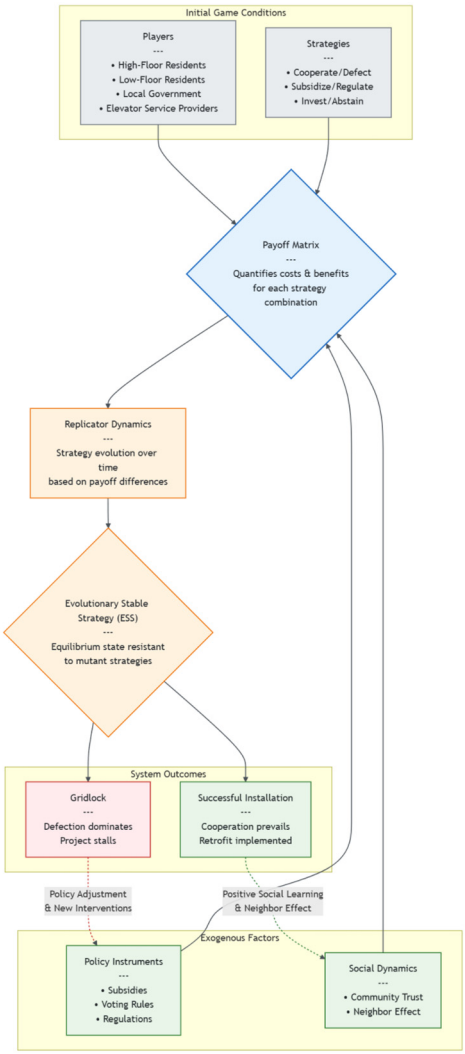

Figure 1. conceptual framework (Author, 2025)

(This figure illustrates the conceptual framework for the

systematic review. The central game involves four key players: high-floor residents, low-floor residents, the government and elevator service providers. Their strategic choices interact within a payoff matrix, which is shaped by external policy instruments (e.g., subsidies, voting rules) and social dynamics (e.g., community trust, neighbor effects). The resulting payoffs drive the evolution of strategies over time, as described by replicator dynamics. This process leads to an Evolutionary Stable Strategy (ESS), which manifests as a real-world outcome, either gridlock or successful installation. Crucially, these outcomes create feedback loops: successful projects can generate positive social learning that influences future games, while persistent gridlock may prompt further policy adjustments from the government, making the entire system dynamic and adaptive.)

5. Methods & Review Protocol

5.1. Research Questions (RQs)

This systematic review is guided by four primary research questions designed to deconstruct and synthesize the application of EGT to the elevator retrofitting problem:

- **RQ1:** Who are the key players, what are their strategic choices and what are the core assumptions (bounded rationality) in EGT models of elevator retrofitting and analogous urban public goods projects in China?
- **RQ2:** How do these models construct the payoff matrices? What specific economic, social and political parameters (installation costs, property value premiums, government subsidies, compensation payments, negative externality costs) are quantified to determine strategic outcomes?
- **RQ3:** What specific policy instruments (changes in voting thresholds, subsidy structures, compensation schemes, innovative financing models) are modeled as interventions and how do they mathematically alter the replicator dynamics of the system?
- **RQ4:** What are the identified evolutionary stable strategies (ESS) under different policy scenarios and what are the critical thresholds (minimum subsidy level, required compensation ratio) needed to shift the system from a non-cooperative to a cooperative equilibrium?

5.2. Search Strategy

The scope of this review encompasses both international and Chinese sources to comprehensively capture scholarship available in English and Mandarin, international searches will be conducted across Web of Science, Scopus, SpringerLink, ScienceDirect and Taylor & Francis Online. For Chinese scholarship, searches target the China National Knowledge Infrastructure and Wanfang Data. All databases are searched from their inception up to the final search date without restrictions on publication status. Conference papers and early-view articles indexed within these databases are included if their full texts are accessible. A Boolean strategy is developed and tailored to the syntax of each database using controlled vocabulary where available and free-text terms elsewhere. Search strings are constructed in both English and Mandarin to maximise retrieval as the core English template combines the methodological lens with the policy domain and the geographical scope as follows: ("evolutionary game theory" OR "replicator dynamics") AND ("elevator retrofitting" OR "elevator installation" OR "urban renewal" OR "community governance" OR "public goods") AND ("China" OR "Shanghai" OR "Beijing"). The Mandarin template follows similar concepts: (Evolutionary game) AND (Elevators are installed in old buildings OR Elevators should be added to existing residential buildings OR Urban renewal OR Community governance) AND (China). Field tags, proximity operators and truncation are adapted per database to balance recall and precision as reference lists of included studies and closely related reviews will be hand-searched to identify additional records. All retrieved citations are exported to a reference manager for de-duplication prior to screening.

