Rev. Int. Contam. Ambie. 38 (Environmental Science and Policy for Sustainable Development) 95-108, 2023
https://doi.org/10.20937/RICA.54590

THE ENVIRONMENTAL QUALITY INSPECTION MODEL OF THE CONSTRUCTION OF SEA CROSSING BRIDGES WITH BASED ON THE EVOLUTIONARY GAME THEORY

Modelo de inspección de la calidad ambiental de la construcción de puentes marítimos con base en la teoría evolutiva de juegos

Dongling ZHANG[1]*, Jian ZHANG[1] and Shugang YU[2]

[1] Department of Civil Engineering, Henan Vocational College of Water Conservancy and Environment, Zhengzhou 450008, China.
[2] Zhengzhou University Multi-Functional Design and Research Academy Co., Ltd., Zhengzhou 450002, China.

*Author for correspondence: fglkuy@126.com

(Received: October 2021; accepted: March 2022)

Key words: construction process, quality testing, multi-party supervision, government, public, construction enterprises.

ABSTRACT

In order to reduce the impact of sea crossing bridge construction on the environment, it is necessary to adopt the method of multi-party supervision to detect the environmental quality in the construction process. Therefore, this paper constructs an environmental quality inspection model of cross-bridge construction based on evolutionary game theory. The model includes the physical means detection model between the government, the public, and construction enterprises and the tripartite evolutionary game supervision model. A reasonable test method is chosen according to the actual situation, game monitoring on the environmental quality of bridge construction is conducted, and the monitoring points are carefully arranged. Finally, the government needs to improve the basic system of pollution management, put forward effective supervision strategies, strengthen supervision measures, establish a pollution evaluation system, and punish enterprises that do not actively control pollution. The construction environmental quality of the sea crossing bridge is obtained through the actual detection, and the supervision improvement strategy is analyzed through the game model.

Palabras clave: proceso de construcción, pruebas de calidad, supervisión multipartita, gobierno, público, empresas constructoras

RESUMEN

Para reducir el impacto de la construcción de puentes marítimos en el ambiente, es necesario adoptar el método de supervisión multipartes para detectar la calidad ambiental en el proceso de construcción. Por lo tanto, este documento construye un modelo de inspección de calidad ambiental de la construcción de puentes marítimos de cruce con base en la teoría evolutiva de juegos. El modelo incluye el modelo de detección de medios físicos entre el gobierno, el público y las empresas de construcción y el modelo de supervisión evolutiva tripartita. Se elige un método de prueba razonable de acuerdo con la situación real, se lleva a cabo un monitoreo de la calidad ambiental de la construcción del puente y los puntos de monitoreo se organizan cuidadosamente. Por último,

el Gobierno debe mejorar el sistema básico de gestión de la contaminación, proponer estrategias eficaces de supervisión, reforzar las medidas de supervisión, establecer un sistema de evaluación de la contaminación y castigar a las empresas que no controlan activamente la contaminación. La calidad ambiental de la construcción del puente de cruce marítimo se obtiene a través de la detección real, y la estrategia de mejora de supervisión se analiza a través del modelo de juego.

INTRODUCTION

China has a long and winding coastline, and its natural geographical advantages provide convenient transportation and fast information for many coastal cities. However, the complex offshore or bay brings inconvenience to life and transportation between the two places. With the continuous progress of science and technology, the cross-sea bridge has gradually become an important traffic building connecting the two sides of small and medium-sized sea areas. The sea crossing bridge refers to the sea bridge across the straits, bays and estuaries, which has a long length, large span and high headroom, so it has a high technical requirement and is the embodiment of the top bridge technology (Lee et al. 2019). At present, the main sea crossing bridges that have been built in China are Xiamen Bridge, Donghai Bridge, Zhoushan Sea crossing bridge and the famous Hangzhou Bay Sea crossing bridge. The construction of cross-sea bridges has dramatically improved the traffic environment, saved distance, and made it convenient for citizens to travel. However, the building of sea crossing bridges has not brought all the positive effects, and the adverse effects also exist correspondingly, mainly reflected in the negative impact of the construction of the sea crossing bridges on the surrounding environment quality (Moreno Ceballo et al. 2019). Under the advocacy of contemporary environmental protection, how to achieve a win-win situation between construction and environmental protection of sea crossing bridge has become the focus of research (Haverinen-Shaughnessy et al. 2018).

In the above context, the environmental quality inspection of the construction of cross-sea bridges is the key to achieve a win-win situation. The environmental quality inspection of construction of sea crossing bridges includes physical inspection and quality supervision (Caceres et al. 2019). The former is better, but there are many problems for the latter. First, there is no a systematic detection system. Second, feasible and efficient policies and measures still need to be innovated. The concrete embodiment is that the construction environment quality inspection demands a systematic project. In the comprehensive implementation of the construction environment quality prevention and control work, it needs the joint efforts of various parties, the unified coordination and management and the guarantee of the relevant organization system. At present, in the process of construction environmental quality testing, all regional departments are independent, there is narrow local protectionism, and they pay too much attention to the interests of the current region and the near-term interests, which leads to the difficulty of mutual promotion and coordination in construction environmental quality testing (Liu et al. 2019). Secondly, the effect of policies and measures for construction environmental quality inspection is also unsatisfactory, because there are differences in the expression of demands of multi stakeholders involved in construction environmental quality inspection. For example, in the implementation of quality inspection, due to the serious pollution caused by some high pollution and high energy consumption construction, when the government closes it according to law, it will affect the interests of these construction enterprises and even local governments. There will be some resistance and protest, so as to respond negatively. If we want to improve the efficiency and benefit of the construction environmental quality inspection of the bridge, we can only cooperate with each other, and assist each other. In order to reduce the impact of sea crossing bridge construction on the environment, it is necessary to adopt the method of multi-party supervision to detect the environmental quality in the construction process. This paper takes this as the starting point, explores the evolution process of supporting selection made by multiple subjects with the idea of game theory. The essence of the selection of various measures and policies in the environmental quality inspection of the construction of the cross sea bridge is the sub optimal choice made by multiple stakeholders based on their own interests and values, which is an effective implementation and rapid change of the protection and governance of the construction environment is of great significance.

GAME MODEL OF ENVIRONMENTAL QUALITY INSPECTION IN THE CONSTRUCTION OF SEA CROSSING BRIDGES

The environmental impact factors of the construction of sea crossing bridges run through the whole project, including preparation, construction period and operation period.

