sustainability

MDPI

Article

Research on Evolutionary Game and Simulation of Information Sharing in Prefabricated Building Supply Chain

Rumeng Zhang and Lihong Li *

School of Management, Shenyang Jianzhu University, Shenyang 110168, China; zhang.rumeng@outlook.com
* Correspondence: lilihong022@126.com

Abstract: Enterprises in the prefabricated building supply chain (PBSC) only share information according to their interests, which is bound to cause conflicts of interest and reduce the efficiency of supply chain operations. To promote information sharing (IS) in PBSC, it is necessary to construct an evolutionary game model that fits the realistic network. In this paper, based on the integration of existing research, 13 influencing factors of IS in PBSC are analyzed comprehensively from the perspective of information ecology theory. In addition, due to the complexity and uncertainty of the PBSC, enterprise interaction and supply chain network structure affect the IS decision. Therefore, this paper builds an evolutionary game model of IS in PBSC under a scale-free network, and conducts numerical simulation analysis with MATLAB 2017 software to analyze the evolution law of enterprise IS under different situations. The results show that (1) when the network scale is large, the density of information sharers generally increases, and the speed of network evolution to a steady state generally slows down; (2) eight factors can promote the increase in information sharers' density, and five factors can inhibit it, but factors have no significant effect on the speed of network evolution to reach the steady state. Based on the simulation results, this paper proposes countermeasures and suggestions such as strengthening the support of the policy environment and social environment, setting up the demonstration benchmark of leading construction enterprises, establishing a directional information resource database, and improving information technologies and risk management systems to provide the scientific basis for government supervision and enterprise decision making.

Keywords: prefabricated building supply chain; information sharing; scale-free network; evolutionary game; MATLAB

check for updates

Citation: Zhang, R.; Li, L. Research on Evolutionary Game and Simulation of Information Sharing in Prefabricated Building Supply Chain. *Sustainability* **2023**, *15*, 9885. https://doi.org/10.3390/su15139885

Academic Editors: Jianghang Chen, Jie Chu, Jianxin Fang and Yiping Jiang

Received: 4 May 2023
Revised: 12 June 2023
Accepted: 19 June 2023
Published: 21 June 2023

1. Introduction

Under China's efforts to achieve "carbon peaking and carbon neutrality", prefabricated buildings have been promoted nationwide as a construction method in line with the country's green, low-carbon transformation and high-quality development goals. The prefabricated building supply chain (PBSC) involves many interdependent and interconnected enterprises [1], integrating logistics, capital flows, and information flows into a highly complex network structure. It has high requirements for information sharing (IS) in the whole life cycle of project decision making, implementation, operation and maintenance, demolition, and recycling [2]. However, many enterprises are weak in IS because of the hidden danger of trade secret disclosure and the high cost of human resources. On the one hand, PBSC is represented by various types of enterprises, including construction units, general contractors, design units, specialized subcontractors, component manufacturers, material and equipment suppliers, logistics and transportation units, regulatory units, operation and maintenance units, and demolition and recycling units. On the other hand, PBSC performance for enterprises has different endowment or behavioral characteristics, with significant differences in enterprise scale, production capacity, profitability, and other aspects. Such heterogeneity leads to information asymmetry in PBSC enterprises, aggravates the problem that benefits from IS are not proportional to costs, and may lead to low project quality, cost overruns, claims, and conflicts [3]. In addition, the evolving nature of supply chain networks leads to incorrect IS among policy and corporate decision makers, which can have serious unintended consequences [4]. How to effectively promote IS in PBSC enterprises has become a crucial problem to be solved urgently.

The complexity of PBSC brings volatility, uncertainty, and fuzziness [5,6], which makes it difficult for PBSC to share information. So far, scholars' research on IS in PBSC can be divided into three categories. Combined with the application and obstacles of building information modeling (BIM) in prefabricated buildings [7], some scholars have studied the combination of integrated data multiplexer or radio frequency identification or multi-agent or blockchain and BIM to realize IS in PBSC [2,8,9]. Most scholars construct incentive mechanisms of IS [10] and supply chain management framework [11], aiming at problems such as "bullwhip effect" and "opportunistic behavior" in IS [2,12,13]. Constrained by bounded rationality and information asymmetry [14], enterprises in the supply chain will only partially provide the information they have mastered to maximize their interests. However, some scholars pointed out that enterprises can achieve better profitability by sharing information in the supply chain [15]. Therefore, some scholars quantified the factors affecting enterprise IS as parameters and analyzed the influence of parameter changes on enterprise IS [16,17].

As BIM and other information-sharing technologies become more and more mature, more and more prefabricated construction enterprises participate in supply chain IS. Most of the existing research systematizes the IS and neglects the interaction between enterprises in the PBSC. However, the IS between enterprises is not only affected by the income of the other enterprises but also by the interaction relationship between enterprises and the supply chain network structure. It is important to consider the interaction of prefabricated construction enterprises and supply chain network structure into the IS game model. In addition, these studies are mainly based on static and qualitative perspectives. It is of great practical significance to analyze the influencing factors and evolution process of IS in PBSC from dynamic and quantitative perspectives.

In conclusion, this paper integrates the factors affecting IS in PBSC from the micro level, adds the evolutionary rules of the scale-free network into the evolutionary game model, and conducts evolutionary game simulation analysis under different situations. The following three problems are intended to be solved: (1) What kind of network structure does the IS in PBSC have, and what kind of interaction relationships are there in the network? (2) How can the evolutionary game model be constructed under a scale-free network? (3) How does the IS in PBSC evolve in different situations? This paper can not only supplement the theoretical research on the IS in PBSC under the network game but also provide some references for the government to formulate relevant policies, supply chain enterprises to make future IS decisions, and PBSC sustainable development.

The structure of this paper is organized as follows. We summarize the literature on PBSC, IS in the supply chain, evolutionary game, and scale-free network in Section 2. Section 3 builds the evolutionary game model of PBSC under a scale-free network. In Section 4, this paper fits the above model for analyzing the influence of changes in different influencing factors on the evolutionary results, then discusses specific strategies to promote IS in PBSC in Section 5. Finally, Section 6 concludes this study.

2. Literature Review

2.1. PBSC

O'Brien and Fischer proposed the idea of construction supply chain in 1998 [18,19]. However, there still needs to be a clear definition of PBSC due to differences in study scope and perspectives. In this paper, PBSC is defined as an integrated and coordinated network structure involving construction units, general contractors, design units, professional subcontractors, component manufacturers, material and equipment suppliers, logistics and transportation units, supervisory units, operation and maintenance units, and demolition and recycling units in the whole life cycle of project decision making, implementation, operation and maintenance, and recycling [20,21]. As shown in Figure 1, the general contractor is at the core of the information-sharing network. Prefabricated construction projects usually adopt an EPC mode in the project [22], and each enterprise in PBSC is connected through the core enterprise general contractor [21]. PBSC management is divided into external and internal integration [23]. Research on the external integration of PBSC aims to design reasonable cost-sharing [24], risk management and control [25], and benefit allocation models [26]. Internal integration ensures real-time sharing of market requirements, inventory status, production plans, demand forecasts, and delivery plans among all participants [23].

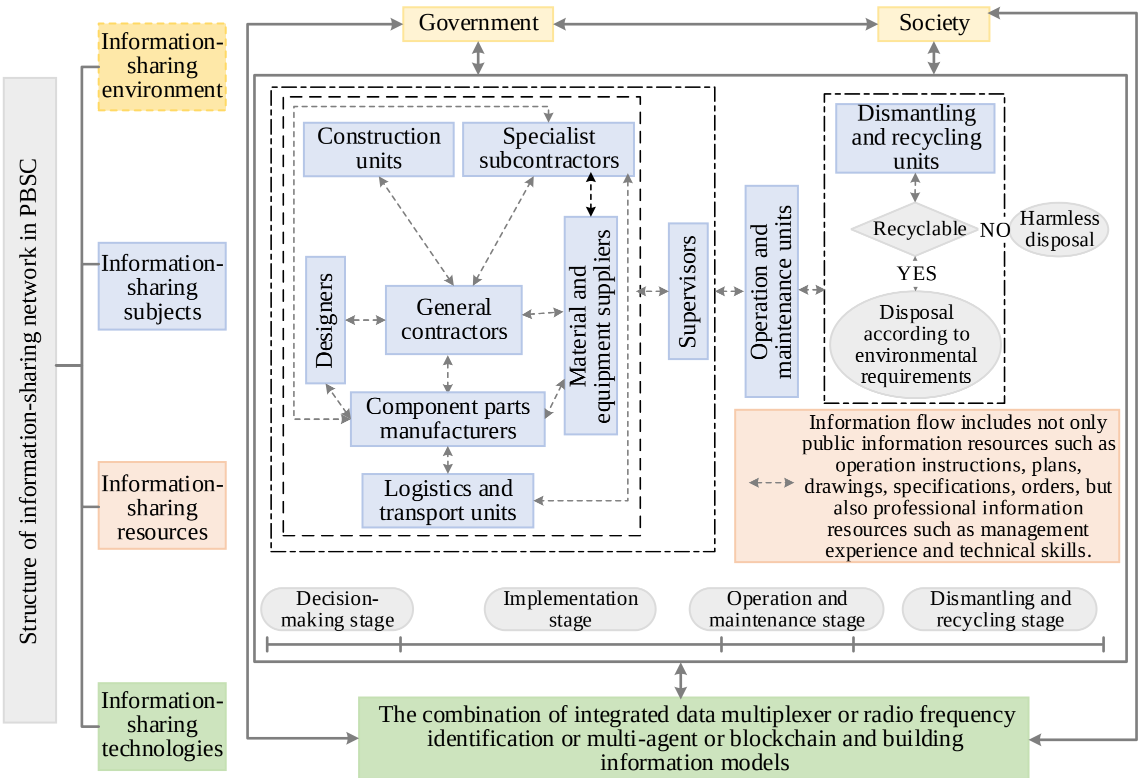


Figure 1. Structure of information-sharing network in PBSC.

