

RESEARCH ON INSPECTION AND CERTIFICATION INDUSTRY BASED ON DISSIPATIVE STRUCTURE THEORY

by

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The paper discusses dissipative structure of inspection and certification industry from the angle of openness, non-equilibrium, non-linearity, and random fluctuation. Then the paper puts forward some suggestions for developing the inspection and certification industry based on dissipative structure theory.

Key words: *inspection and certification, dissipative structure, entropy theory*

Introduction

Inspection and certification activity originate from information asymmetry and it is the activity of providing information positively for smooth progress of the trade activities. Inspection and certification industry is essentially the remedy for market failures and the supplement for the market system. It has an important role in the aspects of strengthening quality safety, promoting industrial development, maintaining consumer rights and interests and so on. There is lots of literature deal with the topic. How to choose certification body was explored [1] and evaluation of certification effectiveness was carried out [2]. The role of the third-party certifications [3-6] and auditor independence certification were also explored [7-9]. The implementation of quality management system was also researched [10-13] and the supervision of inspection and certification bodies was discussed [14-16]. Other standards and certifications were also explored [17-20]. Also, cartels and clubs, resource dependent and new institutionalism theories were used to explain the reasons for the widespread registration of standards [21].

By the end of 2017, the number of national certification and accreditation inspection and testing institutions reached 36977, an increase of 9.44% over the end of 2016. The total business incomes of certification and accreditation inspection and testing institutions reached 263.252 billion ¥, an increase of 13.51% over the previous year. The employment population of 1213000 people in the whole year, an increase of 89% over the previous year. The total labor productivity reached 217000 ¥ per person. China has issued more than 17.553 million valid certificates and more than 587000 certificated organizations.

The number of certificates and certificated organizations in China ranks first in the world for many years. For example, the number of ISO9001 certificates in China has been shown in tab. 1, showing that the ISO9001 certificates in China have shown a steady growth trend and reached the peak in 2015.

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Table 1. Number of ISO9001 certificates in China in the past decade

Years	Number
2008	179400
2009	183327
2010	196527
2011	203899
2012	216034
2013	239747
2014	247764
2015	256840
2016	267570
2017	280645

The dissipative structure is the important component of self-organization phenomenon. Self-organization theory is a system theory consisting of dissipative structure theory, synergetics theory, hypercycle theory, fractal theory and chaos research. Its structure can be divided into equilibrium and dissipative. The former is a structure that can maintain balance without material energy and information exchange with the outside, while the latter refers to the structure that can keep order only by constantly exchanging material energy and information with the outside. To form dissipative structure, the system must meet the following four conditions: firstly, the system must be open and it is the basic conditions for the formation and development of dissipative structure, secondly, the system is far from equilibrium state, thirdly, non-linear interaction mechanism must exist within the system, which is the inherent power for the system evolving from disorderly to orderly, fourthly, the system must exist fluctuations, which is the incentive of driving system jump

into the dissipative structure branch. So far, many scholars have made a lot of scientific research achievements with the theory of dissipative structure, which proves the feasibility of the theory in the fields of physics, economy, management and so on [22-25]. The inspection and certification industry conforms to the four conditions of self-organizing evolution of dissipative structure theory and few paper discussed the area. The paper tries to fill the gap.

Dissipative structure analysis of inspection and certification industry

Openness of the industry

Puligozin put forward the theory of dissipative structure in 1969, pointing out that by exchanging energy and information with the outside world, and when the external conditions reach a certain condition, it will change in a new state orderly in time and space. Assuming the materials, information and energy from external is Q_e and internal is Q_i . Then we suppose the exchange of materials, information and energy per unit time as fluctuation. Without violating the second law of thermodynamics, the total entropy, dS , of the system consists of the exchange, $d_e S$, between the system and the outside and the $d_i S$ generated by the entropy in the system. The dQ_e/dt and dQ_i/dt represent the external and internal fluctuation:

$$dS = d_i S + d_e S = -\frac{dQ_e}{dt} + \frac{dQ_i}{dt} \quad (1)$$

So when the value of time variable is larger:

$$\Delta S = \Delta S_e + \Delta S_i = \frac{\Delta Q_e}{\Delta t} + \frac{\Delta Q_i}{\Delta t} \quad (2)$$

when $\Delta Q_e/\Delta t = \Delta Q_i/\Delta t$, the system keep relative stability, $\Delta S_e = \Delta S_i$. When $\Delta Q_e/\Delta t < \Delta Q_i/\Delta t$ the dissipative motion of the non-linear system far from the equilibrium state decreases, and the system changes from disorder to order, which is called dissipative structure state. It can be seen that the opening of the system can neither be very small nor completely open.