1) Early stage of construction. During the construction period, road filling, foundation excavation and other engineering activities will lead to surface vegetation destruction, surface disturbance, soil exposure and local landform change. Construction activities such as land acquisition, foundation construction, material and equipment and earthwork transportation will occupy and destroy urban roads and increase traffic load. Some demolition and resettlement will have a certain impact on the quality of life of residents (Magdovitz et al. 2020).
2) Construction period. Noise generated by excavators, pile drivers, heavy loaders, transport vehicles and other mechanical equipment during construction will affect the surrounding residential areas, schools, hospitals and other sensitive points. Wastewater from production and operation during construction, especially mud wastewater from bored pile construction, and domestic sewage discharged from the construction site will affect the surrounding areas. Construction work will affect the environment. The impact of gas is represented by dust pollution, which mainly comes from earthwork, surface excavation and transportation (Wu et al. 2018).
3) Analysis of environmental impact characteristics during operation period. The environmental impact during the operation period mainly comes from the pollution impact of vehicle noise and exhaust gas on the surrounding environment, as well as the landscape impact of roads and bridges on the surrounding environment (He et al. 2020).

In this form, the quality and effect of environmental testing is particularly important. Environmental inspection includes physical inspection and quality supervision. However, the process of quality supervision will be affected by various factors such as procedures, which will lead to the deviation of the final environmental testing results. Therefore, it is necessary to strengthen the supervision of this process to ensure the quality of environmental testing. Under normal circumstances, in the process of environmental testing, the whole program blank is used to control the internal quality. In addition, we should give full play to the role of supervisors and record the environmental conditions, distribution, operation specifications, and other behaviors through supervisors. If there is a sudden situation, we can also find problems in time through monitoring data to prevent problems from evolving. Therefore, it is necessary to strengthen the supervision of weak links of environmental quality in environmental testing. Only by strengthening the quality supervision and management and establishing the supervision and supervision system can the quality of environmental testing be continuously improved (Elwin et al. 2020). Therefore, from the perspective of evolutionary game theory, this paper analyzes the environmental supervision, and takes it as an innovation point to improve the environmental quality detection model of the construction of sea crossing bridges (**Fig. 1**).

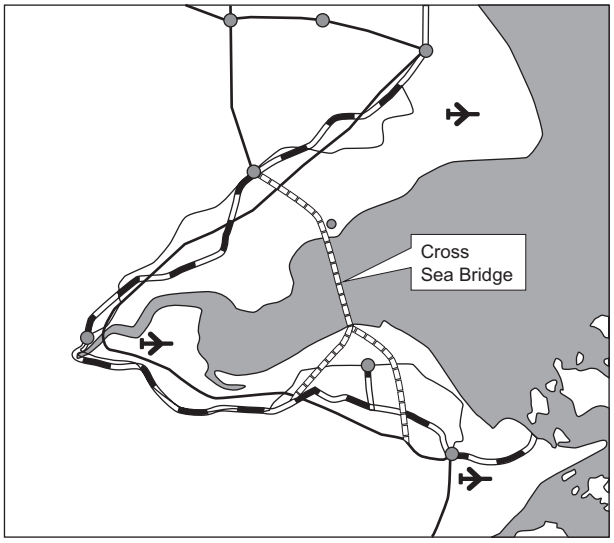

Fig. 1. The sea crossing bridge area studied in this paper.

Physical inspection of construction environment quality of sea crossing bridges

The physical inspection of the construction environment quality of cross-sea bridges is divided into three points: environmental testing instruments, environmental testing methods and testing points. The following three aspects are described.

Environmental testing instrument

Detection instrument is the most basic equipment in the whole process of environmental detection.

Therefore, the quality of environmental testing instruments is directly related to the quality of the final environmental testing (Zuo et al. 2020). In every testing link, the sensitivity and precision of the instrument will be required. If there is a problem with the detector itself, it will lead to the deviation of the sample results (Glinskii et al. 2020). At the same time, different instruments are generally required for the detection of different samples to ensure the accuracy. Environmental quality testing instruments are generally various sensors, as shown in **Table I.**

Environmental testing method

Every environmental quality inspection has its own inspection method. Under normal circumstances, the detection method will be selected according to the national or industrial standards. If there is no standard, the relevant testing personnel shall select appropriate testing instruments and methods according to the tested substances to ensure the accuracy of the test data. To ensure the quality of environmental testing, it is necessary to select a reasonable test method based on the actual situation in order to improve the quality of testing (Watanabe et al. 2018). The environmental detection method is shown in **Table II**.

Detection of the distribution of points

Under normal circumstances, the distribution of points will also affect the quality of environmental testing. The so-called point layout is the point location of environmental detection. The setting of point locations should be arranged according to the specified requirements (Yang et al. 2020). Meanwhile, the representativeness and integrity of point locations should be considered. The pollution sources should be avoided to ensure the quality of the final environmental testing as much as possible. However, many staff members lack prudence and careful consideration when choosing the location, such as neglecting the influence of the weather, resulting in the lack of authenticity of the final detected data, which affects the quality of final environmental testing (Zacharski et al. 2018). At the same time, there are also some staff who select the detection points through detailed evaluation and calculation. However, due to the special environmental factors, it is difficult to foresee the impact of these factors on environmental detection.

Game monitoring of construction environment quality of sea crossing bridges

At present, there are still some deficiencies in the research of environmental quality supervision,

TABLE I. ENVIRONMENTAL TESTING INSTRUMENTS.

Category	Testing instrument
Special instrument for air quality inspection	SP sampler (large and medium flow); PM10 sampler (large and medium flow); PM2.5 sampler; coarse (PM2.5-10) fine (PM2.5) particulate dual channel sampler; air particulate classification sampler; dust sampler; acid rain automatic sampler; gas sampler; gas monitor (SO_2, NOx, CO, O_3, HC1, $C1_2$, CH, etc.); ambient air ground automatic monitoring system; smoke dust sampler; flue gas sampler; on-line automatic monitoring system of flue gas; on-line automatic monitoring system of flue gas SO_2; on-line automatic monitoring system of flue gas NOx; on-line automatic monitoring system of flue gas parameters O_2, humidity, pressure, flow rate, etc.; photochemical smoke monitoring system
Special instrument for environmental water quality detection	Water quality sampler; sewage sampler; COD meter; BOD meter; oil concentration meter; dissolved oxygen meter; colorimeter; turbidity meter; salinemeter; total organic carbon (TOC) meter; total nitrogen meter; total phosphorus meter; ammonia meter; cyanide meter; free chlorine meter; automatic monitoring system of environmental water quality; sewage flow measurement and online continuous monitoring system; automatic and continuous monitoring system of pollutants
Emergency detection instrument for environmental pollution accident	Portable gas chromatograph (with PID detector, which can monitor most organic pollutants in the field); vehicle mounted X-ray fluorescence spectrometer (which can be used for the investigation of metal pollution in soil and solid waste field); vehicle mounted GC/MS instrument; portable spectrophotometer; toxic and harmful gas monitor ($C1_2$, CO, combustible gas, CH_4, benzene series, etc.); alarm device (CO, CH_4, $C1_2$, H_2S, gasoline leakage, etc.); simple and fast detection tube; fast BOD tester; portable dissolved oxygen tester; mobile monitoring vehicle
Testing instruments for other elements	Noise monitor; automatic noise monitoring system; vibration monitor; field strength meter; omni-directional broadband field strength meter; broadband electromagnetic field strength meter; power frequency field strength meter; large area screen ionization chambers a spectrometer; whole body counter; environmental radiation dose rate meter; remote sensing and telemetering system of ecological environment; operation state monitor of environmental protection facilities and monitoring instruments

TABLE II. ENVIRONMENTAL TESTING METHOD.