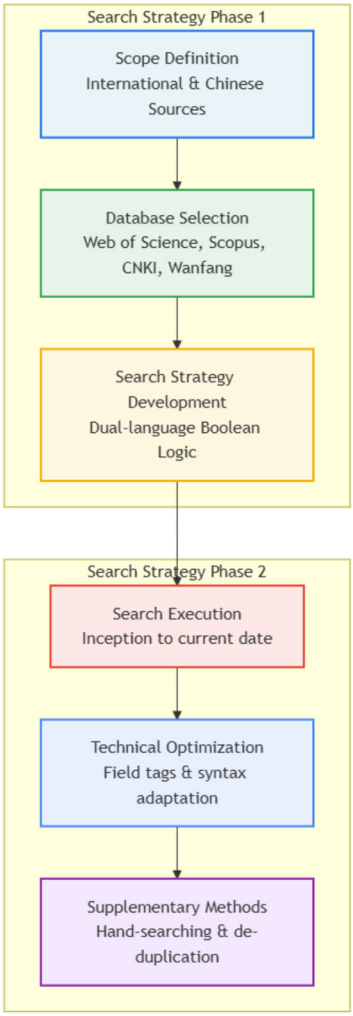

Figure 2. Search strategy for this review (Author, 2025)

5.3. Inclusion and Exclusion Criteria

To enhance the rigor of this review, predefined inclusion and exclusion criteria were systematically applied to make sure that selected studies conceptually aligned with evolutionary game theory and demonstrated substantive relevance to elevator retrofitting initiatives in China as summarised in table 1. Studies were deemed eligible if evolutionary game theory served as their primary analytical framework, typically evidenced by the incorporation of dynamic update rules such as replicator dynamics, imitation or learning processes or an explicit examination of evolutionary stability. Substantive relevance necessitated either a direct focus on the installation of lifts in existing

Chinese residential buildings or a comparable collective-action problem within Chinese urban governance, such as green retrofit programs or the renewal of communal infrastructure involving shared financing and consent mechanisms. To uphold evidential quality and facilitate parameter utility, the review encompassed peer-reviewed journal articles, high-quality conference proceedings from recognized venues and official government documents providing sufficient detail on policy parameters for model calibration. To reflect contemporary policy evolution and modeling practices, the temporal scope was restricted to studies published from 2015 up to the final search date. Conversely, studies were excluded if they relied solely on static game-theoretic formulations without an evolutionary or dynamic component, or if they constituted descriptive case studies or survey reports lacking a formal game model. Outputs concentrating purely on engineering or architectural design without modeling social decision processes were also excluded, alongside editorials, book reviews, news items and other non-peer-reviewed sources; news articles were only considered permissible for documenting factual policy dates or program launches when absolutely necessary.

Table 1. Inclusion and exclusion criteria

Type	Criterion	Operational definition	Rationale	Examples / notes	Screening evidence required
Inclusion	EGT as primary framework	The study builds and analyses an evolutionary or dynamic game (e.g., replicator dynamics, stochastic learning, imitation dynamics) as the central method.	Ensures relevance to strategy adaptation over time rather than static equilibria only.	Replicator ODEs, ESS, agent learning, multi-population EGT.	Model section explicitly states EGT or presents dynamic update equations.
	Domain relevance: elevator retrofits or analogous Chinese urban public goods	Focus on retrofitting lifts in existing residential buildings in China OR a closely parallel collective-action problem in Chinese urban governance (e.g., green retrofits, community infrastructure renewal).	Maintains topical focus while allowing transfer of comparable mechanisms.	Green building subsidies, neighborhood retrofit cost-sharing, communal facility upgrades.	Context section describes Chinese setting and the specific public-good mechanism.
	Publication type and quality	Peer reviewed journal article, high quality conference proceeding, or official policy document with parameter detail.	Assures credibility and usable parameterization for synthesis.	Indexed conferences, State Council or ministry documents with subsidy rules or consent thresholds.	Publisher information or government source, evidence of review or official status.
	Time window	Published from 2015 to the final search date.	Captures contemporary policy regimes and modelling practice.	Post 2015 elevator retrofit pilots, recent EGT formulations.	Publication date in database record or PDF.
Exclusion	Static game only	Uses classical Nash analysis without dynamic or evolutionary updating.	Does not speak to adoption dynamics or diffusion.	One shot payoff matrix with static equilibrium only.	Absence of dynamics or learning rules in methods.
	Descriptive only without formal model	Qualitative cases, surveys, or narrative reports that discuss retrofits but provide no formal game theoretic model.	Cannot be synthesized within EGT constructs.	Interview studies, non-model policy commentary.	Methods section shows qualitative only approach.
	Purely technical engineering focus	Analyses technical design, construction logistics, or mechanical systems without modelling social decision processes.	Outside scope of stakeholder coordination and incentives.	Lift shaft design, structural reinforcement calculations only.	Technical methods with no socio-economic model.
	Non peer reviewed or non-authoritative sources	Editorials, news, book reviews, or grey literature lacking review, news used only for factual policy dates if necessary.	Limits bias and unverifiable claims.	Media commentary, blogs.	Source type in record, lack of peer review.

