

THE COLLABORATION IN THE ACTION PLAN FOR A BLUE SKY OF CHINESE MUNICIPAL GOVERNMENT BASED ON TEXT DATA MINING AND SOCIAL NETWORK ANALYSIS

La colaboración en el plan de acción para un cielo azul del gobierno municipal chino
basado en la minería de datos de texto y el análisis de redes sociales

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ABSTRACT

Constructing a collaborative mechanism through the self-organizing movement within the system is the main development direction of China's future mechanism of innovation. The reform of the administrative system can give full play to the role of the collaborative mechanism. This article comprehensively uses data mining and social network analysis to analyze the collaboration of China's municipal departments in air pollution control. Text data includes 101 municipal policies. The paper reveals the collaboration problems in air pollution control and proposes suggestions from the perspective of the departmental responsibility. First, from the perspective of inter-departmental collaboration, the lack of responsibility for Department of Finance, Department of Housing and Urban-rural Development, Department of Ecology and Environment, Department of Industry and Information Technology, Department of Transport, Department of Public Security, and Department of Development and Reform is the most obvious, indicating that the comprehensive management departments should be strengthened to assume responsibilities, while the specialized management departments should also be strengthened. Second, from the perspective of intra-departmental responsibility collaboration, the most obvious situation is that the collaborations of responsible for promoting new-energy vehicles, air pollution control in autumn and winter, increasing tax-free incentive policy support, development of inter-modality, adjusting regional industrial layout, optimizing freight structure, and increasing economic policy support are insufficient. The number of departments responsible for supervision should be increased, as well as the number of departments responsible for guidance.

Palabras clave: control de la contaminación del aire, colaboración interdepartamental, colaboración responsable, parámetro de orden

RESUMEN

La construcción de un mecanismo de colaboración a través del movimiento auto-organizado dentro del sistema es la principal dirección de desarrollo del futuro mecanismo de innovación de China. La reforma del sistema administrativo puede desempeñar

plenamente el papel de mecanismo de colaboración. Este artículo utiliza exhaustivamente la minería de datos y el análisis de redes sociales para analizar la colaboración de los departamentos municipales de China en el control de la contaminación del aire. Los datos de texto incluyen 101 políticas municipales. El documento revela los problemas de colaboración en el control de la contaminación atmosférica y propone sugerencias desde la perspectiva de la responsabilidad departamental. En primer lugar, desde la perspectiva de la colaboración interdepartamental, la falta de responsabilidad del Departamento de Finanzas, del Departamento de Vivienda y Desarrollo Urbano-rural, del Departamento de Ecología y Ambiente, del Departamento de Industria y Tecnología de la Información, del Departamento de Transporte, del Departamento de Seguridad Pública y del Departamento de Desarrollo y Reforma, es muy evidente, lo que indica que se deben fortalecer los departamentos de gestión general para que asuman sus responsabilidades, al tiempo que se deben fortalecer los departamentos especializados de gestión. En segundo lugar, desde la perspectiva de la colaboración de responsabilidad intradepartamental, la situación más obvia es que las colaboraciones de los responsables de promover vehículos de nuevas energías, el control de la contaminación atmosférica en otoño e invierno, aumentando el apoyo a las políticas de incentivos libres de impuestos, el desarrollo de la intermodalidad, la adaptación del diseño industrial regional, la optimización de la estructura del transporte de mercancías y el aumento del apoyo a la política económica, son insuficientes. Debería aumentarse el número de departamentos encargados de la supervisión, así como el número de departamentos encargados de la orientación.

INTRODUCTION

Traditional bureaucratic administration relied on the refinement of professional division of labour to improve administrative efficiency and decentralize government functions to multiple government departments. The refinement of the division of labour had led to the continuous expansion of the scale of the government, and it had also made the management coordination mechanism more complex. Because of the limited management span, administrative management present a pyramid structure, which leads to increased costs and low administrative efficiency (Ren 2015). New public management redefined the government's functions, the government need to transform from paddling to steering. They introduced competition mechanisms among government departments to save expenses and improve management efficiency. However, when the administrative management structure transforming from a pyramid structure to a flat structure, the lack of management levels had led to a weak management coordination mechanism, resulting in numerous independent entities. Departmentalism, civil servant prioritizes departmental interests, also emerged (Gu and Zhang 2019). The lack of cooperation between departments had led to fragmentation of government functions, making it difficult to deal with complex ecological and social issues (Hood and Dixon 2015). Zadek (2008) pointed out that collaborative governance

