Simulation on Multiple Supervision Strategy of Construction Waste in China

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Abstract. Along with the rapid urbanization of China, the construction waste disposal becomes an urgent problem than ever before. Through evolutionary game simulation, we studied the evolution law of government - enterprise - social governance system by using simulation and analyzed the case of "12 20" special heavy landslide accident in Shenzhen construction waste dumping site. Results indicate that the economic efficiency of the risk strategies, the strength of social supervision, the punishment intensity of government and the cost coefficient of illegal waste disposal all have a significantly influence on the multi-parties evolutionary game model. It is concluded that, for the effective supervision of construction waste disposal, government should build social supervision mechanism, promote the strength of social supervision, enhance the punishment intensity of government, and reduce the risk income of waste disposal enterprises.

Keywords: Construction Waste Management, Evolutionary Game Simulation, Multiple Supervision Strategy.

1. Introduction

Waste disposal and management belong to complex system. Some scholars have discussed the game problem between government supervision and enterprises pollution. Game models can help get a strategic decision making for participants [1]. In the Game Model, the cost of pollution control, the rate of pollution charge, penalty for local government, implementation cost of environmental regulation, and the reduction of pollutants have great impacts [2, 3]. Yang et al. constructed Bayesian-based models to find feasible way to convert waste crisis [4, 5].

A government-oriented environmental governance system will be built, with enterprise as the main body, involving the social organization and the public participation. It aims to form the government - enterprise - social governance system of construction waste disposal supervision in China. As it is a complex system, a game model of the evolutionary game between the waste disposal enterprise and the government regulators will be built, which is embedded in the social supervision. The process of the game will be analyzed from the group strategy selection between the economic efficiency and the
social supervision exposure. Moreover, it is found and improved the evolution rule of government enterprise social governance system strategy through the simulation.

2. Improvement of strategy analysis and simulation of government - enterprise - social governance system

2.1. Improvement for governance system

China focused on the key problems and weak links of environmental protection, strove to resolve outstanding environmental problems and reform the ecologically environmental supervision system, and put forward “build social management pattern of co-construction, co-governance, co-sharing”, which can not only satisfy the people's new expectations but also provide scientific guidance for the construction and improvement of government - enterprise - social governance system.

Improvement of government-dominated governance system. First, the law and regulation system for waste disposal should be improved. The supervision should be strengthened, the law should be strictly implemented, and environmental violations should be severely cracked down. Second, the pollution emission standard should be improved. The hard constraint should be imposed on the enterprises with waste disposal to achieve the development and protection together. Third, the severe punishment system should be improved. The violation cost should be substantially improved, and the economic efficiency of enterprises with violations for waste disposal should be significantly reduced, which makes the enterprises not go one step beyond the prescribed limit.

Improvement of enterprise-dominated governance system. First, the responsibility of enterprise with the waste disposal should be strengthened. The enterprises with the waste disposal are mainly responsible for the pollution regulation, and they must strictly obey the national laws and regulations as well as the pollution emission standard for legal waste disposal. Second, the environmental credit evaluation should be improved. The environmental credit evaluation is an important component for the social credit system. The simulation mechanism for environmental protection trustworthiness and punishment mechanism for dishonesty are constructed to urge enterprises to continuously improve the environment and legally dispose the waste. The illegal enterprises would be listed in the “Blacklist” by the construction of environmental credit evaluation system, which would make dishonest enterprises hard to move forward. Third, the system for the mandatory disclosure of environmental information should be established. The enterprises should open environmental information by themselves, which could benefit the conscious implementation of environmental social responsibility as well as government and social supervision.

Improvement of social organization and public participation governance system. On the one hand, the public should be guided and pushed to participate in the government - enterprise - social governance system. The social management ideas should be innovated, the governance system should be expanded and opened, as well as some methods should be adopted, such as environmental publicity increase, simulation and restraint mechanisms improvement, and so on, so as to form a good situation with everyone involved and everyone’s duty. On the other hand, social organizations and public management should be standardized. More attention should be paid to the guidance of social organizations and the public to form the environmental protection supervision and management mechanism involving in the social organizations and the public. Starting from the scope, ways and methods of social organizations and the public for environmental supervision, the participation behaviors of the social organizations and the public are standardized to drive the social organizations and the public to implement self-management, self-service and self-supervision according to the law in the governance system.