5.4. Thematic Analysis

We applied thematic analysis to organize and interpret findings across included studies in a way that was aligned with the evolutionary game theory following Braun and Clarke's (2006) thematic analysis guidelines, we proceeded in six phases and wrote in the past tense throughout our research notes to preserve an auditable trail (Nowell et al., 2017). First, we familiarized ourselves with the material by reading full texts alongside the structured extraction fields for players, strategies, payoff parameters, policy instruments and evolutionary stability conditions. Second, we generated initial codes through line-by-line coding of the results and discussion sections, adapting Thomas and Harden's approach so that descriptive codes mapped to our constructs while allowing inductive additions where studies introduced novel mechanisms or contexts (Thomas & Harden, 2008). Third, we collated codes into candidate themes that captured recurrent patterns in coordination problems and policy levers, such as consent thresholds, cost-sharing fairness, subsidy calibration and learning dynamics. Fourth, we reviewed these themes against the coded extracts and the full evidence set, checking internal coherence and distinctiveness; discrepancies were resolved through analytic memoing and team discussion rather than relying on mechanical agreement statistics, consistent with reflexive thematic analysis (Braun & Clarke, 2019). Fifth, we defined and named themes with brief analytic narratives that stated the central organizing concept and noted

boundary conditions. Finally, we produced the synthesis by linking themes to the EGT model space and to policy implications for elevator retrofitting, highlighting convergence, credible disagreements and gaps. Credibility was enhanced through an explicit codebook, an audit trail of theme revisions and cross-checking of theme assignments across Chinese and international sources (Nowell et al., 2017).

6. Results and Findings

6.1. Characterizing the Players and Their Payoffs

Across recent studies, payoffs are starkly asymmetric and hinge on floor location, subsidy design and the distribution of externalities across households, for high-floor residents, the dominant private return is a resale "premium effect" once a lift is added as hedonic and quasi-experimental studies in Beijing and other large cities document statistically significant appreciation with effects increasing by floor and more pronounced in older, single-aspect stock where a lift most improves access (Ma et al., 2022; Zhang, 2024). These estimates are heterogeneous as premium effects narrow in very high price quantiles and in buildings where baseline accessibility is already good, indicating that high-floor payoffs are context-dependent rather than universal (Zhang, 2024). In contrast, low-floor residents face a different calculus as they bear persistent negative externalities such as loss of daylight and outlook, noise, privacy intrusions and façade shading on top of construction disturbance. Recent simulation and field-based assessments show measurable changes in local microclimate and sound fields under typical retrofit designs, supporting the practice of explicitly monetizing these costs in bargaining and in payoff matrices (Ding et al., 2025; Chen, 2024). Case and policy analyses from Chinese municipalities consistently report that opposition is concentrated on the first and second floors, where shadowing and privacy concerns are greatest as disputes are commonly managed through compensation schedules or design modifications (setbacks, light-well clearance, glass shafts) before consent is secured (Deng, 2022; Xinhua News, 2018).

For the local government, payoffs are chiefly social and political in facilitating ageing-in-place, easing mobility constraints in walk-up estates and signaling responsiveness to demographic change offset by fiscal outlays and administrative burden. Central and municipal communications emphasize elevator retrofitting as a "livelihood project" linking it to wide urban-renewal programs as national reporting cites 2019–2024 improvements across 280,000 old communities with elevator installation a stated priority (State Council, 2025; China Daily/Qiushi, 2025). Municipal subsidy standards are material relative to capital costs as Beijing's current policy provides a substantial per-lift cap and allows complementary instruments (provident-fund withdrawals, maintenance-account use) to lower household shares and reduce up-front frictions (State Council, 2025). Similar logics are visible in Shanghai and Hangzhou pilot practices where local subsidies combine with procedural rules "one household initiates; consensus triggers action" to preserve legitimacy while accelerating delivery (Xinhua News, 2018; Fan, 2021). More broadly, China's green-retrofit regime shows that targeted cash grants and star-rating incentives can shift private returns enough to scale adoption, although fiscal ceilings necessitate careful calibration across programs (Baker McKenzie, 2024; Global Sustainable Buildings Guide, 2024). For elevator service providers (ESPs) and property managers, expected payoffs depend on predictable demand, payment security and portfolio scale where public transfers and building participation reach viable thresholds, firms can price installation and maintenance to yield acceptable returns.