is the only way to solve complex ecological and environmental problems, and there is no alternative. Meijers and Stead (2004) believed that the government faces cross-border issues in the policy-making process, which goes beyond responsibility of a single department and requires collaboration between departments. Matei and Dogaru (2013) emphasized that in the process of policy formulation, the government should strengthen collaboration between departments to balance conflicts of interest. Hoel (1997) found that good inter-departmental collaboration is conducive to improving the efficiency of policy implementation. Lee et al. (2011) found that a collaborative policy is better than a single policy, and an effective policy combination can achieve better performance. The academic community widely recognized collaboration as the best means to solve the fragmentation of government functions and improve administrative efficiency. The Blair government of the United Kingdom put forward the concept of collaborative government, using the collaboration formed by the self-organizing movement to build a collaborative mechanism between departments to enhance the administrative efficiency of cross-domain public issues. Hicks (2002) further proposed the construction of an overall government, which provides seamless services to citizens through the construction of a collaborative mechanism and process re-engineering by integration. Due to the fragmentation and the rule of man, the Chinese government can only establish

departmental cooperation mechanisms aimed at short-term benefits through self-organizing movements, but it is difficult to establish a collaborative mechanism aimed at long-term benefits, and cannot meet the needs of citizens for services. Therefore, the bureaucratic coordination mechanism has been developed in China. Since the 17th National Congress of the CPC, the Party has repeatedly proposed improving the collaboration and cooperation mechanism of departments. Although it can partially solve the problem of fragmentation of government functions, due to the limitations of bureaucratic capabilities, it cannot cope with numerous public service needs, and it is impossible to refine the mechanism, which makes it impossible to solve the problem of fragmentation of government functions and is relatively inefficiency. The Fourth Plenary Session of the 19th CPC Central Committee put forward focus on promoting the optimization of the functions of state institutions, synergy and efficiency, and building a synergy mechanism is the main direction of the government's future mechanism of innovation. Inter-departmental collaboration does not obscure the division of responsibilities of the departments, but is based on a clear division of responsibilities (Chen 2015). The Fourth Plenary Session of the 19th CPC Central Committee further called for optimizing the responsibility system of government departments and regarded it as the core of improving the administrative system. Scientific division of the responsibilities of government departments, optimizing the allocation of responsibilities of government departments, and forming a good collaboration relationship between departments and responsibilities within the government have become a new topic for promoting the modernization of government governance systems and governance capabilities in the new era. The battle to defend the blue sky is one of the three tough battles for China's ecological environment governance. It is not only the in-depth practice of the concept of green development, but also the inherent requirement of the goal of building a beautiful China, which can promote the transformation of the economy and society to high-quality development. At present, China attaches great importance to air pollution control. The report of the 19th National Congress of the CPC proposed to adhere to the common governance of the whole people, source prevention and control, continue to implement air pollution prevention and control actions, and win the battle to defend the blue sky. Therefore, from the perspective of collaboration, this study explores the inter-departmental collaborative relationship and intra-departmental responsibility collaborative

relationship of the municipal government in air pollution control. Research reveals the collaboration problems existing in air pollution control, and then optimizes the allocation of responsibilities of government departments, which is of great significance to the construction of internal departments and responsibility collaborative mechanisms within the policy, as well as a scientific and reasonable administrative system.

The policy stipulates the actions to be taken by the local government and the corresponding participants. The current academic study takes policy text analysis as an important path to quantitatively analyse the governments' collaboration in air pollution control, which is mainly divided into the following six research stages. First, it analysed the measurements of the external characteristics of policy texts. Sun and Wen (2017) conducted quantitative statistics on the policy text based on the external characteristics of the promulgating subject, time, type, etc., to describe the basic situation of air pollution control policy formulation. It mainly reflected the collaboration in the statistical aspects of policies issued jointly by multiple departments. Second, it analysed the content analyses of policy texts. Because external feature statistics cannot meet the functional analysis requirements of air pollution control policies, quantitative researches on policy texts have developed in the direction of content analysis. Wu and Zhao (2018) used policy tools as the analysis unit to qualitatively define the policy text decomposed into several policy tools. The functional status of multi-department joint promulgation of policies is analysed from the perspective of the policy tool type. Third, it was the network analyses of the promulgators. Because the statistics of external characteristics cannot provide an in-depth analysis of the collaborations of policy promulgators, Zhao (2020) used social network analysis methods to analyse the network characteristics of the promulgators, to reveal the deficiency of inter-departmental collaborations in policy making. Fourth, the keyword networks were analysed. Since it is impossible to conduct in-depth analysis of the policy content by taking policy tools as the analysis unit, Wu et al. (2019) took the term as the analysis unit, selected keywords from the policy texts by frequency, and then clustered the policy themes according to the co-occurrence network of the keywords to conduct in-depth analysis of the policy themes. Fifth, researches on the order parameter for collaborations of promulgators. Since social network analysis methods are difficult to