As a highly integrated complex system with the social environment, the inspection and certification industry is constantly exchanging material and energy with the outside world, and is affected by natural, society, politics, culture, economy and technological policies and

other systematic environmental factors. At present, the openness of China's inspection and certification industry needs to be improved. To a certain extent, the market share is in the hands of foreign inspection and certification bodies, and the social recognition of China's inspection and certification institutions needs to be further improved. According to the Economic Reference Daily of October 10, 2017, more and more consignees require certificates of inspection and certificates issued by foreign-funded bodies. The market of export commodity inspection and certification has been monopolized by foreign-funded bodies in a sense. According to the survey of Ningbo Certification and Accreditation Association, foreign-funded bodies occupy more than 85% of the market of import and export of inspection and certification in Ningbo city of China.

Non-equilibrium of the industry

The concept of entropy comes from thermodynamics. It was proposed by Clausius in Germany in 1864. In 1882, Boltzmann developed the theory of entropy and interpreted it as *lost information*. He believed that *Entropy depends on the probability of the arrangement of microscopic particles in the system*, that is, an isolated system must spontaneously return to the equilibrium state of maximum entropy. He analyzed the thermodynamic system and determined that entropy was a measure of the degree of micro-chaos or disorder of the system.

Let a thermodynamic system in equilibrium consist of two parts A and B , and the entropy and state probability of the two parts A and B are, respectively, S_A , S_B , and P_A , P_B the entropy and state probability of the total system are S and P .

Since entropy is a generalized quantity, the total entropy of the system is equal to the sum of the internal and external entropy of the system, $S = S_A + S_B$. According to the multiplication rule of probability, the probability that two specific states of the system occur at the same time:

$$P = P_A P_B \quad (3)$$

$$S = f(P) = f(P_A P_B) \quad (4)$$

and

$$S = S_A + S_B = f(P_A) + f(P_B) \quad (5)$$

so

$$f(P_A P_B) = f(P_A) + f(P_B) \quad (6)$$

The function that satisfies this relation has logarithm only:

$$\ln P = \ln(P_A P_B) = \ln(P_A) + \ln(P_B) \quad (7)$$

So Boltzmann determined the following functions:

$$S = k_b \ln P \quad (8)$$

where k_b is called Boltzmann constant and S – the called entropy function.

In the theory of dissipative structure, an open system can form an orderly-organizational structure only when it is far away from the equilibrium state, and it can be sensitive to the fluctuation of the system. When the system changes abruptly, a new ordered structure can be formed. Equilibrium state refers to the state in which the elements of the system are in the most disordered and disorganized state with the maximum degree of entropy, freedom and disorder. Non-equilibrium is the source of order, and the key to the problem is to keep away from equilibrium state. The inspection and certification industry is composed of many different subjects.

The inspection and certification bodies have some differences in resources, information and technological strength. There is a big gap between China's certification and ac-

creditation innovation level and original technological capabilities compared with developed countries. The main standards and rules of certification and accreditation are still formulated by developed countries. China's certification bodies mainly serve the domestic market, with a low international market share and few internationally renowned certification bodies. Their professional competence and technical level of employees need to be further strengthened. The reform of certification and accreditation system should be deepened and better services for enterprises should be provided. Innovation ability should be consolidated and credibility of certificates should be heightened. Also social co-governance should be improved, so as to continuously improve the quality of certification and accreditation, and enhance the innovation ability and market competitiveness of China's certification industry. In the process of formulating the 13th Five-Year Plan for the Development of Certification, Accreditation, Inspection and Testing, the National Accreditation Regulatory Commission has carried out research on the evaluation indicators of the powerful countries of certification and accreditation. Of the 12 indicators for international comparison, 7 of them are in the middle level or relatively backward, and less than half of the leading indicators are in the world.

Non-linearity of the industry

Physicist Hacken pointed out that the reason why the system can be orderly structured is that the control parameters reach a certain critical value. After that, the internal subsystems have a non-linear interaction. Non-linearity is a dynamic mechanism and the system generates and evolves through complexity. It is also a bridge connecting the simplicity and complexity of the system. Each subsystem must be non-linear and the process from disorder to order among subsystems is a non-linear process. The system is in a non-equilibrium state. Mathematically, a dynamic process can be described by a set of differential equations. For example, for the simplest univariate system, the dynamic equation describing the change of state variable X with time t :

$$\frac{dX}{dt} = f(X, A) \quad (9)$$

where X can be used to describe the degree of order of the system, which is called order parameter; A is the control parameter.