2.2. IS in the Supply Chain

Information ecology theory was proposed by Horton F. W in the 1980s, emphasizing the harmonious coexistence of humans, information, environment, and technology factors in the information ecosystem. This theory explains the process of information dissemination and diffusion from the perspective of the ecosystem [27]. It has good explanatory power and applicability in information resource management and user information behavior [27]. This paper applies the theory of information ecology to the research of IS in PBSC. It constructs the structure network from the four dimensions of the information-sharing subjects, resources, environment, and technologies, as shown in Figure 1. IS enhances collaboration among decentralized PBSC enterprises and increases supply chain transparency and traceability [28]. It is a key factor in the success of supply chain management [29,30]. Human beings are the subjects of IS, and their information absorption capacity plays a significant role in promoting IS [31]. Information resources strongly regulate supply chain resilience [32]. Studies have shown that when the total amount of IS between enterprises in the supply chain is large, it is challenging to form cooperative sharing [17]. Modern information technologies such as BIM and blockchain promote the real-time acquisition and sharing of information among building supply chain subjects [33,34]. Information technologies have also reduced human error [35]. However, IT security risks also adversely affect supply chain productivity and competitiveness [36]. In terms of the policy environment, increasing incentives and penalties can improve the probability of IS and shorten the decision-making time [17]. Scholars have identified many factors affecting IS from different dimensions, which provides a theoretical basis for this paper.

2.3. Evolutionary Game Theory and Scale-Free Networks

Evolutionary game theory is a theory that combines game theory analysis with dynamic evolutionary process analysis [37]. The purpose of the game is to realize the increase in its income, so that the whole system gradually converges to the Pareto optimal state [38]. Under the premise of limited rationality and incomplete information, the core of game analysis is no longer the optimal strategy choice of game players, but the strategy adjustment process, trend, and stability of game participants [17]. Some scholars have considered the payoff matrix of the evolutionary game for the two central subjects in the supply chain and considered the influence of the total amount of information, degree of information absorption, cost coefficient, information leakage risk, and punishment mechanism on the IS of the supply chain [16,17].

In this technologically advanced era, every subject in the supply chain is expected to participate in IS [39]. Relevant studies show that enterprise interaction and supply chain network structure will also affect enterprises' willingness to share information [17,40]. Ignoring network factors to study the evolution of IS is biased, which may lead to a disconnection between the research and the real-world situation. In order to describe the local interaction between game players, a more elaborate network model is proposed. Barabasi and Albert found that most real networks, in reality, are scale free [41]. Most nodes only have a small number of neighbor nodes, while a few have a large number of neighbors [41,42]. Therefore, in 1999, they proposed the famous scale-free network [41]. As time goes by, the scale of a scale-free network increases, and new nodes preferentially connect with larger nodes after entering the network [42,43]. Zhu et al. explored community user information-sharing strategies under the Barabasi–Albert scaling-free network and discussed the influences of different parameters and initial conditions on the evolution results of IS [44].

The combination of a scale-free network and the evolutionary game is rarely used in the research of IS in PBSC. Using a scale-free network to study the information-sharing network in PBSC is of practical significance [45]. Therefore, using other research as a reference, this paper uses a scale-free network and evolutionary game to describe the interactive correlation structure and strategy selection paradigm among enterprises. It provides a new research model for understanding and analyzing enterprises' IS in a complex interactive environment.

2.4. Research Gap

The literature review shows that scholars have carried out some research on IS in PBSC, which also provides an important theoretical basis for this paper. However, the existing research has the following shortcomings:

1. The existing research mainly focuses on the game between two or three subjects in the supply chain. However, with the development of information-sharing technologies, more and more PBSC subjects participate in IS. The interaction between enterprises and the network structure of the supply chain are also more complex.
2. In addition to the influence of information-sharing subjects and information-sharing resources on IS decisions among enterprises, government policies and the development of social support technologies also have a significant impact on IS. Most studies consider government policies but ignore the evolution of IS in prefabricated buildings under social support and technological development.
3. Existing research mainly focuses on analyzing enterprises' IS decisions through classical game theory but fails to consider the topological characteristics of real networks, which is a lack of scientificity and authenticity. In addition, the research methods also lack the use of a scale-free network evolutionary game to study IS in PBSC.

Based on the theory of information ecology, this paper regards information-sharing subjects, information-sharing resources, information-sharing technologies, and information-sharing environment as a whole. By simulating the real information-sharing network in PBSC through a scale-free network, the evolution law of IS in PBSC with the change in information absorption capacity, technology application degree, and enterprise reputation value is revealed. The results of the evolutionary game are compared by simulation. It is expected to provide a theoretical basis for promoting IS in PBSC, and fill the research gap in the evolutionary game of IS in PBSC under a scale-free network. This paper can provide a decision reference for the IS strategy adopted by prefabricated buildings, and provide a reference for government supervision and enterprise decision making.

3. Construction of Scale-Free Network Game Model

3.1. Problem Raising

Under the drive and supervision of the government and society, the enterprise takes advantage of the rapidly developing information technologies to effectively control the professional and public information resources to ensure the quality and quantity of the project delivery and the overall benefit of PBSC as far as possible, as shown in Figure 1. However, in the PBSC information-sharing network, each enterprise tries to obtain more information from the other agents while reducing the amount of information it shares. It makes it difficult to achieve and maintain a high level of IS in PBSC, resulting in a "prisoner's dilemma".

3.2. Basic Assumptions

During the evolution of the information-sharing network in PBSC, enterprises generally adjust their IS through revenue. Based on the evolutionary game model under a scale-free network and IS in PBSC, the basic assumptions of this paper are summarized as follows:

H1. *The information-sharing network in PBSC is a scale-free network $G(V, L)$, which is an unauthorized undirected network. The nodes in the network are enterprises, and the lines indicate that the two parties have a cooperative relationship [40].*

H2. *All game enterprises are under bounded rationality and information asymmetry [46–48]. Due to the specificity and limitation of the cooperation object of enterprises, it is difficult for enterprises to obtain relevant information about all enterprises in the supply chain. So, they do not play with all the enterprises involved in IS. They play with the enterprises in their neighborhood [40].*

H3. *In the game between Enterprise i and Enterprise j IS, the behavioral strategy set of both parties is only (IS, information non-sharing) [17]. The probability of choosing a strategy is related to the benefit of IS, and there is the possibility of misjudgment and not choosing the optimal strategy [40]. This paper assumes that all enterprises involved in IS adopt the same policy for updating rules. Each enterprise determines the strategy choice for the next round of the game only according to the income of the current game round when the strategy is updated [40].*

3.3. Game Model Establishment

Based on the current research results [17,49], this paper summarizes the influencing factors into four dimensions: information-sharing subjects, resources, technologies, and environment according to the information ecology theory. To ensure the comprehensiveness and scientificity of the influencing factors, the information-sharing subject dimension considers the self-efficacy of the enterprise [50], the information-sharing resource dimension considers the usefulness and usability of the information [51,52], the information-sharing technology dimension considers the security and facilitation of the technology [53,54], and the information-sharing environment dimension considers the interactive atmosphere [55]. As shown in Figure 2, the influencing factors are quantified as parameters. The benefit function of IS of PBSC includes the benefits, costs, risks, and penalties [17,49,56]. Among them, the benefits are divided into direct benefits, spillover benefits, collaborative benefits, and incentive benefits. Both enterprises can gain additional collaborative and direct benefits if they share information. If only one party shares information, the collaborative benefit is 0 [17]. When both parties choose to share information, they obtain incentive benefits. If one party does not share the information, the incentive benefit accrues to the other party [49].

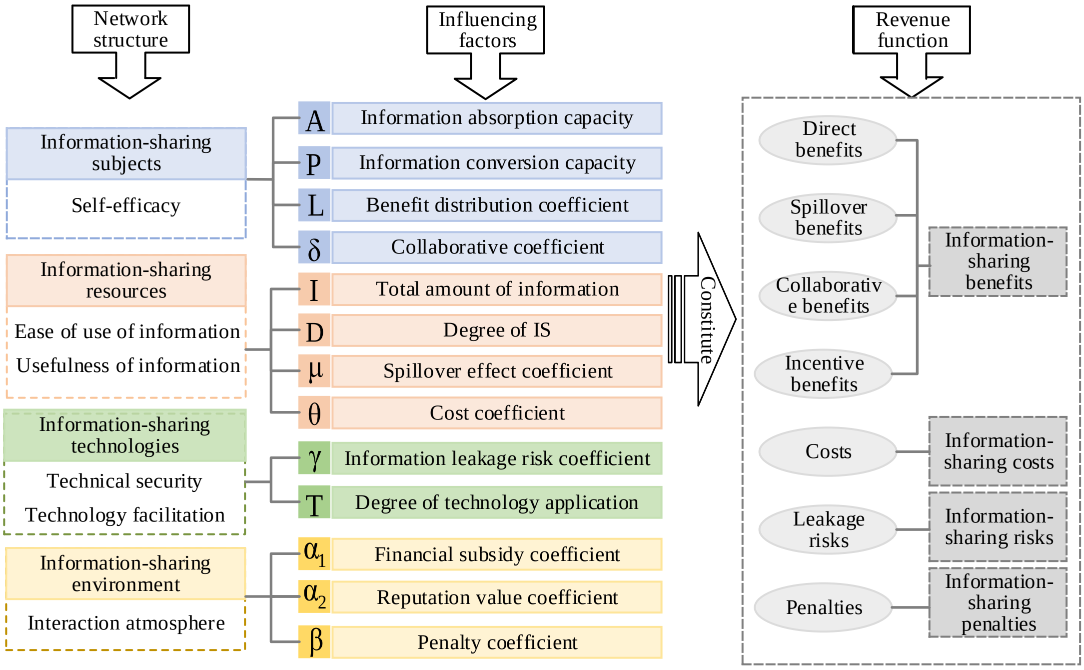


Figure 2. Structure of PBSC IS income function.

3.3.1. Information-Sharing Benefits

The direct benefits of IS $\Pi_{Di} = L_i(P_iA_iI_jD_j + P_jA_jI_iD_i)$ are the benefits obtained by Enterprise i according to the proportion of benefit distribution. $P_iA_iI_jD_j$ and $P_jA_jI_iD_i$ represent the direct benefits of IS between Enterprise i and Enterprise j in the cooperation process. L_i and L_j denote the benefit distribution coefficients between Enterprise i and Enterprise j, $L_i + L_j = 1$. In general, the benefits are distributed among enterprises by signing contracts. The objective gaps in the total amount of information I_i, the degree of IS D_i, the information absorption capacity A_i and the ability to convert information into benefits P_i in the pre-collaboration period of enterprises make the direct benefits of enterprise IS influence the decision [57]. In this paper, the product of the total amount of information and the degree of IS is equal to the amount of IS (I_iD_i).