establish a connection with governance effectiveness in the quantitative study of collaborations, Li et al. (2017) first qualitatively distinguished the level of promulgators as well as the laws and regulations issued by type and gave them different points and then multiplied them as the policy strength. Then, they considered whether the two promulgators are collaborated as a binary variable, and the policy strength multiplied by the binary variable was used as the degree of collaboration of the promulgators. They carried a regression analysis of the collaborative degree of the promulgators and governance efficiency out to reveal the order parameter of government inter-departmental collaborations. Sixth, researches on the order parameter for the collaboration of governance measures and governance objectives. It is difficult to fully explain the governance effectiveness based on the collaborations of policy promulgators. Zhang et al. (2014) qualitatively decomposed the content of the policy text into governance measures and governance goals and assigned different scores according to the detailed level of the text content. They considered whether the two governance measures and governance goals are collaborative as a binary variable, and multiplied the scores by the binary variable and the policy strength to obtain the collaborative degree of governance measures and the collaborative degree of governance objectives. Then, the regression analysis with governance efficiency was carried out, and the order parameter of actions collaborations and goals collaborations are studied (Zhang et al. 2015). In general, the predecessors' quantitative researches of the collaboration of government departments in air pollution control is relatively comprehensive and in-depth, involving inter-departmental collaborations, actions collaborations, goals collaborations. Based on that, a relatively complete research system has been constructed.

However, there are still some shortcomings in the quantitative research on the collaboration: First, there is a lack of collaborative researches on policy enforcement departments. Previous studies mainly focused on the decision-making collaborations of policy-making departments, and ignored the collaborations of policy implementation departments. The collaborations of responsible departments have a more important impact on the effectiveness of air pollution control. Second, there is a lack of collaborative researches on the order parameter. In the past, most studies have analysed inter-departmental collaborations of the central government in different periods to explore the law, but neglected the study of

the inter-departmental collaborations of the municipal governments in the same period. The time span of the research is too long, and the research is susceptible to changes in environmental factors, which makes it impossible to reveal the order parameters of the main body's collaboration. Communicating the order parameters to other subjects in the organization to reduce the waste of time and resources caused by unnecessary competition is the main significance of collaborative research (Bao 2019). As the middle-level government of China, researches on the collaborations of the municipal government's departments are more practical meaning in improving the effectiveness of air pollution control. Third, there is a lack of researches on the responsibilities of government departments. The collaborations have established based on a clear division of responsibilities. Based on the existing structural law of collaboration, allowing government departments to assume scientific and reasonable responsibilities, so that the collaboration mechanism can be fully brought into play, and higher governance efficiency can be achieved. In view of this, this study is based on the analysis framework of the governance subject, the governance measure, and the governance subject-governance measure proposed by predecessors (Zheng et al. 2017). The research uses the R language to excavate the 101 municipal Three-year Action Plan To Win The Battle For A Blue Sky (hereinafter referred to as Plan), to analyse departmental collaborations and responsibility collaborations in the Plan, through which we propose improvement suggestions for the construction of the collaboration mechanism and the reform of the administrative system. This research will provide a reference for improving the effectiveness of municipal government air pollution control.

DATA PROCESSING AND RESEARCH METHOD

Data source and processing

The policy stipulates the actions to be taken and corresponding participants in the battle for a blue sky, which is equivalent to constructing a system in government departments and actions. This system stipulates the scope of self-organization of the battle for a blue sky, that is to say, the order parameters are generated through self-organization movement between departments and actions within the system. When the order parameters are formed, there will be structural laws within the system. Departmental collaboration and action collaboration have taken

shape, and a collaboration mechanism can be built. Since the existing division of responsibilities will restrict collaboration, it is necessary to reform the administrative system and give full play to the role of the collaboration mechanism to improve efficiency.