When $X = 0$, the system is in an disordered state.

When $X \neq 0$, the system is in an ordered state (dissipative structure state).

If the order parameter equation is linear:

$$f(X, A) = (A - Ac)X \quad (10)$$

then

$$\frac{dX}{dt} = f(X, A) \quad (11)$$

where Ac is a fixed value, or threshold. There's only one solution to this equation $X = 0$. Indicates that the system is in a disordered state. According to mathematical stability theory: as time, t , goes to infinity, the order parameter, X , finally only has two cases of zero (stable) and infinite (unstable), so it is impossible to derive the dissipative structure branch. This is the behavior of the system and there is no bifurcation or mutation in the disorderly state of the system.

If the order parameter equation is non-linear:

$$f(X, A) = (A - Ac)X - X^3 \quad (12)$$

then

$$\frac{dX}{dt} = (A - Ac)X - X^3 \quad (13)$$

There are three stationary state solutions of the equation: $X = 0$, $X = -A - Ac$, $X = A - Ac$. With the stability theory, when $A < Ac$, $A - Ac$ is meaningless, only branch solution $X = 0$, and it is stable. When $A > Ac$, even though the solution $X = 0$ exists, it is no longer stable. When $X = \pm A - Ac$, the solutions also exist ($X \neq 0$) and they are stable when t tends to infinity. They're equivalent to dissipative branches, and this branch cause is due to the non-linear term. This is reflected in the non-equilibrium system behavior is with fork, mutation, lag, self-agitation, self-organization, self-creation, self-growth, self-revival and even chaotic movement and other non-mediocre behavior. Therefore, the physical meaning of the non-linear term is the non-linear interaction in the system, that is, the synergistic effect and coherent effect between the parts (or subsystems) of the system. The interactions are coherent, coupled and feedback, so it is also called a non-linear positive feedback mechanism. This kind of non-linear interaction can make the system evolve from quantitative change to qualitative change then to a new spatio-temporal ordered structure.

The whole system of inspection and certification involves many aspects and is not isolated. For example, the development of inspection and certification business can improve the training business, and the development of domestic business can promote the foreign inspection and certification business. Because of the non-linear relationship between the elements of the inspection and certification industry, which restricts and promotes each other, the internal elements of the inspection and certification industry will have an expanding effect, and the internal structure of the system will change dramatically, thus forming a new orderly structure. The non-linear interaction in the inspection and certification industry shows that China's inspection and certification industry should take the road of agglomeration development, and agglomeration development is the inevitable trend of the development of the inspection and certification industry. In the process of development, false inspection, perfunctory certification, low-price competition and other situations occur from time to time, which seriously damage the credibility of the inspection and certification industry. On September 11, 2017, the State Accreditation Regulatory Commission informed that 25 registered personnel of a certification institution in Shanghai, including the main shareholders of the company, had falsely reported their auditing experience and cheated registered personnel to be disqualified. According to the website of the China Accreditation and Accreditation Association, 189 auditors were disqualified in December 2018 due to lack of on-site auditing and falsification of their qualifications.

Random fluctuation of the industry

Self-organizing system can only occur when it is far away from equilibrium state, while maintaining the system far from equilibrium state requires fluctuation be realized, so fluctuation is the development incentive to form a new orderly structure. Fluctuation plays an important role in inspection and certification. It can be divided into positive fluctuation and negative fluctuation. Positive fluctuation can promote the evolution of inspection and certification industry in an orderly way, while negative fluctuation will increase the confusion of inspection and certification industry. Fluctuations are accidental, random and disorderly, and play different roles in different states. Policy, market environment, innovation and people's awareness of participation can all become fluctuations in the development of certification industry. Certification industry is a high-tech service industry encouraged by the state. The National Strategic Emerging Industries Development Plan of the 13th Five-Year Plan of 2016 lists certification industry is a national strategic emerging industry. At the same time, certification and accreditation is an important part of the National Quality Infrastructure (NQI). In the Outline of Quality Develop-

ment promulgated by the State Council, it is clearly put forward that the improvement of certification and accreditation system should be taken as an important measure of quality power. This series of documents have promoted the orderly development of the inspection and certification industry. The total business incomes of inspection and testing and certification services have exceeded 200 billion RMB*, making it the fastest growing inspection and certification market in the world. However, there is still a long way to go in terms of service quality and business innovation ability of inspection and certification institutions in China. According to a survey published by Import and Export Manager magazine, SGS continues to rank first in the *ranking of the most trusted inspection and certification institutions for foreign trade enterprises in 2017* and has long occupied the top place, followed by Rhine TUV Group, UL and Intertek with *China Quality Certification Center* ranking only sixth.