Collaborative benefits of IS $\Pi_{Si} = \delta_iT_i(P_iA_iI_jD_j)^m(P_jA_jI_iD_i)^n$ refer to the benefits formed by enterprises' IS to achieve information interoperability, cooperation and reciprocity, and resource integration [17]. δ_i represents the coefficient of information collaboration ability, which is jointly determined by enterprises' degree of information complementarity and communication and coordination ability. m and n respectively represent the elastic coefficients of IS of Enterprise i and Enterprise j, namely, the degree of change in cooperative benefits caused by the income changes of both parties, $m + n = 1$, m and $n > 0$. T_i represents the degree of application of information-sharing technologies such as BIM by prefabricated building enterprises.

Information-sharing spillover benefits $\Pi_{Ei} = \mu_iA_iI_jD_j$ are the external benefits generated when Enterprise j adopts information-sharing strategies [58], benefited by Enterprise i. μ_i represents the ability of Enterprise i to absorb its information technologies or management systems when PBSC Enterprise j shares information.

Information-sharing incentive benefits $\Pi_{Ii} = \Pi'_{Ii} + \Pi''_{Ii} = \alpha_1I_iD_i + \alpha_2I_iD_i = (\alpha_1 + \alpha_2)$ I_iD_i are the value of social corporate reputation and government financial subsidies that enterprises receive for sharing information. Incentive mechanisms can encourage IS in the supply chain [59]. The decision to enterprise IS can not only obtain government financial subsidies but also improve the image and reputation of enterprises, so as to generate reputation value and promote the development of enterprises in the future [60]. α_1 is the incentive coefficient of the corporate reputation value and α_2 is the incentive coefficient of financial subsidies.

3.3.2. Information-Sharing Costs

Information-sharing costs $\Pi_{Ci} = \theta_i I_i D_i$ indicate the cost that Enterprise i invests in the process of IS. Enterprises with information-sharing technology platforms and management systems need to invest a certain amount of information-sharing costs. The sharing cost is proportional to the cost coefficient θ_i and the amount of information shared by Enterprise i [17].

3.3.3. Information-Sharing Risks

Information leakage risks $\Pi_{Li} = \gamma_i I_i D_i$ refer to the loss caused by information leakage after sharing. On the one hand, when the information of PBSC enterprises is over-shared, the business secrets unique to the enterprises themselves may be leaked. On the other hand, if the stability of the information repository is poor and the security traceability of the information storage is low, problems such as information plagiarism, loss, and tampering may put the information security of that enterprise at risk [61]. This, in turn, undermines trust and market competitiveness among supply chain enterprises [9]. Therefore, the amount of IS and the level of risk of information leakage γ_i have become hindrances for enterprises to share information.

3.3.4. Information-Sharing Penalties

Penalties β_i are costly penalties negotiated by the company to the non-sharing party through a formal agreement or informal commitment. Penalties are used to compensate for the losses of the sharing party. Punishment is an important mechanism to promote the evolution of cooperation [17].

The payoffs of the game between Enterprise i and Enterprise j are different under different combinations of strategies. According to the dynamics of enterprise decision making in the process of IS, the game benefit matrix of "IS—information non-sharing" between Enterprise i and Enterprise j is constructed. The payoff matrix of the information-sharing game in PBSC is shown in Table 1.

Table 1. The payoff matrix of the information-sharing game in PBSC.

		Enterprise *j*	
		IS	**Information Non-Sharing**
Enterprise i	IS	E_i=$\Pi_{Di} + \Pi_{Si} + \Pi_{Ei} + \Pi_{Ii} - \Pi_{Ci} - \Pi_{Li}$ E_j=$\Pi_{Dj} + \Pi_{Sj} + \Pi_{Ej} + \Pi_{Ij} - \Pi_{Cj} - \Pi_{Lj}$	F_i=$\Pi_{Ii} - \Pi_{Ci} - \Pi_{Li} + \beta$ G_j=$\Pi_{Ej} - \Pi''_{Ii} - \beta$
	Information Non-Sharing	G_i=$\Pi_{Ei} - \Pi''_{Ij} - \beta$ F_j=$\Pi_{Ij} - \Pi_{Cj} - \Pi_{Lj} + \beta$	H_i = 0 H_j = 0

3.4. Evolution Rules of Scale-Free Networks

3.4.1. Density of Information Sharers

At the initial moment of the game, enterprises choose the information-sharing, and information non-sharing strategy as the initial game strategy with probability p_0 $(0 < p_0 < 1)$ and $1 - p_0$, respectively. The proportion of information-sharing enterprises in the whole network at moment t is called the density of information sharers [40]:

$$f_c(t) = n_c(t)/N \tag{1}$$

where $n_{c(t)}$ represents the number of information sharers at the t moment. N indicates the number of enterprises in the entire network, that is the network scale.

3.4.2. Game Enterprise Information Penetration Mechanism

During the game, if Enterprise j chooses an information-sharing strategy, it may obtain shared information from Enterprise i, resulting in changes in the total amount of information [14,62]. In the game, the growth of the total amount of information of an enterprise is related to the probability S of information penetration [63]. In this paper, with reference to the relevant research of Zhao et al., the expression of the total amount of information of Enterprise i at $t+1$ moment can be obtained as follows [14]:

$$I_i(t+1) = \begin{cases} I_i(t) + SD_j I_j(t) & j\ share \\ I_i(t) & j\ does\ not\ share \end{cases} \quad (2)$$

Therefore, the total amount of information changes dynamically in the game at different moments, which leads to the change in the game income matrix related to the total amount of information. That is, the game income matrix changes dynamically in each round.

3.4.3. Game Enterprise Strategy Update Rules

Based on evolutionary game theory, IS in PBSC enterprises are bounded rationality. They cannot immediately find the optimal strategy, but keep learning, updating, and adjusting their strategies according to the real-time benefits in the process of the game. To satisfy the assumptions of bounded rationality, FEMI rules are adopted in this paper. The specific rule is to randomly select an enterprise in the neighborhood and adjust W based on whether or not to participate in the IS game strategy with a probability. W is expressed as [40]

$$W_{S_{i,t} \to S_{j,t}} = \frac{1}{1 + exp\left[\left(U_{i,t} - U_{j,t}\right)/\eta\right]} \quad (3)$$

$S_{i,t}$ and $S_{j,t}$ are the strategies of Enterprise i and Enterprise j at the t moment. $U_{i,t}$ and $U_{j,t}$ are the total revenue of Enterprise i and Enterprise j at the t moment. η is the environmental noise level, which indicates the irrational choice of each enterprise in the evolutionary game of IS in PBSC. In other words, aa is the probability that enterprises will still insist on not changing their strategies when their benefits are smaller than those of neighboring enterprises. Based on the existing research, the ambient noise level η is set as 0.1 in this paper [64,65].

3.4.4. Broken Edge Reconnection Mechanism of the Information-Sharing Network in PBSC

In this paper, an edge reconnection mechanism with preference is adopted. At the t moment, an edge is randomly selected to disconnect the original connection and start the reconnection with a probability p. The method is to disconnect one end of the selected line and then connect to other nodes with probability p. Nodes are not allowed to reconnect themselves to themselves and to repeat connections between nodes. The probability of a node i connecting to a node j is [40]

$$p_{ij,t} = \sum_{i \in G} \frac{U_{j,t}^{\varphi}}{U_{i,t}^{\varphi}} \quad (4)$$

where φ is the preference tendency. $\varphi = 0$ represents a non-preferred connection. It is a random connection. This paper selects high-preference connections $\varphi = 1$ [40].

Because in the scale-free network evolutionary game model, the game between enterprises is embedded in the network. The payoffs of the game are not only related to market factors but are also influenced by the network structure and the strategies of neighbors. The characteristic of the network determines that the evolution process cannot be expressed analytically. The simulation analysis provides a method for understanding the enterprise network game relationship in the process of IS in PBSC. Therefore, following the existing research paradigm, this paper uses MATLAB software to analyze the evolution process and results under reasonable parameter settings.

4. Results

4.1. Design of Simulation Experiment

To study the influence of the information-sharing network scale in PBSC, three scale-free networks of different scales are simulated in the simulation. The network scale is 50, 200, and 500.

Each enterprise in the network is randomly assigned two game strategies: IS and non-sharing. The initial probability of IS is set as 0.5, and the density of information sharers is 0.5.

In each round of the game, enterprises update their total amount of information according to Formula (2), update their strategies according to Formula (3), and adjust their cooperative enterprises according to Formula (4).

Using the evolution game depth of IS in PBSC (the density of information sharers $f_c(t)$) and speed (the speed of network evolution to reach steady state v) as measurement indicators, the evolution law of enterprise information-sharing strategy under the changes in parameter values and network scale is studied. $f_c(t)$ used Formula (1) for the specific calculation method.

The specific steps of the simulation experiment are shown in Figure 3.

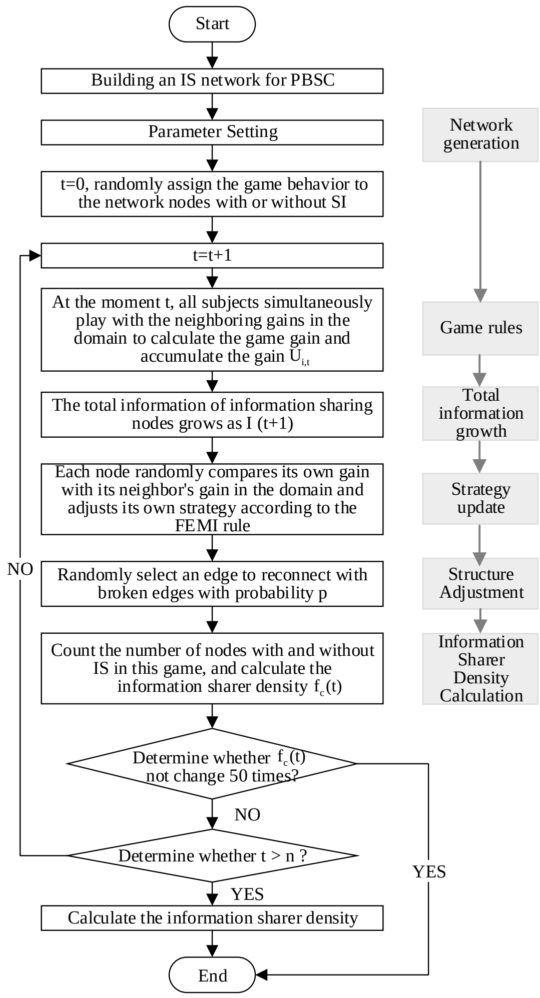


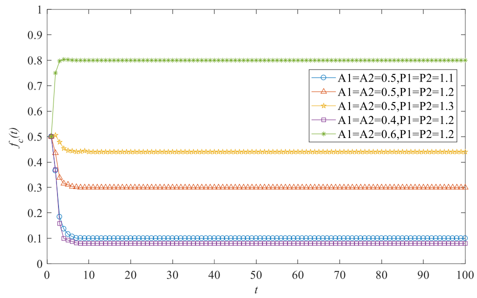
Figure 3. Simulation framework.