Data source

This research collected the *Plan* promulgated by the China's municipal governments since June 2018 as the data source. As for air pollution control efficiency, it is measured by the change of the comprehensive air quality index around one year. In consideration of data availability, 101 municipal governments were selected for analysis.

Data processing

The *Plan* at the central government level defines the air pollution control function, including 61 responsibilities and their corresponding departments. The data cleaning procedures are as follows.

(1) Standardize responsibilities. Since the *Plan* at municipal level is formulated on the basis of the *Plan* promulgated by the central government, there are relatively high similarities in the expression of responsibilities, with slight differences. The sentences in the *Plan* text at central government level can be used as coding standard. Moreover, at municipal level, some responsibilities are split into several specific ones. Some are merged into one responsibility. So, the text that expresses responsibilities needs to be standardized firstly.

(2) Abbreviate and code responsibilities. The abbreviation is used to display results, and the code is used for data mining. Responsibilities and its abbreviation are listed as appendix.

(3) Clean up, abbreviate and code municipal departments. Since the department settings of different cities are not the same, there are also differences in names. China formulated Continuing the Reform of Party and Government Institutions Plan in 2008, in which the central government requires integrate departments with similar functions, also known as super-ministry system reform. According to that, municipal government departments are abbreviated and code. (See appendix)

(4) Taking department-responsibility as the unit of mining data, the data of all municipal governments is combined into a data set, which contains 8610 data.

Research method

Association rule mining

Using the R language, the research uses the Apriori algorithm in the arules tool to mine the association

rules of the data set. By association rule mining, three tables will be generated. (1) Through mining the relationship between departments and responsibilities, a department-responsibility co-occurrence table will be generated. (2) Through mining the relationship between department and department, a cross-departmental relationship table will be generated. (3) Through data conversion of the department-responsibility relationship table, a responsibility connection table will be generated.

Social network analysis

Social networks could display co-occurrence relationships. Using the R language and i-graph tools, this paper performs social network analysis on the department-responsibility co-occurrence table, departmental co-occurrence table, and responsibility connection table. The data mining result is a multi-value relationship table, which needs to be converted into a binary relationship table before social network analysing. Under normal circumstances, social networks can only show the existence of a relationship, or not. If yes, namely 1, otherwise 0. The connection between nodes cannot show multi-value. That is, it cannot show the frequency of node connection. However, the connection with high frequency has more contribution to the network than the low frequency ones (Yu 2017). To obtain the core network can express the frequency, and thus obtain a high-frequency node relationship, the multi-value table is converted into a binary table by setting the threshold (Guo et al. 2020). This research uses thresholds to illustrate the difficulty of constructing a collaborative mechanism for departments and actions. In the policy text of the local government, if there is a co-occurrence relationship between a certain department and another department, it is recorded as 1, otherwise it is recorded as 0. Since the policy text of the local government contains numerous actions, each action will have a co-occurrence relationship between departments. So the probability of recording it as 1 is higher. In this case, among 101 local governments, if the sum of the values of Department A and Department B is less than the median, it means that the co-occurrence relationship between these two departments is relatively small, showing that it is difficult for the two departments to construct collaborative mechanism across the country. This method is also used for the analysis of the responsibility connections in the policy text of the local government. This study uses the median value –101 samples, the median value is 51– as the threshold to construct the core network. Since we

only focus on the direct co-occurrence and connection between nodes, the following network structure characteristics are mainly investigated.

(1) Network density. The network density measures the closeness of the overall network connection, which is the ratio of the actual relationship number to the theoretical maximum relationship number. The greater the network density, the closer the relationship between nodes. Formula (1) is as follows.

$$\text{Network Density} = \frac{L}{N(N-1)/2} \quad (1)$$

In the formula, L is the number of connected edges in the network, and N is the number of nodes in the network.

(2) Degree of centrality. The degree of centrality measures the importance of a node in the network. It is the number of nodes directly contacts other nodes in the network. The bigger the degree of centrality, the more important the position of the node in the network. Formula (2) is as follows.

$$C_D(N_i) = \sum_{j=1}^n x_{ij} \quad (i \neq j) \quad (2)$$

In the formula, $CD(N_i)$ represents the degree of centrality of node i , x_{ij} is the direct connection between node i and j , $\sum x_{ij}$ is the number of direct connections between node i and other $n-1$ nodes, and n is the number of nodes in the network.