According to the characteristics of openness, non-equilibrium, non-linear interaction and fluctuation mechanism of China's inspection and certification industry, combined with the current development situation and existing problems of China's inspection and certification industry, the following self-organizing development path is put forward.

Self-organizing development of the inspection and certification industry

It is necessary to enhance social participation and improve the openness of the industry

The origin of certification service can be traced back to the establishment of Lloyd Register during 1760. Certification services have restored in China since the membership of China in ISO resumed in 1978. One of the earliest Chinese certification bodies is QCCECC which was established on April 25th, 1981. In 1992, Shanghai Audit Centre of Quality System (SAC), one of the first accredited third-party certification bodies was formed. In 2001, the Certification and Accreditation Administration of China is established to manage, supervise and co-ordinate various kinds of certification services in China. With the open market policy in the certification industry since 2006, the number of certification bodies has grown in China from 137 accredited certification bodies in 2005, to 158 in March 2017. In the meantime, almost all major international players have entered into the China to provide certification services. The service providers include ITS, TUV, UL, BSI, BV, SGS, and DNV, to name a few. First of all, It is necessary to introduce the hearing system, encourage the public to participate in the adjustment and reform of the inspection and certification system. Also, it is necessary to integrate the media and reform the media positioning in the industry. By inviting the people deeply participate in the media. The propaganda methods for different levels of audiences and produce propaganda materials in different categories should be studied. Secondly, the establishment of reporting funds and other means to mobilize the enthusiasm of the people to report violations of law is necessary. Thirdly, it is necessary to give full play to the association's role in personnel registration, training and development, membership services, self-regulation, technical standards and cooperation in inspection and certification business at home and abroad.

It is necessary to improve the service quality and the supply level of inspection and certification industry

First of all, it is necessary to vigorously carry out service marketing. As the activities of inspection and certification bodies are a kind of service, which has the characteristics of

* 1 RMB = 0.14 \$

imperceptibility, inseparability, difference, non-storage and lack of ownership, the characteristics of service products determine that service marketing and physical product marketing have different essential characteristics. The marketing work should be based on the tangibility, reliability, assurance, responsiveness and empathy of the service, tapping the needs and expectations of customers. Classified management of valuable key customers, comprehensive use of network marketing, knowledge marketing and other means, around brand loyalty, enhance the overall marketing ability of the brand. Follow-up visits should be conducted in time after the end of the business. Emphasis should be laid on the opinions and suggestions of the enterprises. Complaints should be dealt with in time and the results should be communicated with the customers. Because the characteristics of service industry lead to low customer stickiness and low loyalty, customer satisfaction is very important. Secondly, brand building should be paid attention. Making brand development strategy is an inevitable requirement for the maturity and development of modern inspection and certification bodies. In top-level design, it is necessary to establish a perfect brand strategy implementation system from the aspects of enhancing brand awareness, improving brand human resources, improving brand management organizational structure, and perfecting brand rules and regulations; in crisis management, it is necessary to register domestic and foreign trademarks in time. We should improve the anti-counterfeiting measures of certificate reports, properly carry out certificate counterfeiting work, maintain brand reputation, enhance brand crisis awareness, set up crisis public relations teams and appropriate resolution of events that damage brand reputation. In the area of social responsibility, we should actively shape the image of fulfilling social responsibility and form the brand scale effect by carrying out activities such as testing and certification of popular science education and volunteer service. Furthermore, interface management should be strengthened. The inspection and certification process often takes the form of project team, the inspection and certification personnel temporarily form a project team, and the activities of the team will end with the completion of the project. To improve the sensitivity of employees to knowledge and information, professional vision will reduce the sensitivity to knowledge. We should cultivate the habit of systematic thinking and look at each other's roles and interactions systematically. At the same time, we should make the knowledge of different technical personnel have boundaries, and provide support and guarantee for the quick and good implementation of inspection and certification projects.