Category	Testing instrument
Optical instruments	Visible spectrophotometer; ultraviolet spectrophotometer; fluorescence spectrophotometer; flame photometer atomic absorption spectrophotometer; atomic fluorescence photometer; plasma emission spectrometer; X-ray fluorescence spectrometer
Electrochemical instrument	PH meter, ion meter, potentiometer, oscillopolarograph, anode dissolution meter, conductivity meter
Chromatographic instruments	Ion chromatograph; gas chromatograph; high pressure liquid chromatograph; gas chromatography-mass spectrometry; liquid chromatography-mass spectrometry; chromatography-Fourier infrared spectroscopy
Biological monitoring instruments	Biological microscope; biochemical incubator; stereomicroscope; biological sample processing equipment and chemical composition analysis instrument

most of which are related to the problems between governments and enterprises. However, in the process of supervision, it is necessary to study the game relationship between the government and enterprises, the public and enterprises, and the government and the public. Therefore, this paper constructs an evolutionary game model among regulators, the public, and construction enterprises, analyzes their strategic choice and the influence of parameters, and presents the evolutionary stable equilibrium solution (Tang et al. 2018; Yu et al. 2020).

Research background of evolutionary game theory

Game theory, is a theory and method to study how individuals or organizations make decisions and balance decisions based on the information they have under certain environmental conditions and rules constraints, and to obtain corresponding results or benefits from their respective decisions. "Prisoner's dilemma" is a classical model in game theory, which reflects the contradiction between individual rationality and collective rationality, and is the best and simplest abstraction of the phenomenon of non-cooperation in human society (Fishman 2020, Lam 2019, Paudel et al. 2019).

In the traditional classical game model, it is assumed that the participants are completely rational, but in real life, for decision-makers, it is difficult to achieve complete rationality, which is limited by the social environment and people's thinking limitations. When the evolutionary game theory is introduced into the analysis of biological evolution phenomenon, organisms are regarded as participants of limited rationality.

With the deepening of the research on evolutionary game theory, many economists introduced evolutionary game theory into the field of economics, which was used to analyze the social institutional change, industrial evolution and stock market, etc. At the same time, the research on evolutionary game theory began to deepen from symmetric game to asymmetric game, and made some achievements (Li and Li 2020, Zhang and Gao 2019). Since the 21st century, evolutionary game theory has made further development. Some scholars have discussed the cooperative evolutionary game problem with one side imitating and the evolutionary game problem with random disturbance benefit. These studies make the evolutionary game theory system more perfect.

Evolutionary game model has been successfully applied to economics, management, sociology and other research fields, which reasonably explains many phenomena in the process of economic and social development, and also provides a scientific forecast for some development trends of economy, management and society, and then has made great achievements (Hai et al. 2020, Sun et al. 2019). It can be said that evolutionary game theory has gradually become the economic management hot area. In short, the application of evolutionary game theory has penetrated into all walks of life. Therefore, based on evolutionary game theory, this chapter establishes environmental supervision model and strengthens the role of supervision in environmental detection. Only by strengthening the quality supervision and management and establishing the supervision and supervision system can the quality of environmental testing be continuously improved.

Model hypothesis

The evolutionary game does not need the condition that participants are rational and complete information. It analyzes the interaction and co evolution of participants through dynamic discussion.

A three-party game model is established. The main body of the model is the construction enterprises, the local governments and the public that implement the supervision, and the following assumptions are put forward respectively:

1) It is assumed that the economic benefit of normal operation of the construction enterprise is R. If the construction enterprise actively implements energy conservation and emission reduction to control pollution, it needs to pay the treatment cost C_1. However, if the construction enterprise does not control the pollution, it will get higher profits, but the environmental degradation will be criticized by the public, so it will appeal to the government or sue the enterprise, which will affect the reputation of the construction enterprise. Therefore, in the case of public participation in supervision, the enterprise causing environmental pollution will pay ecological compensation CP to the public according to the requirements of the government. The most direct way for the government to encourage the construction enterprises to actively implement energy conservation and emission reduction is to give economic incentives. Therefore, assuming that the construction enterprises will get a compensation from the local government for pollution control, it is recorded as P. With the improvement of social requirements for the environment and the public awareness of environmental protection, people will prefer to buy green products, which means that enterprises that pay attention to environmental protection will have greater sustainable competitive advantage in the long run. We record the reputation and competitive advantage lost by construction enterprises due to environmental pollution as reputation cost H_1. With the development of the times, the public awareness of environmental protection continues to improve, green production will certainly become a trend, the reputation cost of enterprise pollution H_1 will increase significantly, and enterprise pollution will not be worth the loss.
2) In order to punish the construction enterprises, the government will get a profit f by imposing a fine (or environmental tax) on them. At the same time, the government needs to pay a regulatory cost C_2, including a large number of human, material and financial resources. However, if the local government is lax in the supervision work, and the pollution is aggravated by the serious pollution discharge, the government will encounter more complaints and petitions, and lose trust with the public. Here, we call the losses caused by the local government's lax supervision, the public's accusation of allowing pollution, and the influence of prestige as political costs as H_2.
3) For the public, actively participate in the supervision of environment and construction enterprises. If problems are found and reported to the government in time, C_3 supervision cost will be paid. The pollution behavior of construction enterprises will directly cause damage to the public, which is recorded as D.

The establishment of tripartite game model

The tripartite game matrix under the condition of public participation and non-participation in supervision is shown in **tables III** and **IV**.

TABLE III. TRIPARTITE GAME MATRIX UNDER PUBLIC PARTICIPATION AND SUPERVISION.