Correlation analysis

Through the correlation analysis of the co-occurrence and connection frequency of municipal governments and the effectiveness of air pollution control, the order parameters of collaboration can be explored. The correlation analysis has two purposes. One is to find the order parameters of inter-departmental collaboration, which is revealed by correlation analysis of the inter-departmental co-occurrence frequency and air pollution control efficiency. The other is to find the order parameters of responsibility collaboration which is revealed by correlation analysis of responsibility connection frequency and air pollution control efficiency.

RESULTS

Analysis of collaboration in air pollution control at municipal level

Structural functionalism believes that structure is a system of actions, which is composed of a series of independent social actions with coupling relationship

(Parsons, 2018). The responsibility system, that is, the structure, refers to the organic entirety comprised the tasks undertaken by various government departments. There must be actors in actions, and in the same way, there must be government departments that assume responsibilities. The connection between actors is established on the basis of actions, and vice versa. In this study, the collaboration relationships include inter-departmental collaboration and intra-departmental responsibility collaboration. The former one is established based on shared responsibilities, and the latter one is based on the department that undertake two responsibilities. Network usually presents co-occurrence and connection. In order to explore the order parameter of collaboration in the municipal government's air pollution control, this study analyses the structural characteristics of the one-mode network composed of inter-departmental or responsibility. Then we analyse the correlativity between co-occurrence frequency, connection frequency, and air pollution control efficiency. Then, based on the analysis of order parameter and co-occurrence network, the collaboration problems in air pollution control at municipal level could be analyzed.

Inter-departmental collaboration in the air pollution control at municipal level

(1) The status quo of the inter-departmental co-occurrence network in air pollution control.

Based on the inter-departmental relationship table, this research analyses the structural characteristics of the inter-departmental co-occurrence network in air pollution control.

Figure 1 shows the core network of inter-departmental collaborative in air pollution control that the co-occurrence frequency of nodes exceeds the threshold. The core network is the part with a high frequency of co-occurrence between departments. This core network scale is 25 departments, and the network density is 0.275. It is a low-density network, indicating that the departments in the core network are not closely connected. The general network shows all types of inter-departmental co-occurrence, whose network scale is 43 departments. The number of departments in the general network is nearly doubled compared to that in the core network. The network density is 0.434, which is a medium-density network, showing that the tight degree of inter-departmental is average. The major departments in the core network are *Department of Ecology and Environment* (D7), *Department of Development and Reform* (D9), *Department of Industry and Information Technology* (D10), *Department of Housing and Urban-Rural*

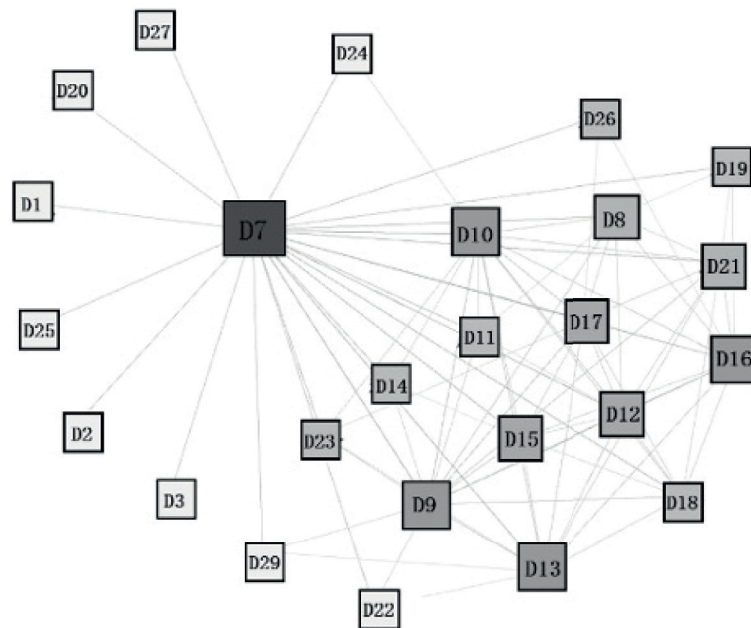


Fig 1. The core co-occurrence network of inter-departmental collaboration in air pollution control at municipal level.