Alternatively, where resident conflict threatens completion or leads to arrears, expected value falls below entry cut-offs (Fan, 2021) as related evolutionary game models in adjacent markets reinforce the mechanism via tripartite games of government–insurer–user participation in elevator insurance show that credible mixes of subsidies and penalties push both suppliers and users toward stable participation equilibria (Zhang, 2024b). Analogous EGT applications in construction and demolition waste (CDW) recycling and construction safety supervision also generalize to the retrofitting dilemma, reward–penalty schemes and higher supervision probabilities curb free-riding and shift populations toward cooperation, whereas overly intrusive state action can crowd out other monitors (Long et al., 2020; Ma et al., 2020; Gong et al., 2021; Ning et al., 2022). Additionally, city-scale spatial studies detect clustering and spillovers in elevator adoption reinforcing peer effects and social learning which suggest that observed successes alter expectations and, therefore, payoffs in neighboring estates over time (Dai et al., 2022).

Table 2. Key parameters in payoff matrices for elevator retrofitting games

Parameter	Description	Unit	Sources
Installation cost	Design, manufacture, civil works, installation; household shared cost before/after subsidy	¥ per lift	State Council (2025); Fan (2021)
Annual maintenance cost	Annual maintenance, electricity, inspection, repair	¥/year	State Council (2025)
Property value gain (premium)	Post-installation property value premium by floor	% or ¥	Ma et al. (2022); Zhang (2024)
Government subsidy/ transfer	Government transfer lowering capital cost	¥ or % of installation cost	State Council (2025); Baker McKenzie (2024)
Compensation paid to lower floors	Side-payments from high- to low-floors to offset externalities	¥ per household	Deng (2022); Chen (2024)
Monetized externalities borne by lower floors	Monetised externalities (light, noise, privacy, thermal) borne by lower floors	% value or ¥	Ding et al. (2025); Chen (2024)
Social welfare/ policy payoff to government	Social welfare/policy payoff to government (ageing-in-place, harmony)	Utility or proxy	State Council (2025); China Daily/Qiushi (2025)
Profit (or NPV) for the elevator service provider	ESP profit margin/NPV conditional on project risk	% of installation cost or ¥	Fan (2021); Zhang (2024b)

It is apparent that the payoff matrix can be parameterized using observed or policy-specified quantities as installation and maintenance costs borne by households, floor-specific value gains, monetized externalities for lower floors, government transfers and consent rules, inter-household compensation; and firm margins (Chen, 2024; Deng, 2022; Xinhua News, 2018).

Cost–benefit exercises and municipal practice also show that settlement depends less on the level of total cost than on the distribution across floors and stakeholder groups, hence the centrality of transparent formulas and consent thresholds in moving buildings from stalemate to agreement EGT-consistent evidence from adjacent policy fields indicates that when governments calibrate subsidy levels and enforcement probabilities to local typologies and when ESPs can scale with predictable cashflows, populations converge toward cooperative equilibria where these levers are weak or misaligned, cycling or defection persists (Long et al., 2020; Ma et al., 2020; Gong et al., 2021; Ning et al., 2022). It is thus apparent that the economics of the payoff matrix drives long-run outcomes, a summary of the key parameters in payoff matrices for elevator retrofitting games is summarized in table 2.

6.2. The Decisive Role of Government Intervention

Across China's retrofit programmes, both evolutionary game models and city-level evidence point to one common trend where calibrated government intervention shifts the payoff matrix and moves buildings from stalemate to cooperation. Instruments that matter most are (i) subsidies and penalties that reduce private cost shares and raise the expected return to cooperation, (ii) decision rules that replace unanimity-style vetoes with qualified majorities, (iii) compensation frameworks that internalise low-floor externalities. When these levers pass city-specific thresholds, cooperative strategies diffuse reinforcing with the concept of evolutionary adjustment under learning and imitation (Cai et al., 2025; Wang et al., 2025). Municipal co-funding directly lowers household capital outlay, dampening free-riding incentives and easing coalition formation among mid- and upper-floor owners as policy and feasibility studies report that predictable caps and eligible-cost definitions reduce bargaining delay and provider risk, especially in older stock (Ouyang, 2025; Chu et al., 2022). Evolutionary models calibrated to China's urban policy contexts show threshold behaviour where below a critical subsidy share or supervision probability defection remains attractive, beyond it, cooperation becomes evolutionarily stable and spreads through the resident population (Cai et al., 2025; Wang et al., 2025). Empirically, subsidy layering (city + district + provident-fund access) has been linked to faster approvals in pilot areas, while weak or volatile support correlates with stalled petitions (Fang et al., 2024; He et al., 2025).