4.2. Parameter Description

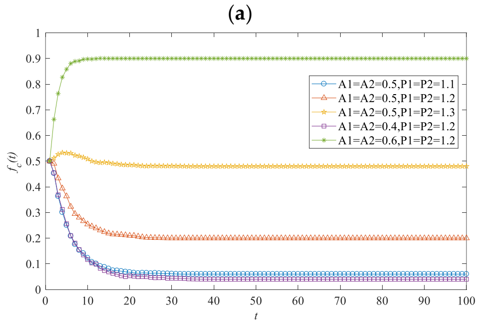
According to the information-sharing game model in PBSC game model and specific evolution rules established above, the MATLAB 2017 software is used to conduct the simulations. This paper not only refers to the value of numerical simulation parameters formulated by Xu [40] but also to the consulting results of PBSC enterprises and experts in scale-free network-related fields. Accordingly, the simulation parameters of the information-sharing network in PBSC evolutionary game set are as follows: $I_i = 10, D_i = A_i = P_i = 0.7, \alpha_1 = 0.2, \alpha_2 = 0.4, \gamma_i = 0.45, L_i = 0.3, \mu_i = 0.84, \theta_i = 0.8, \beta_i = 1, m = n = 0.5, \delta_i = 0.6, T_i = 0.3$. Each simulation contains 100 iteration time steps. Each group of parameters tests 50 times to ensure the stability of simulation results, and the average value of the network evolution measurement index is selected to study the evolution of the information-sharing network [40].

4.3. Simulation and Sensitivity Analysis

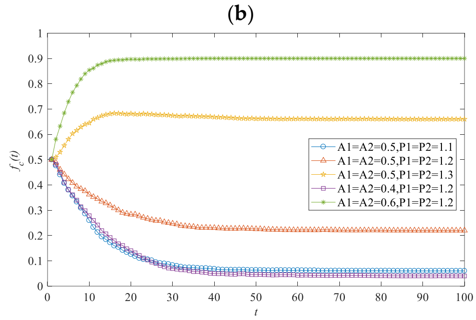
Under the above initial setting conditions, the values of parameters in different situations are shown in Table 2. Other parameters remain unchanged. In this paper, using the scale-free network of 50, 200, and 500 nodes as the carrier, MATLAB software is used to simulate the influence of different parameter values on the IS of PBSC enterprises under different network scales. In Figures 4–9, the simulation results for the three network sizes are named (a), (b), and (c). The x-axis is the number of games, and the y-axis is the density of information sharers.



(**a**)



(**b**)



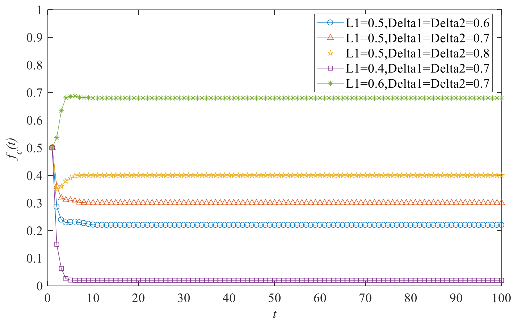
(**c**)

Figure 4. Influence of information absorption capacity and information conversion capacity on network evolution. (**a**) Evolution of small-scale networks. (**b**) Evolution of medium-scale networks. (**c**) Evolution of large-scale networks.

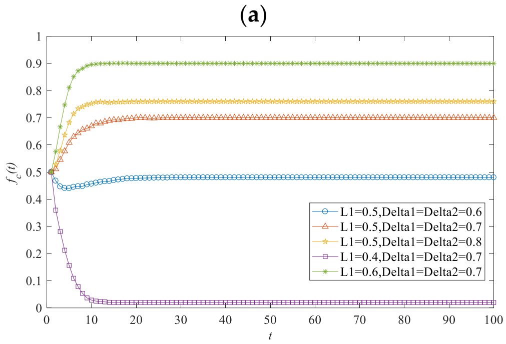
Table 2. Network evolution data with different parameter values.

Dimensionality	Parameter	Parameter Values	$\overline{f_c(t)}$	$\Delta\overline{f_c(t)}$	$\overline{v}$	$\Delta\overline{v}$
Information-sharing subjects	Information absorption capacity	0.4	0.05	0.81	-	×
		0.5	0.24		42	
		0.6	0.87		20	
	Information conversion capacity	1.1	0.07	0.45	42	2
		1.2	0.24		42	
		1.3	0.53		44	
	Benefit distribution coefficient	0.4	0.09	0.76	-	×
		0.5	0.62		31	
		0.6	0.85		25	
	Collaborative coefficient	0.6	0.49	0.18	32	×
		0.7	0.62		31	
		0.8	0.67		29	
Information-sharing resources	The total amount of information	8	0.84	−0.55	36	×
		9	0.56		35	
		10	0.29		41	
	Degree of IS	0.4	0.99	−0.98	23	17
		0.5	0.56		35	
		0.6	0.01		40	
	Cost coefficient	0.6	0.98	−0.86	16	34
		0.7	0.75		34	
		0.8	0.12		50	
	Spillover effect coefficient	0.21	0.77	−0.15	38	×
		0.42	0.75		34	
		0.84	0.61		38	
Information-sharing technologies	Information leakage risk coefficient	0.3	0.93	−0.67	27	6
		0.33	0.71		30	
		0.36	0.25		33	
	Degree of technology application	0.4	0.58	0.21	40	×
		0.45	0.71		30	
		0.5	0.79		33	
Information-sharing environment	Reputation value coefficient	0.4	0.09	0.89	46	−14
		0.45	0.80		44	
		0.5	0.99		32	
	Penalty coefficient	1	0.02	0.78	22	22
		2	0.80	0.81	44	

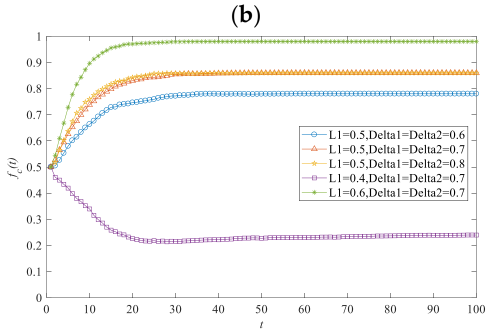
For a fixed parameter value, the average value of $f_c(t)$ in small-, medium-, and large-scale networks is used and denoted as $\overline{f_c(t)}$. The difference between $\overline{f_c(t)}$ for different values of the same parameter is denoted as $\Delta\overline{f_c(t)}$. Similarly, for a fixed parameter value, the average value of v under small-, medium-, and large-scale networks is used and denoted as $\overline{v}$. The difference between $\overline{v}$ for different values of the same parameter is denoted as $\Delta\overline{v}$. In Table 2, "-" indicates that the game has not reached a stable state in the evolutionary period, so the average value cannot be calculated. "×" in Table 2 indicates that when this parameter changes, the speed at which the network reaches the steady state changes irregularly.



(**a**)

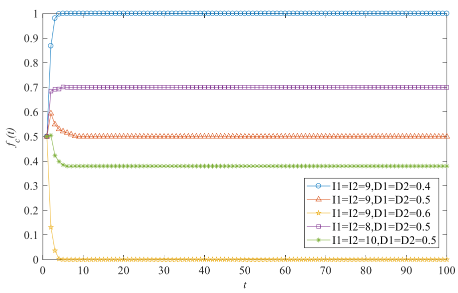


(**b**)



(**c**)

Figure 5. Influence of benefit distribution coefficient and collaborative coefficient on network evolution. (**a**) Evolution of small-scale networks. (**b**) Evolution of medium-scale networks. (**c**) Evolution of large-scale networks.



(**a**)

Figure 6. *Cont*.

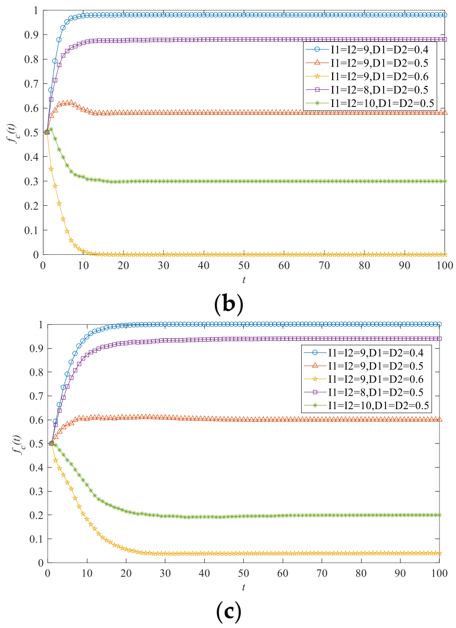


Figure 6. Influence of total amount of information and degree of IS on network evolution. (**a**) Evolution of small-scale networks. (**b**) Evolution of medium-scale networks. (**c**) Evolution of large-scale networks.