Construction enterprises	Government	
	Detect	No detect
Pollution	(R-H_1-F-C_P, F-C_2, -C_3+C_P-D)	(R-H_1, -H_2, -C_3-D)
No pollution	(R-C_1+P, -C_2-P, -C_3)	(R-C_1, 0, -C_3)

TABLE IV. TRIPARTITE GAME MATRIX WITHOUT PUBLIC PARTICIPATION IN SUPERVISION.

Construction enterprises	Government	
	Detect	Detect
Pollution	(R-F-H_1, F-C_2, -D)	(R-H_1, -H_2, -D)
No pollution	(R-C_1+P, -C_2-P,0)	(R-C_1,0,0)

If the probability that the construction enterprise still chooses to discharge pollution is x_1, the probability that the enterprise does not discharge pollution is $x2$. If the probability of local government implementing supervision strategy is Y_1, the probability of local government not implementing supervision strategy is Y_2. If the probability of public participation in supervision is Z_1, the probability of public non participation in supervision is Z_2. Construction enterprises, government and the public are represented by S_1, S_2 and S_3 respectively.

1) Game strategy of construction enterprises
According to the payment matrix, the expected return functions of pollution and non-pollution for construction enterprises can be calculated as follows:

$$\begin{aligned} S11 &= \left(\mathrm{R}-\mathrm{H}_1-\mathrm{F}-\mathrm{C}_\mathrm{P}\right)y1z1+ \\ &\left(\mathrm{R}-\mathrm{F}-\mathrm{H}_1\right)y1z2 \\ &+\left(\mathrm{R}-\mathrm{H}_1\right)y2z1+\left(\mathrm{R}-\mathrm{H}_1\right)y2z2 \\ &=-\mathrm{C}_\mathrm{P}y1z1-Fy1+R+\mathrm{H}_1 \end{aligned} \tag{1}$$

$$\begin{aligned} S12 &= \left(\mathrm{R}-\mathrm{C}_1+\mathrm{P}\right)y1z1+\left(\mathrm{R}-\mathrm{C}_1+\mathrm{P}\right)y1z2 \\ &+\left(\mathrm{R}-\mathrm{C}_1\right)y2z1+\left(\mathrm{R}-\mathrm{C}_1\right)y2z2 \\ &=Py1+R-\mathrm{C}_1 \end{aligned} \tag{2}$$

The average expected earnings of construction enterprises are:

$$S1 = xS11+x2S12 \tag{3}$$

According to Eq. (1) and Eq. (2), it can be concluded that the replication dynamic differential equation for construction enterprises to choose non pollution is:

$$\begin{aligned} &\frac{dx}{dt}=x1\left(S11-S1\right)= \\ &x1x2\left[-\mathrm{C}_\mathrm{P}y1z1+\mathrm{C}_1-\mathrm{H}_1\right] \end{aligned} \tag{4}$$

In the same way, the average expected return of the government and its replication dynamic differential equation can be calculated.

2) Game strategy of government

$$\begin{aligned} S21 &= \left(\mathrm{F}-\mathrm{C}_2\right)x1z1+\left(\mathrm{F}-\mathrm{C}_2\right)x1z2 \\ &+\left(-\mathrm{C}_2-\mathrm{P}\right)x2z1+\left(-\mathrm{C}_2-\mathrm{P}\right)x2z2 \\ &=\left(-\mathrm{C}_2-\mathrm{P}\right)+x1\left(F+P\right) \end{aligned} \tag{5}$$

$$S22 = -\mathrm{H}_2x1z1-\mathrm{H}_2x1z2=-\mathrm{H}_2x1 \tag{6}$$

$$S2 = y1S21+y2S22 \tag{7}$$

$$\begin{aligned} &\frac{dy}{dt}=y1\left(S21-S2\right)= \\ &y1y2\left[\left(-\mathrm{C}_2-\mathrm{P}\right)+x1\left(F+P+H_2\right)\right] \end{aligned} \tag{8}$$

3) Game strategy of the public

$$\begin{aligned} S31 &= \left(-\mathrm{C}_3+\mathrm{C}_\mathrm{P}-\mathrm{D}\right)x1y1+\left(-\mathrm{C}_3-\mathrm{D}\right)x1y2 \\ &+\left(-\mathrm{C}_3\right)x2y1+\left(-\mathrm{C}_3\right)x2y2 \\ &=\mathrm{C}_\mathrm{P}x1y1-Dx1-C_3 \end{aligned} \tag{9}$$

$$S32 = -Dx1y1+\left(-D\right)x1y2=-Dx1 \tag{10}$$

$$S3 = z1S31+z2S32 \tag{11}$$

$$\frac{dz}{dt}=z1\left(S31-S3\right)=z1z2\left(\mathrm{C}_\mathrm{P}xy-\mathrm{C}_3\right) \tag{12}$$

Let

$$\frac{dx}{dt}=0,\ \frac{dy}{dt}=0,\ \frac{dy}{dt}=0,$$

we can get weight equilibrium points, which are $E1-E8$.

There is an $E9$ in the range .

From:

$$\begin{cases} -\mathrm{C}_\mathrm{P}y1z1+\mathrm{C}_1-\mathrm{H}_1=0 \\ \left(-\mathrm{C}_2-\mathrm{P}\right)+x1\left(F+P+H_2\right)=0 \\ \mathrm{C}_\mathrm{P}xy-\mathrm{C}_3=0 \end{cases} \tag{13}$$

Then:

$$\begin{cases} x=\dfrac{\mathrm{C}_2+P}{F+P+H_2} \\ y=\dfrac{\mathrm{C}_3\left(F+P+H_2\right)}{\mathrm{C}_\mathrm{P}\left(\mathrm{C}_2+\mathrm{P}\right)} \\ z=\dfrac{\left(\mathrm{C}_1-\mathrm{H}_1\right)\left(\mathrm{C}_2+\mathrm{P}\right)}{\mathrm{C}_3\left(F+P+H_2\right)}-\dfrac{F+P}{\mathrm{C}_\mathrm{P}} \end{cases} \tag{14}$$

Game model analysis

1) According to Eq. (14), it can be found that the probability of enterprise emission pollution is

$$x = \frac{C_2 + P}{F + P + H_2}.$$

It can be seen that the strategic choice of enterprises depends on the cost of government supervision, government political cost, government subsidies for pollution control and government fines for enterprise emissions. Therefore, in order to make enterprises reduce the probability of emission pollution, the government should reduce the regulatory cost and increase the punishment of emission. The higher the political cost is, the lower the probability of enterprises choosing emission pollution is (Lin and Wong 2018).