Changing decision rules has also been decisive as cities that moved from near-unanimity to "double two-thirds" or staged approvals materially reduced veto power, Shanghai's reform for example set proposal agreement at two-thirds (by headcount/area) and opened access to housing funds to close financing gaps (China Daily, 2020). Hangzhou's regulation requires two-thirds participation with a supermajority among participants structuring a coalition-building game rather than a unanimity search (Fan, 2021). Moreover, legal analysts attribute persistent delays to legacy "one-vote veto" practices replacing these with qualified majorities realigns incentives and shortens the path to consent (Yang, 2022; Guo, 2023). Beijing's updated operational guidelines similarly formalise willingness consultation, phased approvals and documentation standards to directly increase procedural predictability for all parties (TJXQTY, 2025). As for compensation and cost-sharing, given that first/second floors bear daylight, privacy and noise losses, floor-differentiated cost sharing and side-payments are the main instruments to neutralise the monetized externalities borne by lower floors, as empirical and simulation work quantify reductions in solar irradiation and increases in façade sound levels under common shaft placements with evidence that underpins compensation schedules and design offsets (Ding, 2025; Chen et al., 2025). Case analyses also document litigation risks where compensation is absent or symbolic (Guo, 2023), whereby city casework also demonstrates the importance of transparent formulas: coefficient systems tied to effective floor height or shaft proximity reduce distributive conflict and shorten bargaining cycles (Xining CBA study, 2020). Where formulas are public and anchored in observable impacts, opposition softens and threshold coalitions emerge (Zhou, Liu, & Yang, 2024).

Table 3. Comparative analysis of policy instruments and cost-sharing models in selected Chinese cities

City	Voting threshold policy	Subsidy structure	Typical cost-sharing formula	Compensation mechanism	Sources
Shanghai	Reformed to two-thirds agreement for proposal, staged approvals	City/district cap, access to housing funds permitted	Floor-weighted shares, ground/1st floors often reduced/exempt	Negotiated bands linked to impact	China Daily (2020)
Beijing	Willingness consultation → design → construction, documentation rules	Municipal grants with clear eligible items, administrative guidance	Increasing coefficients by floor height	Direct payments or in-kind adjustments for 1st–2nd floors	TJXQTY (2025), Chu et al. (2022)
Hangzhou	Two-thirds participation, supermajority among participants	City grants, some pilot private-finance models	Percentage escalator by floor, adjustments for shaft placement	Negotiated, community mediation common	Fan (2021), He et al. (2025)
Guangzhou	Community governance rules encourage block-level coordination	District co-funding within budget envelopes	Floor-based coefficients, exemptions for lowest floors	Negotiated, guidance from sub-district offices	Fang et al. (2024)
Xining (case)	Coefficient-based voting and funding proposals	City sharing with resident co-pay	Apportionment coefficient increases with floor	Compensation negotiated per impact metrics	Chen et al., 2020)
Multi-city research	Advocacy-coalition evolution, shift away from "one-vote veto"	Substantial but heterogenous caps	Mix of floor coefficients and exemptions	Formal or ad-hoc compensation to low floors	Deng (2022), Yang (2022), Zhou et al. (2024)

Outside of hard levers, information is also key as studies of Chinese energy/retrofit programmes show that targeted information and peer visibility raise perceived gains and reduce uncertainty about delivery, representing mechanisms that complement fiscal and legal tools in an evolutionary pathway to cooperation (Jia et al., 2021; You et al., 2024). Industry reviews similarly found that demand for retrofits rose after central and local assistance programmes were announced in 2017, with suppliers entering where rule clarity and stable co-funding reduced cash-flow risk (Hitachi Review, 2020). Broader urban-renewal EGT models find that credible reward–penalty mixes plus workable participation rules stabilise cooperative equilibria among government–investor–resident triads, providing a valuable insight that maps neatly onto the elevator dilemma (Wan et al., 2022; Sustainability Tripartite Game, 2023). As a whole, intervention works when the bundle is calibrated including adequate subsidy shares, qualified-majority voting and compensation that meaningfully offsets externalities. Where any one element is weak, gridlock persists and where all three are tuned to local building typologies and fiscal capacity, cooperation becomes the dominant strategy and spreads across estates (Fang et al., 2024; Ouyang, 2025; Zhang, 2021).