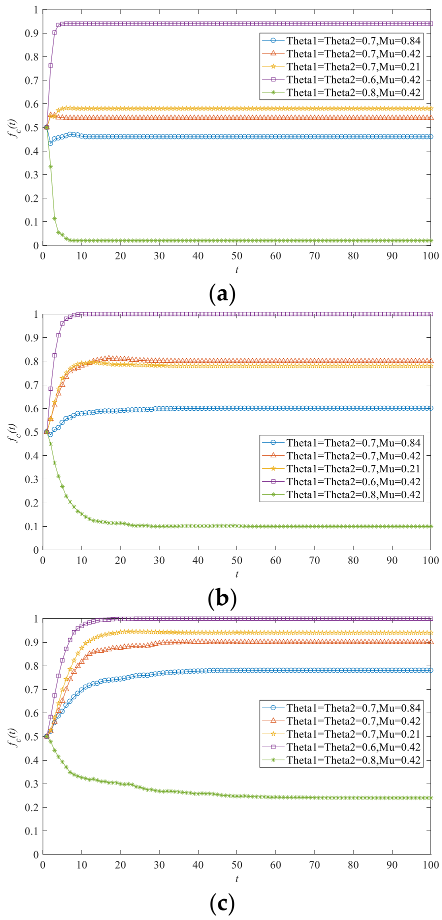
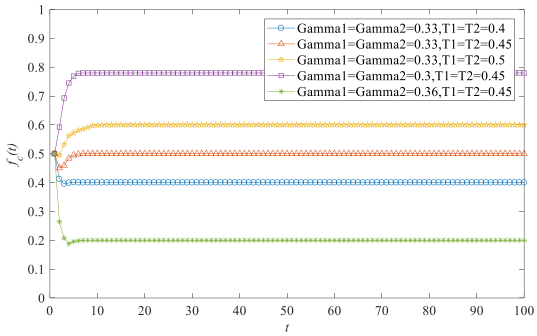
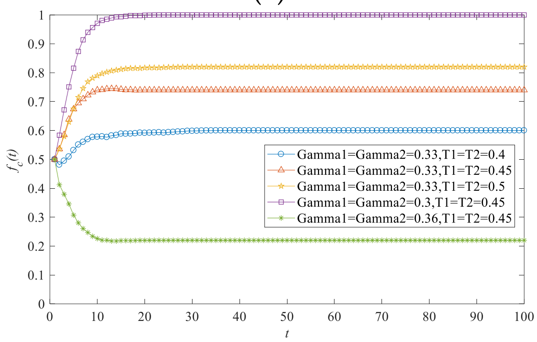


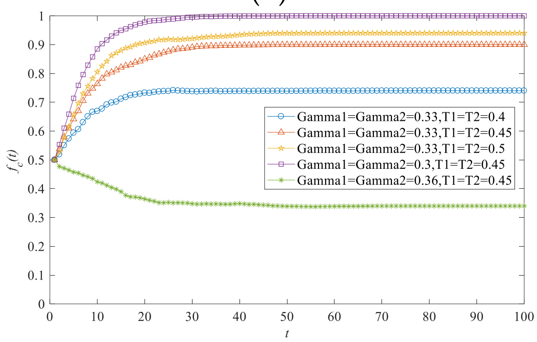
Figure 7. Influence of cost coefficient and spillover effect coefficient on network evolution. (**a**) Evolution of small-scale networks. (**b**) Evolution of medium-scale networks. (**c**) Evolution of large-scale networks.



(**a**)

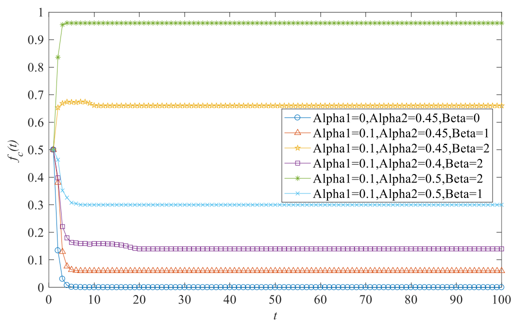


(**b**)



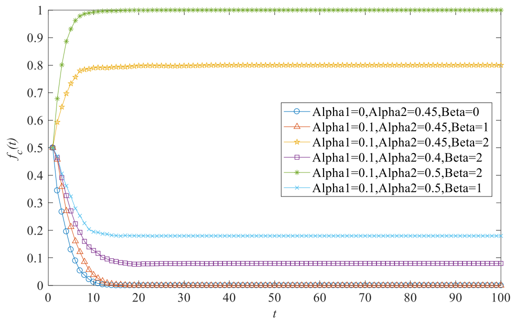
(**c**)

Figure 8. Influence of information leakage risk coefficient and degree of technology application on network evolution. (**a**) Evolution of small-scale networks. (**b**) Evolution of medium-scale networks. (**c**) Evolution of large-scale networks.

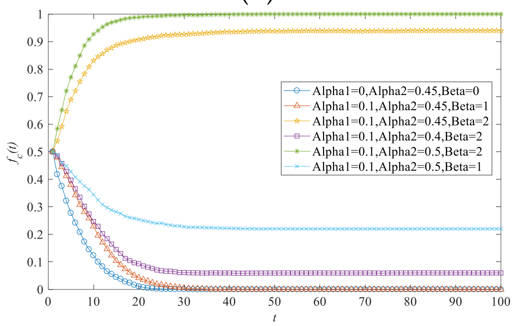


(**a**)

Figure 9. *Cont*.



(**b**)



(**c**)

Figure 9. Influence of reputation value coefficient and penalty coefficient on network evolution. (**a**) Evolution of small-scale networks. (**b**) Evolution of medium-scale networks. (**c**) Evolution of large-scale networks.

Data from Figures 4–9 were extracted and processed to obtain network evolution data with different parameter values and different network scales, as shown in Tables 2 and 3.

Conclusion 1: According to $\widehat{f_c(t)}$, $\Delta\widehat{f_c(t)}$, $\hat{\upsilon}$, $\Delta\hat{\upsilon}$ and in Tables 2 and 3, it can be seen that with the expansion of the network scale, the speed of network evolution to a steady state slows down, but the density of information sharers generally increases. It is because prefabricated buildings have entered a stage of rapid development, and the expansion of network scale is conducive to the heterogeneous PBSC enterprises to choose more suitable partners to expand their benefits.

4.3.1. Influence of Information-Sharing Subjects on Network Evolution

Information absorption capacity A_i, information conversion capacity P_i, benefit distribution coefficient L_i, and collaborative coefficient δ_i increased by 0.2, $\overline{f_c(t)}$, respectively by 0.81, 0.45, 0.76, and 0.18, as shown in Figures 4 and 5. It indicates that the higher the ability of the information subjects, the more people choose the information-sharing strategy in PBSC. However, it has no common effect on the speed of network evolution to reach a steady state. In large-scale networks, when the information absorption capacity or benefit distribution coefficient is too tiny (A_i = 0.4 or L_i = 0.4), the steady state $f_c(t)$ is not reached within 100 iteration time steps. In large-scale networks, small information absorption capacity leads to less direct benefits, collaborative benefits, and spillover benefits from IS. An unsatisfactory benefit distribution coefficient leads to less direct benefits from the IS of PBSC enterprises. As a result, the income of enterprise IS ($E_i + F_i$) is smaller than that of the non-sharing ($G_i + H_i$) strategy. However, since the initial density of IS sets at 0.5, half of the enterprises choose to share information, and their total amount of information increases according to Formula (3). At this time, the income ($E_i + F_i$) increases, and the income ($E_i + F_i$) of enterprise IS may be higher than that of the non-sharing ($G_i + H_i$) strategy. Especially in large-scale networks, more companies compare revenues with each other and change strategies. The income change makes it impossible for enterprises to make decisions quickly, so the evolution results fluctuate.

Table 3. Network evolution data in different network scale.

Dimensionality	Parameter	Number of Network Nodes	$\widehat{f_c(t)}$	$\Delta\widehat{f_c(t)}$	$\hat{v}$	$\Delta\hat{v}$
Information-sharing subjects	Information absorption capacity	50	0.39	×	8	×
		200	0.38		26	
		500	0.39		×	
	Information conversion capacity	50	0.28	×	9	77
		200	0.25		32	
		500	0.31		87	
	Benefit distribution coefficient	50	0.33	0.36	9	×
		200	0.54		21	
		500	0.69		×	
	Collaborative coefficient	50	0.35	0.48	9	48
		200	0.65		26	
		500	0.83		57	
Information-sharing resources	The total amount of information	50	0.53	×	8	64
		200	0.59		33	
		500	0.58		72	
	Degree of IS	50	0.5	0.05	6	62
		200	0.52		24	
		500	0.55		68	
	Cost coefficient	50	0.5	0.21	7	52
		200	0.63		34	
		500	0.71		59	
	Spillover effect coefficient	50	0.53	0.35	9	54
		200	0.73		39	
		500	0.87		63	
Information-sharing technologies	Information leakage risk coefficient	50	0.49	0.25	7	54
		200	0.65		22	
		500	0.75		61	
	Degree of technology application	50	0.5	0.36	8	58
		200	0.72		28	
		500	0.86		66	
Information-sharing environment	Reputation value coefficient	50	0.59	0.08	12	63
		200	0.63		35	
		500	0.67		75	
	Penalty coefficient	50	0.27	0.2	27	35
		200	0.4		29	
		500	0.47		62	

For a fixed network scale, the average values of the different values of $f_c(t)$ are expressed as $\widehat{f_c(t)}$. The difference of $\widehat{f_c(t)}$ for the network size of the same parameter is denoted as $\Delta\widehat{f_c(t)}$. Similarly, for a fixed parameter value, the average value of v under different parameter values is used and denoted as $\hat{v}$. The difference of $\hat{v}$ for the network size of the same parameter is denoted as $\Delta\hat{v}$. "×" in Table 3 indicates that when the network scale changes, the speed of the network reaching the steady state changes irregularly.

Conclusion 2: The information-sharing subjects can promote the IS, and the effects from the largest to the smallest are absorption capacity, benefit distribution coefficient, conversion capacity, and collaborative coefficient. Absorption capacity and benefit distribution coefficient significantly affect the density of information sharers and determine the speed at which the network evolution reaches a steady state.

4.3.2. Influence of Information-Sharing Resources on Network Evolution

As shown in Figure 6, when I_iD_i = 3.6, 4, 4.5, 5, 5.4, $\overline{f_c(t)}$ decreases from 0.99 to 0.01. When I_iD_i = 4, the density of information sharers increases with network scale. When I_iD_i = 5, the density of information sharers decreases with the decrease in network scale. When I_iD_i = 3.6, 4.5, 5.4, the change in network scale does not affect the density of information sharers. This is because this paper considers the influence of the infiltration mechanism of information on the total amount of information. With the increase in game nodes, the total amount of information "snowballs" increases, and the final evolution result is more different from the initial information-sharing density. As shown in Figure 7, the increase in cost coefficient (θ_i = 0.6, 0.7, 0.8) not only affects the density of information sharers ($\overline{f_c(t)}$ = 0.98, 0.75, 0.12) but also slows down the evolution process of the network ($\overline{v}$ = 16, 34, 50). The spillover effect has little influence on the choice of information-sharing strategy. When the spillover effect is 0.5, 1, and 4 times the direct income of IS (μ_i = 0.21, 0.42, 0.84), $\overline{f_c(t)}$ decreases by 0.15 ($\overline{f_c(t)}$ = 0.77, 0.75, 0.61). Reasonable spillover effects (μ_i = 0.21, 0.42) will promote IS, but the promotion effect is limited. However, an excessive spillover effect (μ_i = 0.84) will lead to a "free rider effect", which is not conducive to IS.

Conclusion 3: Information resources can inhibit IS. Because of an information infiltration mechanism, the amount of IS I_iD_i dramatically influences the density of information sharers. The cost coefficient greatly influences the density of information sharers and the speed of evolution to a steady state.