The government's regulatory cost mainly includes the cost incurred in the process of formulating and implementing regulatory provisions. Therefore, in order to reduce the cost of supervision, the central government first needs to improve the environmental protection law and provide legal basis for local governments. On the other hand, local governments and subsidiary bodies must strengthen cooperation and coordination to support the work of the environmental protection office. For the harm to the environment caused by the illegal pollutant discharge of enterprises, the local government needs to appropriately raise the level of fine according to the severity of pollution. The political cost of the government comes from the supervision and restriction of the public to the government, and the active supervision of the government behavior is exactly what the citizens lack. Local officials tend to seek to improve local economic development but ignore the interests of the public and the satisfaction of government performance. To develop the economy, the provincial government will tend to protect the interests of enterprises without actually implementing the regulatory responsibility and making the masses perfunctory (Fugate and Ferguson-Walter, 2019). Therefore, in order to increase the political cost of the government, residents need to exercise the right to restrict and supervise the local government, and at the same time, residents' satisfaction on the performance of pollution reduction should be considered in the evaluation policy.

2) The probability of government regulation is expressed as

$$y = \frac{C_3 (F + P + H_2)}{C_P (C_2 + P)}.$$

Therefore, the probability of government supervision depends on the cost of government supervision, the cost of government politics, the subsidy of government pollution control and the fine of government to enterprises. It is directly proportional to the cost of public supervision and inversely proportional to the compensation of enterprises to the public. When the cost of the public's active participation in pollution monitoring is too high, or it cannot be effectively monitored, the public will fully rely on the government to strengthen the supervision of enterprises. If the government does not strengthen supervision at this time, it will increase the loss of political cost and force the government to strengthen supervision. Similarly, if the pollution compensation of enterprises to the public is too high, the enthusiasm of the public for enterprise supervision will be increased, and the work that the government needs to supervise will be reduced, so the enthusiasm for enterprise supervision will also be reduced. Therefore, while reasonably allocating the rewards and punishments for pollution control, we should appropriately increase the supervision cost of the public, and reasonably formulate the compensation mechanism that enterprises should give to the public, so as to mobilize the enthusiasm of government departments for supervision.

3) The probability of public participation in monitoring pollution is expressed as

$$z = \frac{(C_1 - H_1)(C_2 + P)}{C_3 (F + P + H_2)} - \frac{F + P}{C_P}.$$

Therefore, the probability of public participation is related to government supervision cost, government political cost, government subsidy for pollution control, government fine for enterprise emission, enterprise pollution compensation for the public, enterprise pollution control cost and enterprise reputation cost. $C_1 - H_1$ means that enterprises need to pay their own costs in the choice of pollution and non-pollution strategies. If $C_1 - H_1$ is large, the cost of pollution control will be greater than the cost of pollution. Enterprises will obviously choose to discharge pollution, which will damage the interests of the environment and the public. The public will also strengthen the supervision and petition to protect their own interests.

VALIDATION ANALYSIS

Overview of the study area

XX is the only island county in YY Province, with an important geographical location. The island has a beautiful environment and dense vegetation. The provincial reserve in the island is known as the "international paradise", with more than 130 kinds of national protection. At the same time, it is also the first 4A level Island eco-tourism area in China, and it is the

holy land of tourism and vacation. At present, marine fishery is still the main industry. The county has a sea area of 4600 square kilometers with developed marine fishing industry, and is one of the top 100 aquatic counties in China. However, the local traffic is extremely inconvenient. Taking ferry is the only way for residents and tourists to get in and out of the island, which makes it difficult to give full play to the advantages of the island, and directly restricts the local economic and social development and the further improvement of people's life. The construction of the bridge has become a long history of XX generations. In a long-term isolated overseas XX Island, many people hope to make more contact with the external environment, use local resources, and develop the local economy. This year, on January 20, 2010, the construction of a new cross sea bridge began. Its construction attracts the world's attention. The re construction of the bridge has brought light to XX people. The dreams of generations are coming true. Many experts also believe that once the bridge is completed, XX's location advantage, especially the port wine advantage, will be brought into full play. The island's unique natural ecological environment and resources will double in value, bring great market benefits and investment effects, and form a new investment boom. XX's characteristic industry will enter the fast lane of development, its production and living conditions will be greatly improved. It will attract more tourists to visit the island. At the same time, the construction of the bridge will be in line with the construction of Xinjin Economic Zone in the eastern region of SS City, so that the construction of SS infrastructure will enter a new stage, improve the sharing of island and urban infrastructure, promote the coordinated development of urban-rural integration of SS and XX, effectively expand the development space of the first city, and accelerate the construction of deep-water ports. After the completion of the bridge, the benefits are considerable.

In January XX, the bridge was approved by the provincial development and Reform Commission. Over the past two years, all the preliminary works of the bridge have been progressing smoothly and have the conditions for commencement. On 16th of this year, the Provincial Department of communications officially approved the construction permit for XX bridge construction project.

Environmental quality testing and analysis equipment

The selection of construction environmental quality inspection and analysis equipment in the study area is shown in **Table V**.

TABLE V. ENVIRONMENTAL QUALITY TESTING AND ANALYSIS EQUIPMENT.

Category	Equipment
Testing equipment	$PM_{2.5}$ sampler
	Air particle classification sampler
	Dust sampler
	Gas monitor
	Toxic and harmful gas monitor
	Water sampler
	Sewage sampler
	Turbidimeter
	Automatic monitoring system of environmental water quality
	Mobile monitoring vehicle
	Noise monitor
	Vibration monitor
	Field strength meter
	Environmental radiation dose rate meter
Analytical equipment	Visible spectrophotometer
	Fluorescence spectrophotometer
	Plasma emission spectrometer
	Gas chromatography-mass spectrometry
	GC-FTIR on line

Environmental pollution level

After the environmental parameters are determined, it is difficult to judge the harm to the environment only by the concentration value of various pollutants participating in the evaluation. Therefore, it is necessary to distinguish the sub-indexes of various pollutants (the ratio of the concentration of a certain pollutant to the concentration of the evaluation standard of the pollutant), that is, the single factor evaluation index of environmental quality that represents the degree of water, air and soil pollution. In this paper, the single factor evaluation index collected is evaluated quantitatively and comprehensively by the method of weighted superposition and weighted evaluation. These indexes can reflect the environmental quality macroscopically and facilitate the comparison of regional environmental quality. The environmental pollution level is shown in **table VI**.

Pollution situation

It can be seen from **table VII** that the construction of the XX sea crossing bridge has caused moderate pollution to the local environment, so it is urgent to carry out effective detection and supervision, which can improve the construction environment and make the construction meet the national standards.

TABLE VI. ENVIRONMENTAL POLLUTION LEVEL.