(This comparative analysis reveals that while the general policy tools are similar, their specific implementation is highly localized. This variation provides a rich empirical basis for testing the predictions of EGT models and understanding which policy configurations are most effective at resolving the elevator dilemma.)

6.3. The Need for Evolutionary Stable Strategy (ESS) with Implications on Governance and Social Dynamics

Across China's retrofit experience the literature points to a clear target for policy design under a cooperative evolutionarily stable strategy (ESS) in which the dominant profile is *Install* (residents), *Accept* (lower floors) and *Subsidize* (government). Importantly, this state does not arise on its own as it is engineered by shifting payoffs until cooperation becomes the best response that resists invasion by defection and remains stable under social learning. Three components are required, first, government subsidy must clear a local threshold and in evolutionary-game terms, transfers need to move a decisive mass of residents especially mid-floor households from negative or marginal net benefits to strictly positive expected returns. Modelling work on urban-renewal tripartite games in China shows exactly this threshold behaviour, whereby when it's below a critical grant share or supervision probability defection remains attractive and when above it, cooperation becomes the population attractor with diffusion via learning and imitation (Zhu, 2022; Li et al., 2022; Wang et al., 2025). Empirical analyses and feasibility studies for elevator additions further emphasise that predictable caps and clear eligible-cost rules shorten bargaining and reduce strategic delay (Chen, 2024; Li, 2019; Chu et al., 2022). In payoff terms, raising the government subsidy does two things simultaneously as it lowers the installation cost borne by households and, by improving perceived deliverability, it increases the expected property value gain for upper floors.

Secondly, compensation must neutralise the externality cost for lower floors where daylight loss, privacy intrusion and noise are credible concerns, floor-differentiated cost shares and side-payments change the sign are critical of the low-floor payoff from negative to at least neutral are critical for eliminating blocking coalitions and allowing a cooperative equilibrium to stabilise (Li et al., 2022; Li et al., 2024). Simulation and case reporting around typical shaft placements (including glass and offset designs) explain why quantifiable changes in solar access and façade exposure provide a defensible basis for compensation schedules that residents perceive as fair, unlocking approvals that would otherwise stall (Chen, 2024; Ding, Li, & Zhao, 2025). Thus, when compensation meaningfully offsets the externality cost, opposition falls and coalitions can form around installation. Thirdly, majoritarian rules must replace vetoes with coalition building as moving from unanimity-style requirements to qualified majorities reconfigures expected returns to obstruction. When proposal and approval stages require two-thirds by headcount and by area (or staged supermajorities among participants), the expected payoff to persistent defection falls because opponents no longer hold absolute vetoes (Dai et al., 2022; Li et al., 2022). In the evolutionary frame, this rule change raises the marginal influence of supportive mid-floors and increases the probability that their cooperation is pivotal—thereby encouraging strategy switching and accelerating convergence.

The same models reflect undesirable but locally stable equilibria, whereby if the government subsidy is weak or volatile, compensation is symbolic and unanimity norms linger, *Oppose/Do-not-subsidize* can lock in as a "gridlock ESS". A second possibility is a low-level equilibrium where approvals inch forward under pressure or pilot quotas but unresolved distributional resentment later surfaces in maintenance non-payment like sustained defection in a different stage of the game (Li, 2019; Chen, 2024). Therefore, the policy task is to apply enough evolutionary pressure, credible rewards and enforcement, workable decision rules and real compensation to push the system out of these basins of attraction and into the cooperative ESS (Zhu, 2022; Li, Zhang, & Wang, 2022; Wang et al., 2025). However, financial levers are necessary but not sufficient as Chinese evidence shows that implementation models, intermediaries and social diffusion materially change effective payoffs. The classic owner-led, self-financing approach imposes high coordination and cash-flow burdens as newer pay-per-use arrangements where a third-party funds installation and recovers costs per ride convert a lumpy capital decision into a low-stakes operating choice. In Hangzhou pilots, the one-yuan-per-ride model was introduced precisely to bypass financing deadlocks and make cooperation feasible in older estates with many pensioners (Elevator World News, 2021; Fan, 2021). When interpreted through the payoff matrix, pay-per-use lowers the installation cost at the household level and, by reducing up-front risk, increases expected cooperation rates, it also improves expected profit for the elevator service provider by stabilising cash flow.