2.2. Simulation of strategy effect

2.2.1. The evolution game model of government-enterprise-social governance system. Take $R_1$ denote the enterprise profits earned from waste disposal, $C_1$ denote the cost associated with legal disposal of
waste, B denote the fees that the government pays to enterprises according to national regulations (transfer payment) after it is confirmed that waste is being legal treated with relevant rules, R₂ denote the reputation earned by the government regulators (utility), and C₂ denote the cost associated with government supervision including the human, material and financial resources invested for the investigation of waste disposal and evidence collection. Cost of waste disposal will decrease if enterprises disposal the waste illegally by failing to implement air pollutant filtering procedures, emitting air pollutants directly, or diluting landfill leachate to below the stipulated standard. Let α denote the coefficient of cost associated with illegal waste disposal (0<α<1), and αC₁ denote the cost associated with illegal waste disposal. The smaller the α, the more serious the illegal waste disposal is, the lower the cost of waste disposal. Let P denote the fine imposed on enterprises by the government due to illegal waste treatment, and P>R₁. Also, let γ denote the possibility that social organizations and the general public expose enterprises that dispose of waste illegally, and 0<γ≤1. The possibility that the violation is not revealed is (1-γ). Let R₀ denote the loss of government reputation and credibility after the legal violation is exposed by social organizations and the general public.

Construction waste disposal enterprises have two strategic options: legal disposal or illegal disposal. The government regulators also have two strategic options: supervision or without Supervision. Definition of these options results in the payoff matrix shown in Table 1.

|                | Government regulators |                  |
|----------------|-----------------------|------------------|
|                | Supervision           | Without Supervision |
| Construction waste disposal enterprises | R₁C₁+B, R₂C₂ | R₁C₁+B, R₂ |
| Legal disposal  | R₁-αC₁-P, R₂          | γ(R₁-αC₁-P) + (1-γ)(R₁- αC₁+B), γ(-R₀) + (1-γ)R₂ |
| Illegal disposal| R₂-C₂                  |                  |

Table 1. The payoff matrix of the social supervision-based game.

2.2.2. Increase the punishment for violations (P). Figure 1 shows the evolutionary results of increase the punishment for violations, in which the horizontal coordinates represent the time, the vertical coordinates represent the probability x of legal waste disposal by enterprises and the supervision probability y of government regulators. The initial values of x₀ and y₀ are 0.3 and 0.7 in Figure 1 (a), respectively. Likewise, the initial values of x₀ and y₀ are 0.7 and 0.3 in Figure 1 (b), respectively. The simulations are carried out for three times as the penalty P of enterprise increases to 5P and 10P, respectively. The results show that the probability x of legal waste disposal by enterprises faster converge to 1 as well as the probability y of government supervision converge to 0 as soon as possible with the increase of the penalty P. Namely, when the punishment for the enterprise is more serious, the enterprises dare not violate the rules but quickly obey the legal waste disposal. Simultaneously, the social supervision can replace the government supervision, so the government would decrease the cost in a way without supervision as quickly as possible.

![Figure 1](image_url)
2.2.3. Increase the cost coefficient of illegal waste disposing ($\alpha$). The increase in the cost coefficient of illegal waste disposal denoting that the impetus improvement of active waste disposal and the decrease of the illegal waste disposal. Figure 2 describes the evolutionary results of increasing the cost coefficient $\alpha$ of illegal waste disposal. The initial values of $x_0$ and $y_0$ are 0.3 and 0.7 in Figure 2 (a), respectively; the initial values of $x_0$ and $y_0$ are 0.7 and 0.3 in Figure 2 (b), respectively; three times of simulations are carried out as $b$ is 0.1, 0.5 and 0.9, respectively. The results suggest that the probability $x$ of legal waste disposal by enterprises more slowly converges to 1 with $\alpha$ increasing, and the probability $y$ of government supervision more slowly converge to 0, which means that the higher the cost coefficient of illegal waste disposal is, the more difficult the illegal waste disposal to be found is. Thus the illegal waste disposal would be slowly changed to the legal waste disposal. It would be a longer period of time for government to supervise the illegal waste disposal of enterprises until they adopt the legal waste disposal strategy.

![Figure 2. Simulation on increasing the cost coefficient of illegal waste disposing.](a) (b)

2.2.4. Increase the social supervision probability ($\gamma$). Figure 3 shows the evolutionary results for the improvement of social supervision probability. The initial values of $x_0$ and $y_0$ are 0.3 and 0.7 in Figure 3 (a), respectively. The initial values of $x_0$ and $y_0$ are 0.7 and 0.3 in Figure 3 (b), respectively. The results show that the probability $x$ of legal waste disposal by enterprises quickly converge to 1, and the probability $y$ of government supervision more slowly converge to 0 with $\gamma$ increasing, which means that the higher the probability of social supervision is, the easier the illegal waste disposal by enterprises to be found is. Hence, the enterprises dare not hold any fluky mentality for the illegal waste disposal, and they would faster take the legal waste disposal measures. If the enterprise violation is exposed by social supervision, the government would lose the reputation and credibility. So the larger the social supervision probability is, the longer the time of government supervision is.