Comprehensive pollution index	Quality status	Class of pollution
0 - 50	Excellent	Grade I
51 - 100	Good	GradeII
01 - 150	Slight pollution	GradeIII (1)
151 - 200	Light pollution	GradeIII (2)
201 - 250	Moderate pollution	GradeIV (1)
250 - 300	Moderate heavy pollution	GradeIV (2)
> 300	Heavy pollution	GradeV

Game analysis of quality supervision

Based on the analysis of the basic situation of the study area, the SD simulation model of evolutionary game is established by MatLab. The main variables involved in the system are determined by the focus analysis of three-party game and the payment matrix, including: the probability of government's choice of supervision, the total revenue of government's tax revenue, the cost of supervision construction enterprises, the penalty for non-governance of construction enterprises, the expected revenue of supervision and the expected revenue of non-supervision, the probability that the industry chooses to continue to pollute, the economic benefits of actively carrying out pollution control, the cost of pollution control, the loss caused by the public refusing to buy the product due to damage, the expected benefits of construction enterprise pollution, the expected benefits of non-pollution, the probability that the public participates in the governance, the tangible and intangible benefits brought to the public by good environmental governance. Based on the causal relationship between the above variables, the study shows their relationship in **figure 2**.

In this paper, the selection of all simulation values is in the sensitivity analysis of government, enterprise and the public to the change of each relevant factor. Therefore, each simulation value does not represent the payment or income value of all parties in the real service-oriented manufacturing project, and different pollution treatment can be assigned according to the actual implementation.

Result analysis

As can be seen from **figure 3**, the probability of corporate polling and public participation (0.01) is a very small mutation in the evolutionary game. However, once they discover that adopting a new strategy will yield higher expected returns, they will quickly switch to a new strategy. In this case,

TABLE VII. POLLUTION OF THE SEA CROSSING BRIDGE.

Project		Sampling point 1	Sampling point 2	Sampling point 3	Sampling point 4	Sampling point 5	Sampling point 6
Air pollution	Maximum value	3.1806	8.0346	24.0148	18.8523	15.7143	
	Minimum value	0.6500	0.6677	0.5955	0.7371	0.3429	
	Arithmetic mean	1.7418	2.2305	2.2264	3.7427	2.6583	
	Index	2.5642	5.8962	17.0539	13.5907	11.2695	
Water pollution	Maximum value	6.0750	8.4069	9.2123	191.5515	385.7143	
	Minimum value	0.4472	0.8808	0.4968	0.9621	0.3369	
	Arithmetic mean	2.0143	3.0239	1.7229	9.6618	18.3530	
	Index	4.5256	6.3175	6.6270	135.6196	273.0498	
Soil pollution	Maximum value	3.0528	3.1354	5.5916	5.2318	5.9083	
	Minimum value	0.4917	0.3077	0.5226	0.1735	0.2754	
	Arithmetic mean	1.1234	1.1717	2.2568	1.3119	1.1702	
	Index	2.3002	2.3668	4.0525	3.8140	4.2589	
Noise pollution	Maximum value	8.3694	12.4600	29.7045	103.3977	457.1429	
	Minimum value	0.4472	0.3854	0.4942	0.9348	0.2449	
	Arithmetic mean	1.5856	2.7693	1.8727	4.7133	12.7664	
	Index	6.0234	9.0255	21.0460	73.1892	323.3748	
Comprehensive pollution index				223.698			
Environmental pollution level				Grade IV (1)			
Quality status				Moderate pollution			

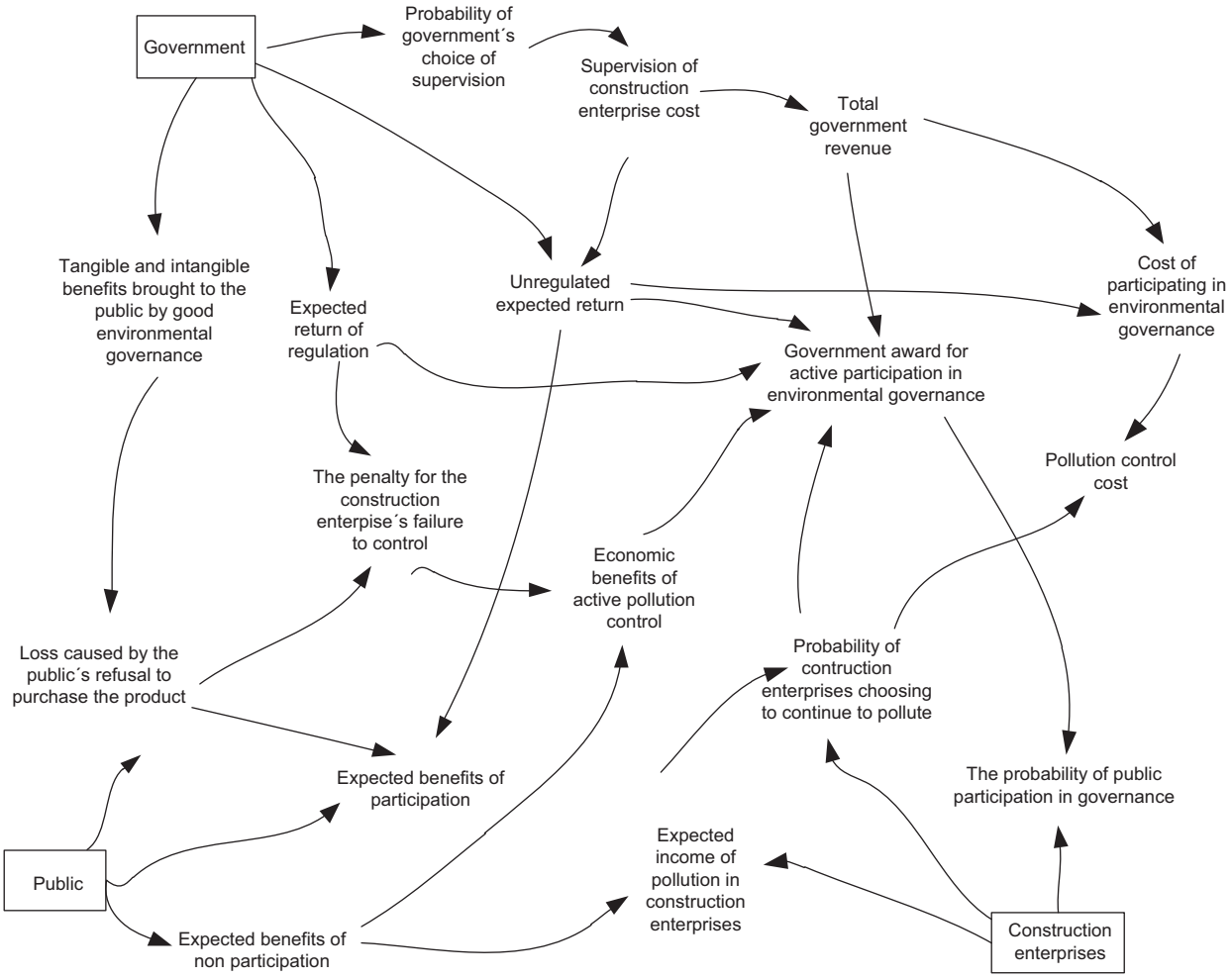

Fig. 2. SD simulation model of evolutionary game.