4.3.3. Influence of Information-Sharing Technologies on Network Evolution

As the risk coefficient of information leakage increases (γ_i = 0.3, 0.33, 0.36), $\overline{f_c(t)}$ decreases by 0.67 ($\overline{f_c(t)}$ = 0.93, 0.71, 0.25), as shown in Figure 8. It indicates that network evolution is particularly sensitive to the change in risk coefficient. When the risk coefficient sets at 0.33, the density of information sharers in the three scale networks changed significantly ($f_c(t)$ = 0.5, 0.74, 0.9). The larger the network scale, the more enterprises share information when the initial proportion of IS is given. At this time, the application of BIM, blockchain, and other prefabricated building information-sharing technologies has also become more complete, and the network's resistance to the risk of information technology leakage has risen significantly. The increase in the degree of technology application (T_i = 0.4, 0.5) can rapidly improve the density of information sharers ($\overline{f_c(t)}$ = 0.58, 0.79). However, in large-scale networks, the influence of the degree of technology application on the density of information sharers presents a marginal decreasing effect ($f_c(t)$ = 0.74, 0.9, 0.94).

Conclusion 4: The risk of information leakage has a strong inhibitory effect on the IS in PBSC, and the degree of technology application promotes the IS in PBSC. Both have little effect on the speed of network evolution to a steady state.

4.3.4. Influence of Information-Sharing Environment on Network Evolution

When the government does not set the reward and punishment mechanism (α_1 = 0, β_i = 0), all enterprises in PBSC choose not to share information, as shown in Figure 9. The coefficient of the fixed policy subsidy is 0.1, and the incentive coefficient of the reputation value is 0.45. When the penalty coefficient β_i is 1, the density of information sharers reaches a stable value $\overline{f_c(t)}$ = 0.02 after 22 rounds of the game. When the penalty coefficient is 2, the average density of information sharers reaches $\overline{f_c(t)}$ = 0.8 after 44 rounds of the game. It indicates that the perfect punishment mechanism encourages enterprises to cooperate and share and improves the speed of evolutionary stability. To a large extent, the punishment mechanism limits the opportunistic behavior caused by the spillover effect of IS to ensure the effective sharing of information. Since the financial subsidy and corporate reputation value assumed in this paper have the same influence on IS in PBSC strategy selection, this paper uses the corporate reputation value as an example for simulation and analysis. When the reputation value coefficient (α_2 = 0.4, 0.45, 0.5) increases, $\overline{f_c(t)}$ increases by 0.89, and $\overline{v}$ increases by 14. On the one hand, in PBSC, the general contractor will pay more attention to the component suppliers' social reputation and brand effect under information asymmetry. On the other hand, as prefabricated building products have the social value of low-carbon emission reduction, IS by enterprises in the supply chain can generate more corporate reputation value. When the reward and punishment mechanisms are perfect (α_1 = 0.1, α_1 = 0.5, β_i = 2), the higher the density of information sharers is ($\overline{f_c(t)}$ = 0.99), the faster the network evolution reaches the steady state ($\overline{v}$ = 32). When the reward and punishment mechanisms are not perfect (α_1 = 0.1, α_1 = 0.4, β_i = 2 or α_1 = 0.1, α_1 = 0.5, β_i = 1), the density of information sharers decreases sharply ($\overline{f_c(t)}$ = 0.09 or $\overline{f_c(t)}$ = 0.23).

Conclusion 5: The information environment can promote the choice of information-sharing strategy in PBSC. The promotion effect of a multi-dimensional policy is better than that of a single policy, so the government should set up reasonable reward and punishment mechanisms. Reasonable punishment mechanisms can promote IS but slow down the steady state of network evolution. Financial subsidies and reputation value can improve the density of information sharers and accelerate the network's speed to reach a steady state and promote the development of prefabricated buildings.

5. Discussion

The simulation of the scale-free network evolutionary game model in Figures 4–9 shows that the information-sharing strategies of PBSC enterprises are dynamically adjusted according to different situations. Prefabricated buildings have the advantage of being green and sustainable. Therefore, with the development of emerging information-sharing technologies such as BIM, the government and society also give corresponding support to the IS in PBSC. In this context, this paper sorts out the influence of factors influencing IS in PBSC, and puts forward countermeasures and suggestions to promote IS, as shown in Figure 10.

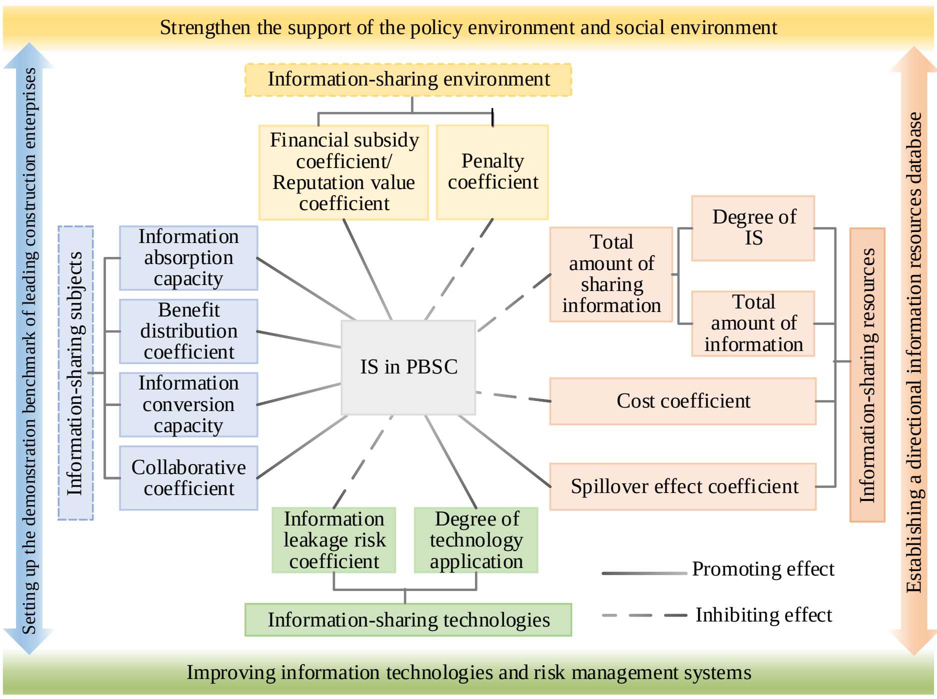


Figure 10. The influence of factors influencing IS in PBSC and the countermeasures and suggestions to promote IS.

5.1. Strengthen the Support of the Policy Environment and Social Environment

Government and social support and supervision can promote IS in PBSC. In order to enhance PBSC's initiative and enthusiasm for IS, the government can introduce special support measures for information management demonstration projects and preferential policies for VAT collection and refund. At the same time, high taxes and fees should be levied on enterprises that maintain the original mode to balance the financial pressure to deal with the information asymmetry caused by all parties considering their interests and achieve the balance of the entire PBSC [3]. Social media should be encouraged and guided to increase the positive publicity of IS in PBSC and improve the value of corporate brand reputation [60]. A green channel for middle and downstream enterprise financing should be opened up along with promoting the development of IS in PBSC from the "environmental end". The "negative effect" of incentive measures also deserves attention [37]. The "negative effect" of incentive measures corresponds to a gradual slowdown in the growth rate of information sharers. For example, when the reputation value coefficient increases from 0.45 to 0.5, the density of information sharers only increases by 19%. Therefore, if the incentive is excessive, the government will bear tremendous financial pressure, and the incentive effect is insignificant. The government needs to implement a dynamic and balanced subsidy and tax policy.

5.2. Set up the Demonstration Benchmark of Leading Construction Enterprises

According to the simulation in Figures 4 and 5 and the sensitivity analysis in Section 4.3, improving the enterprises' information absorption capacity and benefit distribution coefficient can significantly increase the density of information sharers and improve the speed of IS evolution to a steady state. The government can consider setting up a model for leading construction enterprises to create a prefabricated construction industrial cluster with information absorption and strong core competitiveness [66], giving full play to the cluster effect of the supply chain from the "main end", and share the high-input cost of the IS platform. Similar to Conclusion 1, Xu [40] found that expanding the network scale promotes the generation of cooperative behavior. As shown in Figure 1, most non-core enterprises have very few information-sharing relationships in the information-sharing network with scale-free network characteristics, and only general contractors have many information-sharing relationships. Setting up the demonstration benchmark of leading construction enterprises will also help to create an atmosphere of IS in PBSC and strengthen the connection between non-core enterprises, thus expanding the scale of the network [67], and improve the overall competitiveness of enterprises in the enterprise through a scale effect.

5.3. Creating a Directional Information Resource Base

According to the analysis, information-sharing quantity and cost coefficient have an inhibitory effect on network evolution. Excessive IS does not increase the income of all parties in the supply chain but leads to the risk of personal information theft [66]. Nozari and other scholars pointed out that the increase in cost increases the uncertainty in different scenarios [68]. This is a good explanation for the simulation results in this paper that with the increase in cost coefficient, the density of information sharers decreases, and the speed of evolution to a steady state slows down. Therefore, it is imperative to establish a directional information resource base based on the existing database [69]. It can use information means and analysis tools to target objects in all directions and at all times and integrate information resources of the whole life cycle of prefabricated buildings. It helps to create an "information cocoon" in the internal IS system and share PBSC quality information accurately from the "resource end". It controls the huge cost caused by a large amount of information and reduces the spillover benefits of "free-riding" enterprises that do not share information.

5.4. Improve the Information Technology and Risk Management System

In the information-sharing technology dimension, the degree of technology application is essential in promoting network evolution. The government should coordinate and promote the construction of prefabricated building industry information service platforms. Through the new infrastructure, we will give full play to the enabling role of information technologies, break the professional construction barriers, and provide a secure information integration and sharing platform for PBSC enterprises. Information leakage risk has a strong inhibition effect on network evolution. Tan [17] also found that controlling the risk of information leakage can improve the level and efficiency of IS in the supply chain. To solve this problem, they proposed to sign an information confidentiality agreement and set up different rights according to enterprise positioning. This countermeasure is also applicable to heterogeneous PBSC enterprises. Enterprises should strengthen the identity authentication of users and sign information confidentiality agreements according to the information needs of different enterprises in PBSC. Moreover, different rights should be set according to corporate positioning to make all IS traceable [61]. It can improve the information ability of accurate and dynamic scheduling and configuration of people, materials, and machines and promote the sharing of PBSC information from the "technical end".