![Figure 3. Simulation results of increasing the social supervision.](a) (b)
3. Case Study

3.1. Accident overview
In recent years, with the gradually serious situation of urban garbage disposal, various accidents occurred frequently. "12•20" extraordinarily serious landslide accident in Shenzhen construction waste dump site as a typical event has caused 73 deaths, 17 injuries, left 4 others missing. Buried or damaged 33 buildings, affected 90 enterprises, and involved 4630 employees. The direct economic loss caused by the accident reached RMB 881 million. This urban garbage disposal accident of this magnitude has been rarely seen in China in terms of the tragic casualty, profound influence and extensive range.

3.2. Accident analysis
- Enterprises overemphasize the pursuit of profit. Currently, due to defective system construction in China, punishment on illegal and law-breaking is not strong enough when Chinese enterprises are carrying out urban waste disposal, Therefore, enterprise illegal disposal behaviors mainly depend on self-restraint. Hong Ao waste dump site which carryout illegal landfills low cost could also attain huge revenues. As a result, the actual operating companies, Shenzhen Yixianglong Investment Development Co., Ltd. and Lvwei Property Co., Ltd. excessively pursued benefit maximization and severely lacked the awareness of safety production, and repeatedly disregarded local citizens’ disclosure of accident potential dangers.
- Lack of government supervision mechanism. There exist supervisory omissions and dereliction in Shenzhen Municipality and its local urban management departments before the accident. Hong Ao waste dump site just re-applied and proceeded water and environmental protection assessment procedures. Next, the “Certificate of Temporary Reception Venue” was reissued to Hong Ao waste dump site, which aggravated the hidden peril of the accident.
- Defective social supervisory mechanism. Social supervisory organizations represented by social organizations and the public played a certain role in supervising enterprises and regulatory departments. Channels for social supervision are single. Before the accident, local citizens could only seek help from the police and the media to report and disclose the illegal garbage disposal in Hong Ao waste dumping site, indirectly clamped down on the company involved, but failed to report the issue immediately to authorities. The government didn’t pay enough attention to social supervision. Local citizens had written to the provincial government departments to report hidden dangers in Hong Ao waste dumping site but the relevant regulatory authorities in Guangming District treated it with indifference, thus breeding disaster.

4. Results and Suggestions
The “12•20” major landslide accident in the construction waste dump in Shenzhen reveals that when the waste disposal enterprise breaks the rule to dispose waste and the government regulators fail to perform their functions, social supervision plays a part in the evolution of game process of the players. However, the risk strategy income of the waste disposal enterprises and the government regulators far outweigh the cost in the case. Finally, this leads to the unfortunate accident. Therefore, the case reveals:
- Reduce the risk income of waste disposal enterprises and enhance the violation cost of the enterprises. First, integrate law enforcement resources of all kinds and reinforce supervision on violation of the laws. Integrate law enforcement resources of departments including environmental sanitation, safety supervision, labors and so forth. Reinforce the real time sharing of municipal waste disposal information of the enterprises. Establish enterprise’s big data platform to analyze, assess and predict the illegal handling of waste disposal enterprises. Restrict the means of disposal of waste disposal enterprises and reduce the risk income of enterprises. Second, increase the punishment level to enterprises’ violation.
Perfect the government' supervision system and mechanism of waste disposal, and improve the standards for government performance assessment. First, perfect the governmental waste disposal supervisory system. Reinforce governmental departments’ supervision on municipal waste disposal, subdivide the supervisory duties on waste disposal by governments at different levels. Promote to establish a waste disposal supervision structure led by the party and government departments and supervised by the departments based on laws.

Establish social supervisory mechanism and guarantee its effectiveness. Construct pluralistic means of social supervision and solve the problem that there is only a sole reporting channel. Besides means including report, complaint, suggestion, consultation and so forth, more substantial means of participation such as public contact, citizen survey, hearing, consultation commission and so forth so that the government is informed of public opinions, grasp public demands and enhance the supervisory pertinence and effectiveness.

Establish the feedback mechanism of social supervisory opinions and effectively deliver the message in time. In the process of municipal waste disposal supervision, the social supervision depends on the effective delivery of message to play an active role. In the case, the governmental supervisory department fails to build a good information feedback system with the social organizations and the public, which leads to the unfortunate accident. Therefore, the government needs to establish a feedback mechanism of social supervisory opinions. Moreover, the governmental supervisory departments should collect reports on municipal waste disposal from social supervision on a wide range and share the information in real time. On the other hand, feedback the opinions from social supervision through various means such as setting up private telephone, establishing supervisory website and so forth, publicizing the handling suggestions to lower the asymmetry of the information and to guarantee the timeliness and effectiveness of information delivery.

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