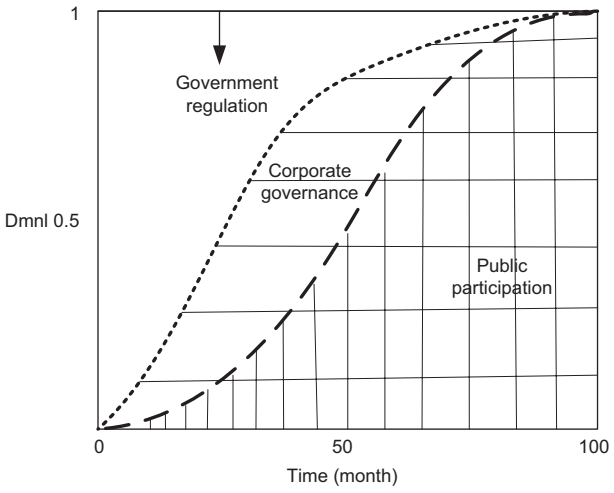

Fig. 3. The changing process of tripartite game.

the system can reach a new equilibrium state and achieve sudden changes in one or more parties through adjustment strategies. Through the simulation of other strategy combinations, it can be found that: 1) When the enterprise pollution changes from 0 to 0.01, it will eventually reach equilibrium state at 1, indicating that the enterprise chooses governance as the best choice; 2) When the public participates in governance, if the government chooses not to supervise, the enterprise will choose strategy 0, that is, it will not work hard, no matter whether it starts from 0 or 1.

DISCUSSION

In this paper, a three-party evolutionary game model of cooperative environment detection is

constructed, and the stability and evolution results of the system under different strategies are analyzed. According to the analysis of the above model, it can be found that enterprises, governments, and the public supervise and restrict each other in the process of collaborative pollution control. The government's participation is core to solving pollution, and the strength of government supervision directly determines the decision-making of enterprises and the public. Based on the above analysis, the following suggestions are put forward:

1) The government needs to improve the basic system of pollution management, strengthen supervision measures, establish pollution assessment system, and clearly define the corporate responsibility in pollution accidents. A perfect evaluation system can not only improve the supervision efficiency and reduce the supervision cost of the government, but also improve the evaluation ability of pollution damage. It can reasonably formulate the pollution compensation of enterprises to the public, reduce the probability of enterprise emission, and increase the probability of government supervision.
2) Whether the construction enterprise takes a positive attitude is closely related to the cost paid by the construction enterprise. In order to limit the pollution discharge of enterprises, the government can punish the enterprises that do not actively control pollution, and should set up different punishment intensity according to different pollution situations. When the amount of punishment exceeds the cost of pollution control, enterprises will choose to participate in pollution control actively, save costs, and implement environmental protection policies. To encourage enterprises to control pollution actively, the government can give specific awards, such as financial incentives or preferential policies, to offset the cost of energy conservation and emission reduction. With this part of the reward, enterprises will have the motive to research better, develop and improve pollution control technology and equipment, and make more significant contributions to pollution control.
3) Public supervision also plays a certain role in the decision-making of enterprises and governments. Effective public participation can increase the strength of government supervision to a certain extent, so as to reduce the pollution of enterprises. However, in fact, the public is in a vulnerable group on this issue, which has neither the right to negotiate directly with enterprises nor the ability to effectively supervise whether the government implements the regulatory responsibility. Therefore, the most effective way of public participation is social media. Through reporting and public opinion, the public can use social media to attract the attention of the whole society and the government. However, in the actual governance, technical barriers are also a big problem. If technology as a whole has not achieved a major breakthrough, the prevention and control of the government, enterprises and the public are still difficult to coordinate. Even if the temporary coordination can be achieved, the overall economy will be affected. With the rapid development of the economy, before the pollution problem worsens to a certain extent, compared with the attention to pollution, the public's desire for materials is more intense, and the economic interests are always ranked in the main position, while the determination and execution of the enterprise and the government will be affected considering the development of the market and economy. In the long run, green development is the fundamental way to solve the dilemma of tripartite game. Only through technological progress and transformation, effectively reducing the cost of emission reduction and pollution control, or turning waste into treasure, can we solve the problem of pollution emission from the source without affecting economic interests. Therefore, a comprehensive understanding of pollution sources and causes is an important research direction. This paper will further combine the influence of pollution sources and other factors on the Yangtze River delta pollution, and study the solution of regional collaborative governance.

CONCLUSIONS

Under the background of rapid economic development, strengthening environmental detection is conducive to maintaining ecological balance. This paper presents the design of environmental quality inspection model for bridge construction based on evolutionary game theory. This paper constructs the detection model from two aspects, physical detection and quality supervision. The physical means detection model and tripartite evolutionary game supervision model between the government, the public and construction enterprises, strengthens the

game monitoring of the environmental quality of bridge construction, and puts forward and analyzes the supervision improvement strategy. However, this paper also has some limitations. In the future research, we will start with the government, the public, and enterprises to put forward more effective strategies for the detection of pollution in the construction environment.

ACKNOWLEDGEMENT

The research is supported by Project for Young Backbone Teachers of Colleges in Henan Province (No. 2019GZGG114).