Development (D16). The major departments in the general network are also these four. In these two networks, the major departments are consistent, indicating that in air pollution control at the municipal level, these four departments have the largest number of co-occurrence in terms of frequency and types with other government departments. Centrality of these two networks are 24(D7), 15(D9), 14(D10), 12(D16) and 42(D16), 38(D16), 37(D10), 33(D9) respectively. The degree of centrality of them is quite different, which shows that except for *Department of Ecology and Environment* (D7), although the other three departments have a co-occurrence relationship with most departments, they only have a high frequency of co-occurrence with a few departments.

(2) The problems of the inter-departmental collaboration network in air pollution control.

In order to reveal the problem, it is necessary to analyse the order parameter of department. Therefore, this study analyses the correlation between the frequency of inter-departmental collaboration and effectiveness of air pollution control. The results are shown in **table I**.

From the perspective of collaboration, there are 24 pairs of inter-departmental co-occurrence and air pollution control efficiency that have a significant correlation (see **Table I**). Among them, 22 types of inter-departmental co-occurrence are significantly positively correlated with the effectiveness of air

pollution control, indicating that with the increase in the frequency of these 22 types of collaboration, the effectiveness of air pollution control has improved. There are 22 structural laws that promote inter-departmental collaboration. On the other hand, there are two types of inter-departmental co-occurrence are significantly negatively correlated with the effectiveness of air pollution control, indicating that with the increase in the frequency, the air pollution control efficiency becomes worse. They need to be integrated. Among them, the *Department of Ecology and Environment* and *Department of Development and Reform*, which are comprehensive management departments, have the most positive correlations. It shows that strengthening the collaborations with the comprehensive management department can improve the efficiency of air pollution control. The most negative correlations in collaborations are those involving *Department of Forestry and Grassland Administration* (D19). This is mainly because of the inconsistency between the interests of the department and the cost in the afforestation. The responsibilities of the *Department of Forestry and Grassland Administration* and related departments need to be integrated to improve the effectiveness of air pollution control.

To reveal the problem of departmental collaboration in air pollution control of municipal governments, it is necessary to analyse the core network of departmental co-occurrence based on order parameter.

TABLE I. CORRELATION TABLE OF INTER-DEPARTMENTAL COLLABORATION AND AIR POLLUTION CONTROL EFFICIENCY.

Inter-departmental collaboration	Correlation coefficient	P value	Inter-departmental collaboration	Correlation coefficient	P value	Inter-departmental collaboration	Correlation coefficient	P value
D7-D9	0.46	0.008	D8-D21	0.374	0.035	D13-D15	0.364	0.041
D7-D10	0.445	0.011	D9-D10	0.397	0.025	D14-D20	0.378	0.033
D7-D14	0.508	0.003	D9-D13	0.359	0.043	D15-D17	0.367	0.039
D7-D15	0.447	0.01	D9-D14	0.363	0.041	D16-D19	-0.384	0.03
D7-D19	-0.46	0.008	D9-D15	0.488	0.005	D17-D18	0.424	0.016
D7-D2	0.389	0.028	D9-D16	0.352	0.048	D6-D5	0.359	0.043
D7-D25	0.428	0.015	D10-D14	0.496	0.004	D6-D4	0.359	0.043
D7-D28	0.378	0.033	D10-D15	0.389	0.028	D25-D3	0.359	0.043

According to the collaboration theory, due to the slaving principle, on the premise of keeping the environmental factors unchanged, the self-organizing movement within the system forms the order parameter. If the order parameters are formed, then there will be structural laws within the system, and departmental collaboration will automatically form. Even if the municipal government does not make special arrangements in management, the collaboration between departments will continue to develop in a more efficient direction under the slaving principle (Bao 2019). This shows that there are objective laws in the collaboration relationship of the municipal government, and a collaboration mechanism should be constructed based on order parameters. The division of responsibilities in the municipal government revealed by the core co-occurrence network of departments needs to be resolved through the reform of the administrative system. In **table I**, the collaboration between *Department of Ecology and Environment* (D7) and *Commission Office of Public Sectors Reform of Municipality* (D28), *Department of Science and Technology* (D14) and *Department of Meteorology* (D20), *Department of Justice* (D6) and *Municipal People's Procuratorate* (D5), *Department of Justice* (D6) and *Municipal Intermediate People's Court* (D4), *Department of Education* (D25) and *Municipal Publicity Department of the CPC* (D3) are significantly positively correlated with the effectiveness of air pollution control. However, the connection is not shown in **figure 1**, indicating that the construction of the collaboration mechanism of these departments is facing the obstacles of the existing administrative system and cannot play its due role. The collaboration between *Department of Forestry and Grassland Administration* (D19) and *Department of Ecology and Environment* (D7), and the collaboration between *Department of Forestry and Grassland Administration* (D19) and