When considering the role of intermediaries and stakeholders, real-world interactions are mediated by neighbourhood committees, owners' congresses and property managers as studies of community governance in China found that these actors provide negotiation platforms, validate information and most importantly resolve conflicts, as they lower transaction costs that otherwise keep groups in defection (Li et al., 2024; Fang et al 2024). From an evolutionary perspective, intermediaries increase the rate and

accuracy of belief updating, accelerating convergence to cooperation when policy parameters are "nearly" sufficient. In terms of neighbour effects and social learning, decisions are not independent across buildings as spatial analyses for Hangzhou identify significant clustering where nearby successful retrofits raise the probability of subsequent approvals in adjacent grids, echoing the principles of social learning and updated expectations about value, disruption and bureaucratic risk (Dai et al., 2022). Broader Chinese urban-renewal research finds similar diffusion patterns as visible completions update priors about returns and delivery risk, raising the perceived property value gain for fence-sitters and, in effect, tilting the payoff matrix without additional cash (Wu et al., 2024; Li et al., 2025). For providers, these same successes reduce perceived default risk and improve expected profit for the elevator service provider, further reinforcing the cooperative path (Wang et al., 2025).

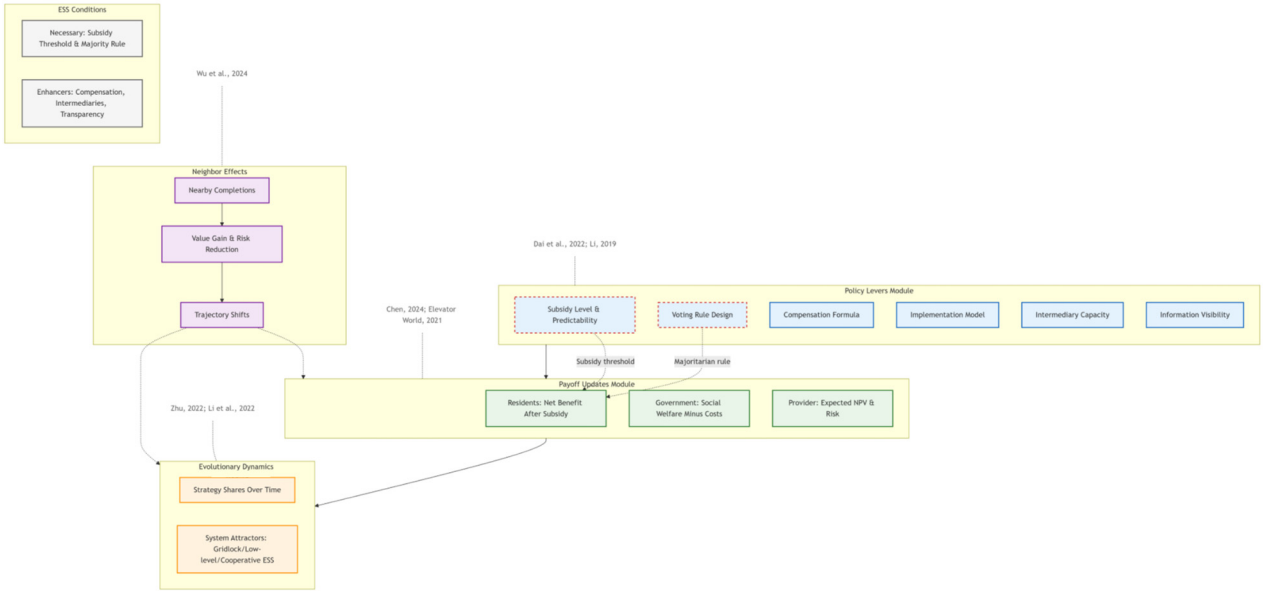

Figure 3. Proposed evolutionary stable strategy (Author, 2025)

(This figure represents the proposed evolutionary stable strategy mapping the causal pathways from policy interventions through economic incentives to evolutionary outcomes in multi-stakeholder elevator retrofitting, illustrating how strategic policy design transforms resident and provider payoffs to shift system dynamics from gridlock toward cooperative equilibrium with neighbor effects and institutional conditions moderating these transitions.)