6. Conclusions

This paper mainly involves three steps to promote IS in PBSC. Firstly, an information-sharing network is constructed based on the literature review and information ecology theory. It finds that the network structure consists of information-sharing subjects, resources, technologies, and the environment. Through the text-mining method, 12 influencing factors of IS in PBSC were identified from four dimensions of network structure.

Secondly, the key to further research is to use a scientific method to explore the influence of influencing factors on IS. This paper studies the network structure of IS in PBSC, sets up the strategy updating the rules of game enterprises, the information infiltration mechanism, and the network disconnection mechanism, and constructs the evolutionary game model under a scale-free network. Establishing scale-free network evolution rules makes the game model better fit the information-sharing network structure.

Finally, using MATLAB software to realize the effect simulation and sensitivity analysis, the system reveals the internal information-sharing requirements. The results show that the density of information sharers and the steady-state speed differ in different situations. When the network scale is large, the speed of network evolution slows down, but the density of information sharers generally increases. The change in the value of each influencing factor can promote or inhibit the density of information sharers in PBSC regularly. However, it has no significant effect on accelerating or delaying the steady state of network evolution. In the long run, the choice of information-sharing strategy is a dynamic process of continuous adjustment and linkage change. Therefore, adjusting these parameters can guide the evolution of IS in PBSC toward Pareto optimization. When improving information-sharing subjects, resources, technologies, and the environment is challenging, the government and enterprises can absorb more enterprises and cultivate them into a large-scale network with scale-free characteristics.

6.1. Implications

This paper further enriches the connotation of PBSC information-sharing research, which is significant to governments, enterprises, and academia.

6.1.1. Managerial Implications

This study identifies the corresponding influencing factors from four dimensions: information-sharing subjects, resources, technologies, and the environment. By adjusting and controlling the corresponding influencing factors, the government and enterprises can find that the key factors affecting the IS in PBSC are the information absorption capacity, the amount of IS, the information leakage risk coefficient, the cost coefficient, the financial subsidy coefficient, and the reputation value coefficient. Therefore, on the basis of strengthening the support of the policy environment and social environment, the government and enterprises can further establish the demonstration benchmark of leading construction enterprises, establish a directional information resource library, and improve the information technology and risk management system. These measures can promote the IS in PBSC, so as to provide inexhaustible power for the sustainable development of the building supply chain.

6.1.2. Academic Contributions

The academic circle has recognized the importance of IS in supply chain operations. However, there is still a research gap in the evolutionary game of IS in PBSC under a scale-free network. In particular, there is a lack of overall research and dynamic analysis on the influencing factors of IS in PBSC. In response to the objective fact that general contractors occupy the core position in PBSC, this study broadens the application area of scale-free networks by modeling the information-sharing network in PBSC through scale-free networks. Through the graphical results, this study directly illustrates the specific role of different influencing factors in the information-sharing network in PBSC in different network scales and supplements the integrity of the IS in PBSC. This model can help other enterprise systems understand supply chain IS and provide inspiration for further research on the supply chain IS of prefabricated buildings.

6.2. Limitations and Further Directions

Although the model constructed in this paper can effectively study the evolution law of IS in PBSC, it still has the following shortcomings: (1) Due to the limitations of the survey objects and conditions, this paper only considers quantifiable indicators as influencing factors to build the model. However, other factors that are difficult to quantify can skew the evolution of the network. (2) Different from the traditional evolutionary game, the evolutionary game model constructed in this paper is only applicable to the game problem under the scale-free network. When analyzing other practical problems, it is necessary to consider the network structure of the research object. It is still the future research direction to further improve the evolutionary game model under a scale-free network and make it more appropriate to describe the game problem of IS in PBSC. In addition, although the model is not suitable for game analysis in small-world networks, random networks, and other networks, it is expected to provide ideas for related research.

Author Contributions: Conceptualization, writing, and original draft preparation were carried out by R.Z. and L.L. Methodology, software, review, writing, and editing were carried out by R.Z. Supervision was carried out by L.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Department of Education of Liaoning Province, grant number LJKR0214. It was also funded by the Liaoning Province social science planning Fund, grant number L22BGL042.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data for this study are available upon request to the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Anbumozhi, V.; Kimura, F.; Thangavelu, S.M. Global Supply Chain Resilience: Vulnerability and Shifting Risk Management Strategies. In *Supply Chain Resilience: Reducing Vulnerability to Economic Shocks, Financial Crises, and Natural Disasters*; Anbumozhi, V., Kimura, F., Thangavelu, S.M., Eds.; Springer: Singapore, 2020; pp. 3–14.
2. Du, J.; Sugumaran, V.; Gao, B. RFID and Multi-Agent Based Architecture for Information Sharing in Prefabricated Component Supply Chain. *IEEE Access* **2017**, *5*, 4132–4139. [CrossRef]
3. Zhao, J.; Ding, S.Z. Information Sharing in Construction Supply Chain. *Key Eng. Mater.* **2010**, *426–427*, 249–253. [CrossRef]
4. Pathak, S.D.; Dilts, D.M.; Biswas, G. On the Evolutionary Dynamics of Supply Network Topologies. *IEEE Trans. Eng. Manag.* **2007**, *54*, 662–672. [CrossRef]
5. Bier, T.; Lange, A.; Glock, C.H. Methods for mitigating disruptions in complex supply chain structures: A systematic literature review. *Int. J. Prod. Res.* **2020**, *58*, 1835–1856. [CrossRef]
6. Gao, Y.; Feng, Z.; Zhang, S. Managing supply chain resilience in the era of VUCA. *Front. Eng. Manag.* **2021**, *8*, 465–470. [CrossRef]
7. Qin, H. Building Information Modelling Implementation in Prefabricated Building Research Field and Barriers Analysis. In Proceedings of the International Conference on Smart Transportation and City Engineering, Chongqing, China, 26–28 October 2021.
8. Xu, Z.; Abualdenien, J.; Liu, H.; Kang, R. An IDM-Based Approach for Information Requirement in Prefabricated Construction. *Adv. Civ. Eng.* **2020**, *2020*, 8946530. [CrossRef]
9. Bakhtiarizadeh, E.; Shahzad, W.M.; Poshdar, M.; Khalfan, M.; Rotimi, J.O. Blockchain and Information Integration: Applications in New Zealand's Prefabrication Supply Chain. *Buildings* **2021**, *11*, 608. [CrossRef]
10. Wang, L.X.; Jiao, X.L.; Hao, Q. Modeling the Incentive Mechanism of Information Sharing in a Dual-Channel Supply Chain. *Discret. Dyn. Nat. Soc.* **2021**, *2021*, 2769353. [CrossRef]
11. Li, J.; Yi, L.; Xiao, Y. Research on Information Sharing Mechanism of Emission Reduction in Supply Chain Based on Blockchain under Information Asymmetry. *Chin. J. Manag. Sci.* **2021**, *29*, 131–139.
12. Wang, E.K.; Li, Y.; Ye, Y.; Yiu, S.M.; Hui, L.C.K. A Dynamic Trust Framework for Opportunistic Mobile Social Networks. *IEEE Trans. Netw. Serv. Manag.* **2018**, *15*, 319–329. [CrossRef]
13. Thonemann, U.W. Improving supply-chain performance by sharing advance demand information. *Eur. J. Oper. Res.* **2002**, *142*, 81–107. [CrossRef]
14. Zhao, N.; Miao, S.; Zhang, Y. A Novel Co-Evolution Model Based on Evolutionary Game about Social Network. *Symmetry* **2022**, *14*, 581. [CrossRef]
15. Nandra, R.; Majumder, A.; Mishra, M. A multi-retailer sustainable supply chain model with information sharing and quality deterioration. *Rairo-Oper. Res.* **2021**, *55*, S2773–S2794. [CrossRef]
16. Guo, B.; Luo, M. Allocation of control right between the participants of building information modeling–integrated project delivery project from the perspective of knowledge sharing. *Int. J. Electr. Eng. Educ.* **2020**, 0020720920928536. [CrossRef]
17. Tan, J.; Jiang, G.; Wang, Z. Evolutionary Game Model of Information Sharing Behavior in Supply Chain Network With Agent-Based Simulation. *Int. J. Intell. Inf. Technol.* **2019**, *15*, 54–68. [CrossRef]
18. Wang, Z.; Hu, H.; Gong, J.; Ma, X.; Xiong, W. Precast supply chain management in off-site construction: A critical literature review. *J. Clean. Prod.* **2019**, *232*, 1204–1217. [CrossRef]
19. O'Brien, W.J.; Fischer, M.A. *Construction Supply-Chain Management: A Research Framework. Information Technology for Civil & Structural Engineers*; Civil-Comp Press: Edinburgh, UK, 1993; pp. 61–64. [CrossRef]
20. Du, Q.; Pang, Q.; Bao, T.; Guo, X.; Deng, Y. Critical factors influencing carbon emissions of prefabricated building supply chains in China. *J. Clean. Prod.* **2021**, *280*, 124398. [CrossRef]
21. Sun, S.; Chen, Y.; Wang, A.; Liu, X. An Evaluation Model of Carbon Emission Reduction Effect of Prefabricated Buildings Based on Cloud Model from the Perspective of Construction Supply Chain. *Buildings* **2022**, *12*, 1534. [CrossRef]
22. Xia, M.M.; Zhao, L.M.; Zhao, L. A Comprehensive Risk-Assessment Method for Prefabricated Buildings Using EPC: A Case Study from China. *Sustainability* **2022**, *14*, 1910. [CrossRef]
23. Liu, Y.; Dong, J.; Shen, L. A Conceptual Development Framework for Prefabricated Construction Supply Chain Management: An Integrated Overview. *Sustainability* **2020**, *12*, 1878. [CrossRef]
24. Kim, Y.-W.; Han, S.-H.; Yi, J.-S.; Chang, S. Supply chain cost model for prefabricated building material based on time-driven activity-based costing. *Can. J. Civ. Eng.* **2016**, *43*, 287–293. [CrossRef]
25. Zarbakhshnia, N.; Soleimani, H.; Ghaderi, H. Sustainable third-party reverse logistics provider evaluation and selection using fuzzy SWARA and developed fuzzy COPRAS in the presence of risk criteria. *Appl. Soft Comput.* **2018**, *65*, 307–319. [CrossRef]
26. Zhou, J.Y.; Ren, D.D. A hybrid model of external environmental benefits compensation to practitioners for the application of prefabricated construction. *Environ. Impact Assess. Rev.* **2020**, *81*, 106358. [CrossRef]
27. Yuan, X.F.; Wang, C.Y. Research on the formation mechanism of information cocoon and individual differences among researchers based on information ecology theory. *Front. Psychol.* **2022**, *13*, 1055798. [CrossRef] [PubMed]
28. Winter, M.; Dopler, S.; Müller, J.M.; Zeisler, A. Information sharing and multi-tier supply chain management of SMEs in the context of Industry 4.0. *Procedia Comput. Sci.* **2023**, *217*, 1378–1385. [CrossRef]
29. Wuni, I.Y.; Shen, G.Q. Stakeholder management in prefabricated prefinished volumetric construction projects: Benchmarking the key result areas. *Built Environ. Proj. Asset Manag.* **2020**, *10*, 407–421. [CrossRef]