It is necessary to focus on intensive development and give full play to the non-linear role of the industry

It is necessary to actively support domestic inspection and certification bodies to go abroad and reduce or exempt financial and tax revenue guide inspection and certification bodies to achieve the organic combination of inspection and certification business to complement each other, provide tracking services for enterprises in the whole industry chain, and strive to take the lead in putting forward advanced evaluation standards and evaluation methods in the international arena. We can learn from some foreign practices, such as Australia and New Zealand, to jointly carry out system certification and establish a joint system certification and accreditation body. Britain and the Netherlands will also open auditor training, registration and Accreditation of system certification institutions to foreign countries to form a quasi-international accreditation body. The EU has been working with the USA, Canada, Australia, and the Netherlands since the twentieth century. New Zealand, Switzerland, Israel, Japan and other countries have reached many bilateral mutual recognition agreements, which have played a significant role in promoting exports. Our country can also learn from the experience of these countries. In

addition, our participation in international standard-setting should be increased and the right to speak in standard-setting should be grasped.

*It is necessary to strengthen supervision after the event,
improve the innovation system and improve the fluctuation
quantity and quality of the inspection and certification industry*

First of all, It is necessary to expand the acceptance scope of third-party inspection and certification. Learning from the experience of foreign acceptance, such as the French, Czech, and Polish governments, in addition the government laboratory testing in the field of product safety, other testing services adopt the method of acceptance of third-party testing results, and establish a complete regulatory system for third-party inspection and certification institutions accepted by the government. Secondly, we should strengthen the application of big data, block chains and cloud computing in the inspection and certification industry, improve the post-event supervision mechanism, integrate and correlate relevant data, and construct a big data supervision model, so as to enhance the government's scientific decision-making and risk prediction ability. Supervising and spot checking the effectiveness and standardization of inspection and certification bodies should be carried out effectively, and special checks for special problems and weak links should be paid attention. Thirdly, the establishment of integrity archives of institutions should set up classification standards for rating of institutions like certification in the field of inspection and certification. Through quantitative analysis and comprehensive evaluation of customer satisfaction, corporate governance, social responsibility and other indicators, it can provide reference for enterprises to select inspection and certification bodies. In addition, the development and research of inspection and certification technology in such important fields as civil-military integration, large aircraft engineering, intelligent robots and national information security should be strengthened, the deep integration of inspection and inspection services should be promoted and the inspection level in new energy, low-carbon environmental protection and wireless navigation, and realize the biomedicine and new technology through the construction of medical detection platform should be carried out effectively.

Conclusion

The paper gets the conclusions that China's inspection and certification industry conformed to the openness, non-equilibrium, non-linear interaction, and fluctuation mechanism of dissipative structure theory. Combined with the current development situation and existing problems of China's inspection and certification industry, self-organizing development path is put forward, including that it is necessary to enhance social participation and improve the openness, improve the service quality and the supply level, focus on intensive development and give full play to the non-linear role and strengthen supervision after the events, improve the innovation system and improve the fluctuation quantity and quality. Many research studies suffer from limitations and the present study is no exception. The paper does not deal with measurement industry which is components of NQI. Also, the inspection and certification industry can be discussed from the ecological niche theory and game theory. All these are future directions.

Nomenclature

A_c – is a fixed value, or threshold, [–]
 dS – exchange of the total entropy, [JK⁻¹]
 $d_e S$ – exchange the system and the outside system, [JK⁻¹]

$d_e S$ – exchange the system and the internal system, [JK⁻¹]
 dQ_e/dt – external fluctuation, [JS⁻¹]
 dQ_i/dt – external fluctuation, [JS⁻¹]

k_b – Boltzman constant, [–]
 P_A – state probability of parts A, [–]
 P_B – state probability of parts B, [–]
 Q_c – information and energy from external, [J]
 Q_e – change of the information and energy from external system, [J]
 Q_i – information and energy from internal, [J]
 ΔQ_i – change of the information and energy from internal system, [J]
 S_A – entropy of parts A, [JK⁻¹]
 S_B – entropy of parts B, [JK⁻¹]
 ΔS – change of the entropy S , [JK⁻¹]
 ΔS_e – change of the entropy from external system, [JK⁻¹]
 ΔS_i – change of the entropy from internal system, [JK⁻¹]

Δt – change of the time, [S]
 X – state variable, [–]

Acronyms

BSI – British Standards Institution
 BV – Bureau Veritas
 DNV – Det Norske Veritas
 ISO – International Organization for Standardization
 ITS – Intertek Test Service
 QCCEC – quality certification for China committee of electronic components
 SGS – Societe Generale de Surveillance S. A.
 TUV – Technischer Uberwachungs Verien
 UL – Underwriter Laboratories Inc.

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