7. Conclusion and Recommendations

Through the application of the evolutionary game theory, the Chinese experience with elevator retrofitting is best understood as a path-dependent, institutionally mediated coordination problem in which asymmetric payoffs by floor height create a default bias toward non-cooperation and in which government policy must therefore do more than subsidise hardware. It must also reshape beliefs, bargaining processes and the informational environment that governs how strategies diffuse over time. The empirical literature consistently records sizeable benefits for upper floors alongside persistent disamenities for lower floors ranging from daylight reduction and privacy loss to noise and construction disturbance so that the initial payoff matrix already privileges obstruction unless the state intervenes to lower household installation costs, limit veto opportunities and compensate those most affected (Ma et al., 2022; Deng, 2022; Guo et al., 2023). Against this background, official designation of elevator addition as a "livelihood project" and the shift from unanimity requirements toward majoritarian rules represent, we argue, a substantive re-engineering of the game rather than a mere procedural tweak, because predictable subsidy caps alter expected returns while staged approvals and "double two-thirds" voting reshape the marginal influence of pivotal mid-floor households, thereby accelerating the transition from scattered advocacy and entrenched opposition to coalition formation (Xinhua News, 2018; State Council, 2025; Zhao et al., 2021). Equally, the emergence of pay-per-use pilots that convert lumpy capital outlays into low-stakes operating payments lowers the entry barrier for pension-heavy buildings and stabilises cash flows for service providers and when these financial and procedural innovations meet visible successes in nearby estates, spatial diffusion effects become apparent as residents update priors about value uplift, disruption risk and administrative reliability, thereby shifting local trajectories toward cooperation with fewer additional fiscal inputs (Fan, 2021; Dai et al., 2022).

At the same time, the review identifies conceptual and empirical gaps that if left unaddressed, risk overstating the precision of current policy guidance and understating the role of institutions that sit between rules on paper and behaviour in practice. Many studies that motivate policy design borrow reward–penalty structures from adjacent domains like green building promotion, construction safety and construction-and-demolition waste recycling where evolutionary models have shown that appropriately calibrated incentives and credible supervision can shift populations toward cooperative strategies. However, portability is not automatic because elevator retrofits combine within-building externalities, floor-indexed private gains and property-rights frictions that complicate direct transfer of parameters and stability results (Long et al., 2020; Ma et al., 2020; Gong et al., 2021; Ning et al., 2022). Parameterisation itself remains uneven while installation cost, subsidy ceilings and premium estimates are increasingly reported, the monetisation of negative externalities and the calibration of compensation schedules

are thin, heterogeneous and rarely anchored in common measurement protocols which weakens both cross-city comparability and the credibility of bargaining formulas during implementation (Chen, 2024; Ma et al., 2022; Zhang, 2024). Moreover, the dominant modelling horizon stops at the installation decision, even though field evidence shows that cooperation can unravel in the operational phase through maintenance arrears, renewed noise complaints or governance fatigue, suggesting that a myopic focus on the "yes/no" vote may mischaracterise the long-run stability of outcomes (Guo et al., 2023). Finally, decision-rule reform is typically treated as an exogenous toggle, yet the effectiveness of "double two-thirds" depends on the mundane but decisive capacities of neighbourhood committees, owners' congresses and property managers to stage agendas, validate information and broker compensation; absent these transaction-cost reducers, the same formal rule can produce far slower convergence and greater post-approval contention, an institutional nuance repeatedly observed in the governance literature and policy commentaries (Li et al., 2024; Kochan, 2015).

Overall, these findings imply a research and policy agenda that foregrounds bundles rather than single levers, heterogeneity rather than averages and process design rather than blunt transfers whereby in practice, cooperative equilibria stabilise when predictable subsidy envelopes rise above local thresholds, when majoritarian and phased decision rules convert veto power into coalition arithmetic without eroding legitimacy and when compensation bands transparently neutralise externalities for lower floors in ways that residents recognise as fair, yet the durability of those equilibria depends on the presence of intermediaries that compress transaction costs and on the visibility of nearby completions that feed social learning (Deng, 2022; Zhao et al., 2021; Dai et al., 2022). We therefore contend that next-generation evolutionary models for this domain should (i) extend beyond the vote to a multi-stage system that includes operation and maintenance, allowing for strategy drift when post-installation grievances emerge; (ii) incorporate institutional channels explicitly giving neighbourhood committees and property managers distinct strategies and cost functions rather than treating them as background conditions; (iii) couple building-level dynamics to spatial diffusion, so that a successful installation in one estate shifts the perceived payoff structure next door without further subsidy, thereby aligning theory with observed clustering. For policymakers, the operational corollary is to publish standardised, floor-indexed cost-sharing and compensation ladders tied to observable design features such as shaft placement and façade orientation, pre-clear a compact catalogue of low-externality shaft solutions to narrow the negotiation space, commit to multi-year subsidy caps to remove strategic delay and deploy pay-per-use pilots where fiscal space is tight but demographic need is acute. This helps to reconfigure both the economic calculus and the process through which residents update beliefs and that, as the evidence suggests are more likely to produce cooperative outcomes that remain stable under the evolutionary pressures of everyday building governance (Long et al., 2020; Gong et al., 2021; Ning et al., 2022).

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