30. Ha, A.Y.; Tong, S.L. Contracting and information sharing under supply chain competition. *Manag. Sci.* **2008**, *54*, 701–715. [CrossRef]
31. Wang, M.X.; Wang, Y.X.; Mardani, A. Empirical analysis of the influencing factors of knowledge sharing in industrial technology innovation strategic alliances. *J. Bus. Res.* **2023**, *157*, 113635. [CrossRef]
32. Zhang, M.; Liu, Y.; Ji, B. Influencing Factors of Resilience of PBSC Based on Empirical Analysis. *Buildings* **2021**, *11*, 467. [CrossRef]
33. Gao, M.Q.; Guo, Y.C.; Hou, H.T.; Wang, P.Y.; Wang, S.B. Assembly process based on supply chain management of prefabricated houses using BIM. *Proc. Inst. Civ. Eng.-Struct. Build.* **2023**. [CrossRef]
34. Shashi; Centobelli, P.; Cerchione, R.; Ertz, M.; Oropallo, E. What we learn is what we earn from sustainable and circular construction. *J. Clean. Prod.* **2023**, *382*, 135183. [CrossRef]
35. Kamali, M.; Hewage, K. Life cycle performance of modular buildings: A critical review. *Renew. Sustain. Energy Rev.* **2016**, *62*, 1171–1183. [CrossRef]
36. Wong, W.-P.; Tan, K.H.; Chuah, S.H.-W.; Tseng, M.-L.; Wong, K.Y.; Ahmad, S. Information sharing and the bane of information leakage: A multigroup analysis of contract versus noncontract. *J. Enterp. Inf. Manag.* **2021**, *34*, 28–53. [CrossRef]
37. Hao, C.C.; Du, Q.; Huang, Y.D.; Shao, L.; Yan, Y.Q. Evolutionary Game Analysis on Knowledge-Sharing Behavior in the Construction Supply Chain. *Sustainability* **2019**, *11*, 5319. [CrossRef]
38. Kong, X.; Xu, Q.; Zhu, T. Dynamic Evolution of Knowledge Sharing Behavior among Enterprises in the Cluster Innovation Network Based on Evolutionary Game Theory. *Sustainability* **2020**, *12*, 75. [CrossRef]
39. Chauhan, R.; Kumar, V.; Jana, T.K.; Majumder, A. A Modified Customization Strategy in a Dual-Channel Supply Chain Model with Price-Sensitive Stochastic Demand and Distribution-Free Approach. *Math. Probl. Eng.* **2021**, *2021*, 5549882. [CrossRef]
40. Xu, J.Z.; Zhai, J.Q.; Li, F.E.; Lv, X.C. Research on Diffusion Mechanism of Green Innovation of Cloud Manufacturing Enterprises Based on BA Scale-Free Agglomeration Network Game. *IEEE Access* **2020**, *8*, 226907–226920. [CrossRef]
41. Barabasi, A.L.; Albert, R. Emergence of scaling in random networks. *Science* **1999**, *286*, 509–512. [CrossRef]
42. Qiu, T.; Liu, J.; Si, W.S.; Wu, D.O. Robustness Optimization Scheme With Multi-Population Co-Evolution for Scale-Free Wireless Sensor Networks. *IEEE Acm Trans. Netw.* **2019**, *27*, 1028–1042. [CrossRef]
43. Broido, A.D.; Clauset, A. Scale-free networks are rare. *Nat. Commun.* **2019**, *10*, 1017. [CrossRef] [PubMed]
44. Zhu, P.P.; Shen, J.; Xu, M. Study on the evolution of information sharing strategy for users of online patient community. *Pers. Ubiquitous Comput.* **2020**, *27*, 689–695. [CrossRef]
45. Zhang, L.P.; Xue, L.; Zhou, Y. How do low-carbon policies promote green diffusion among alliance-based firms in China? An evolutionary-game model of complex networks. *J. Clean. Prod.* **2019**, *210*, 518–529. [CrossRef]
46. Deng, S.; Zhou, D.; Wu, G.; Wang, L.; You, G. Evolutionary game analysis of three parties in logistics platforms and freight transportation companies' behavioral strategies for horizontal collaboration considering vehicle capacity utilization. *Complex Intell. Syst.* **2023**, *9*, 1617–1637. [CrossRef]
47. Cheng, H.L.; Li, J.; Lu, J.; Lo, S.L.; Xiang, Z.Y. Incentive-Driven Information Sharing in Leasing Based on a Consortium Blockchain and Evolutionary Game. *J. Theor. Appl. Electron. Commer. Res.* **2023**, *18*, 206–236. [CrossRef]
48. Shi, P.Z.; Hao, Y.; Sun, C.L.; Zhang, L.J. Evolutionary game and simulation analysis on management synergy in China's coal emergency coordination. *Front. Environ. Sci.* **2023**, *11*, 1062770. [CrossRef]
49. Zhu, Q.; Zong, R.; Xu, M. Three-Party Stochastic Evolutionary Game Analysis of Supply Chain Finance Based on Blockchain Technology. *Sustainability* **2023**, *15*, 3084. [CrossRef]
50. Shore, A.; Prena, K.; Cummings, J.J. To share or not to share: Extending Protection Motivation Theory to understand data sharing with the police. *Comput. Hum. Behav.* **2022**, *130*, 107188. [CrossRef]
51. Jarvenpaa, S.L.; Staples, D.S. The use of collaborative electronic media for information sharing: An exploratory study of determinants. *J. Strateg. Inf. Syst.* **2000**, *9*, 129–154. [CrossRef]
52. Berman, F.; Chien, A.; Cooper, K.; Dongarra, J.; Foster, I.; Gannon, D.; Johnsson, L.; Kennedy, K.; Kesselman, C.; Mellor-Crummey, J.; et al. The GrADS project: Software support for high-level grid application development. *Int. J. High Perform. Comput. Appl.* **2001**, *15*, 327–344. [CrossRef]
53. Fan, K.; Wang, S.Y.; Ren, Y.H.; Li, H.; Yang, Y.T. MedBlock: Efficient and Secure Medical Data Sharing Via Blockchain. *J. Med. Syst.* **2018**, *42*, 136. [CrossRef]
54. Vest, J.R.; Gamm, L.D. Health information exchange: Persistent challenges and new strategies. *J. Am. Med. Inform. Assoc.* **2010**, *17*, 288–294. [CrossRef] [PubMed]
55. Seraj, M. We Create, We Connect, We Respect, Therefore We Are: Intellectual, Social, and Cultural Value in Online Communities. *J. Interact. Mark.* **2012**, *26*, 209–222. [CrossRef]
56. Li, X.; Wang, C.; Alashwal, A.; Bora, S. Game analysis on prefabricated building evolution based on dynamic revenue risks in China. *J. Clean. Prod.* **2020**, *267*, 121730. [CrossRef]
57. Wang, T.; Li, J.; Li, Y. Optimal information sharing strategy for retailer under competitive manufacturers-innovation investment. *Control Decis.* **2020**, *35*, 3006–3016.
58. Wu, J.; Zong, Y.; Liu, X. Cooperative Advertising in Dual-Channel Supply Chain Under Asymmetric Demand Information. *Int. J. Electron. Commer.* **2023**, *27*, 100–128. [CrossRef]
59. Shen, Y.; Xu, M.; Lin, Y.; Cui, C.; Shi, X.; Liu, Y. Safety Risk Management of Prefabricated Building Construction Based on Ontology Technology in the BIM Environment. *Buildings* **2022**, *12*, 765. [CrossRef]

60. Hoffmann, R.; Kittel, B.; Larsen, M. Information exchange in laboratory markets: Competition, transfer costs, and the emergence of reputation. *Exp. Econ.* **2021**, *24*, 118–142. [CrossRef] [PubMed]
61. Lee, D.; Lee, S.H.; Masoud, N.; Krishnan, M.S.; Li, V.C. Integrated digital twin and blockchain framework to support accountable information sharing in construction projects. *Autom. Constr.* **2021**, *127*, 103688. [CrossRef]
62. Gruzauskas, V.; Burinskiene, A.; Krisciunas, A. Application of Information-Sharing for Resilient and Sustainable Food Delivery in Last-Mile Logistics. *Mathematics* **2023**, *11*, 303. [CrossRef]
63. Wu, Y.; Wang, D.; Ma, F. A study on the competitive dissemination of disinformation and knowledge on social media. *Aslib J. Inf. Manag.* 2023, *ahead-of-print*. [CrossRef]
64. Xie, Y.; Chang, S.; Yan, M.; Zhang, Z.; Wang, X. Environmental influences on cooperation in social dilemmas on networks. *Phys. A Stat. Mech. Appl.* **2018**, *492*, 2027–2033. [CrossRef]
65. Wang, X.; Luo, C.; Ding, S.; Wang, J. Imitating Contributed Players Promotes Cooperation in the Prisoner's Dilemma Game. *IEEE Access* **2018**, *6*, 53265–53271. [CrossRef]
66. Xu, M.Y.; Ma, S.J.; Wang, G. Differential Game Model of Information Sharing among Supply Chain Finance Based on Blockchain Technology. *Sustainability* **2022**, *14*, 7139. [CrossRef]
67. Zhao, D.; Ji, S.-f.; Wang, H.-p.; Jiang, L.-w. How do government subsidies promote new energy vehicle diffusion in the complex network context? A three-stage evolutionary game model. *Energy* **2021**, *230*, 120899. [CrossRef] [PubMed]
68. Nozari, H.; Ghahremani-Nahr, J.; Szmelter-Jarosz, A. A multi-stage stochastic inventory management model for transport companies including several different transport modes. *Int. J. Manag. Sci. Eng. Manag.* **2023**, *18*, 134–144. [CrossRef]
69. Tchouanguem Djuedja, J.F.; Abanda, F.H.; Kamsu-Foguem, B.; Pauwels, P.; Magniont, C.; Karray, M.H. An integrated Linked Building Data system: AEC industry case. *Adv. Eng. Softw.* **2021**, *152*, 102930. [CrossRef]