REFERENCES

Caceres J.O., Sanz-Mangas D., Manzoor S., Pérez-Arribas L.V. and Anzano J. (2019). Quantification of particulate matter, tracking the origin and relationship between elements for the environmental monitoring of the Antarctic region. Science of the Total Environment 665(15), 125-132. https://doi.org/10.1016/j.scitotenv.2019.02.116

Elwin M.L., Freeman R.A. and Lynch K.M. (2020). Distributed environmental monitoring with finite element robots. IEEE Transactions on Robotics 36(2), 380-398. https://doi.org/10.1109/TRO.2019.2936747

Fishman M.A. (2020). Polymorphic evolutionary games and non-mendelian genetics. Bulletin of Mathematical Biology 82(2), 1-11. https://doi.org/10.1007/s11538-020-00705-2

Fugate S. and Ferguson-Walter K. (2019). Artificial intelligence and game theory models for defending critical networks with cyber deception. AI Magazine 40(1), 49-62. https://doi.org/10.1609/aimag.v40i1.2849

Glinskii M.L., Glagolev A.V., Speshilov S.L., Grachev, V.A., Plyamina O.V. and Evseenkova T. A. (2020). Development of environmental monitoring in the vicinity of nuclear energy facilities. Atomic Energy 127(3), 166-173. https://doi.org/10.1007/s10512-020-00605-7

Lin G.W. and Wong S.K. (2018). Evacuation simulation with consideration of obstacle removal and using game theory. Physical Review E 97(6), 062303. https://doi.org/10.1103/PhysRevE.97.062303

Hai X., Wang Z., Feng Q., Ren Y., Xu B., Cui J. and Duan H. (2020). Mobile robot ADRC with an automatic parameter tuning mechanism via modified pigeon-inspired optimization. IEEE/ASME Transactions on Mechatronics 24(6), 2616-2626. https://doi.org/10.1109/TMECH.2019.2953239

Haverinen-Shaughnessy U., Pekkonen M., Leivo V., Prasauskas T., Turunen M., Kiviste M., Aaltonen A. and Martuzevicius D. (2018). Occupant satisfaction with indoor environmental quality and health after energy retrofits of multi-family buildings: Results from INSULAtE-project. International Journal of Hygiene and Environmental Health 221(6), 921-928. https://doi.org/10.1016/j.ijheh.2018.05.009

He L., Shao F. and Ren L. (2020). Sustainability appraisal of desired contaminated groundwater remediation strategies: an information-entropy-based stochastic multi-criteria preference model. Environment. Development and Sustainability 23(2), 1759-1779. https://doi.org/10.1007/s10668-020-00650-z

Lam K.Y. (2019). Dirac-concentrations in an integro-pde model from evolutionary game theory. Discrete and Continuous Dynamical Systems - Series B (DCDS-B) 24(2), 737-754. https://doi.org/10.3934/dcdsb.2018205

Lee J.Y., Wargocki P., Chan Y.H, Chen L. and Tham K. (2019). Indoor environmental quality, occupant satisfaction, and acute building-related health symptoms in Green Mark-certified compared with non-certified office buildings. Indoor Air 29(1), 112-129. https://doi.org/10.1111/ina.12515

Li X.J. and Li X. (2020). Perception effect in evolutionary vaccination game under prospect-theoretic approach. IEEE Transactions on Computational Social Systems 7(2), 329-338. https://doi.org/10.1109/TCSS.2019.2960818

Liu J., Liu Y. and Wang X. (2019). An environmental assessment model of construction and demolition waste based on system dynamics: a case study in Guangzhou. Environmental Science and Pollution Research International 27(8), 37237-37259. https://doi.org/10.1007/s11356-019-07107-5

Magdovitz B.F., Gummalla S., Thippareddi H. and Harrison M. (2020). Evaluating environmental monitoring protocols for listeria spp. and listeria monocytogenes in frozen food manufacturing facilities. Journal of Food Protection 83(1), 172-187. https://doi.org/10.4315/0362-028X.JFP-19-190

Moreno Ceballo R., Gonzalez Herrera R., Paz Tenorio J.A., Aguilar Carboney J.A. and Carpio Penagos C.U. (2019). Effects of sediment thickness upon seismic amplification in the urban area of Chiapa de Corzo, Chiapas, Mexico. Earth Sciences Research Journal 23(2), 111-117. https://doi.org/10.15446/esrj.v23n2.72623

Paudel A., Chaudhari K., Long C. and Gooi H.B. (2019). Peer-to-peer energy trading in a prosumer-based community microgrid: A game-theoretic model. IEEE Transactions on Industrial Electronics 66(8), 6087-6097. https://doi.org/10.1109/TIE.2018.2874578

Sun R., Wei Z., Lyu Z., Ding X., Shi L. and Hu S. (2019). Power control algorithm based on non-cooperative game theory in successive interference cancellation. Wireless Networks 25(6), 3297-3305. https://doi.org/10.1007/s11276-018-1722-3

Tang C.H., Lin C.Y., Sun P.P., Lee S.H. and Wang W.H. (2018). Modeling the effects of Irgarol 1051 on coral using lipidomic methodology for environmental monitoring and assessment. The Ence of the Total Environment 627(15), 571-578. https://doi.org/10.1016/j.scitotenv.2018.01.276

Watanabe T., Enomoto R., Muraishi H., Katagiri H., Kagaya M., Fukushi M., Kano D., Satoh W., Takeda T., Tanaka M.M., Tanaka S., Uchida T., Wada K. and Wakamatsu R. (2018). Development of an omnidirectional gamma-ray imaging Compton camera for low-radiation-level environmental monitoring. Japanese Journal of Applied Physics 57(2), 026401.1-026401.5. https://doi.org/10.7567/JJAP.57.026401

Wu H., Tang X., Wang Z., Wu L., Lu M., Wei L. and Zhu J. (2018). Probabilistic automatic outlier detection for surface air quality measurements from the China national environmental monitoring network. Advances in Atmospheric Sciences 35(12), 1522-1532. https://doi.org/10.1007/s00376-018-8067-9

Yang C., Gao F. and Dong M. (2020). Energy efficiency modeling of integrated energy system in coastal areas. Journal of Coastal Research 103(sp1), 995. https://doi.org/10.2112/SI103-207.1

Yu D., Mao Y., Gu B., Nojavan S. and Nasseri M. (2020). A new LQG optimal control strategy applied on a hybrid wind turbine/solid oxide fuel cell/ in the presence of the interval uncertainties. Sustainable Energy, Grids and Networks 21, 100296. https://doi.org/10.1016/j.segan.2019.100296

Zacharski K.A., Southern M., Ryan A. and Adley C.C. (2018). Evaluation of an environmental monitoring program for the microbial safety of air and surfaces in a dairy plant environment. Journal of Food Protection 81(7), 1108-1116. https://doi.org/10.4315/0362-028X.JFP-17-464

Zhang J. and Cao M. (2019). Strategy competition dynamics of multi-agent systems in the framework of evolutionary game theory. IEEE Transactions on Circuits and Systems II: Express Briefs 67(1), 152-156. https://doi.org/10.1109/TCSII.2019.2910893

Zuo X., Dong M., Gao F. and Tian S. (2020). The modeling of the electric heating and cooling system of the integrated energy system in the coastal area. Journal of Coastal Research 103(sp1), 1022. https://doi.org/10.2112/SI103-213.1