Department of Housing and Urban-Rural Development (D16) are significantly negatively correlated with air pollution control efficiency. However, the connection shown in **figure 1** indicates that the inconsistency of benefits and costs between these departments is more serious and integrating responsibilities of these departments should be emphasized.

Responsibility collaboration in the air pollution control at municipal level

(1) The status quo of the responsibility connection network in air pollution control.

If government departments undertake multiple responsibilities, then there is a connection between responsibilities. Although there is no co-occurrence relationship between responsibilities in the data set, their correlation relationship can be established on the basis of the relationship between government departments (Parsons 2018). In this study, the responsibility collaboration connection is established on the basis of the departments undertaking certain two responsibilities. So, the frequency of responsibility connection means the frequency of departments undertaking those two responsibilities. Based on the responsibility connection table, this research analyses the structural characteristics of the responsibility connection network.

Figure 2 shows the core network of responsibility connection in air pollution control at municipal level, where the frequency of departments undertaking certain two responsibilities exceeds the threshold. The network scale of the core network is 61 responsibilities, and the network density is 0.864. Among them, some nodes have a degree of centrality of 59, which are *Motor Vehicle Pollution Control* (R26), *Prevention and Control of Exhaust Pollution from Mobile Machinery* (R27), *Straw Utilization* (R33), *Air Pollution Control in Autumn and Winter* (R35), *Diesel Truck Pollution Control*

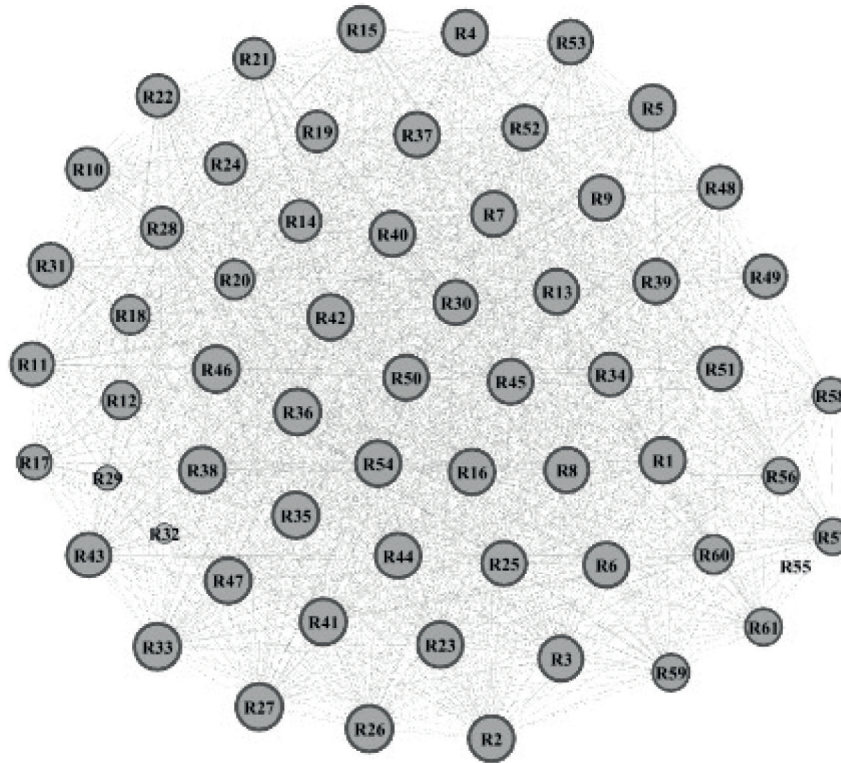


Fig 2. The core network of the responsibility connection in air pollution control at municipal level.

(R36), *VOC's Remediation* (R38), *Emergency Emission Reductions* (R41), *Increasing Economic Policy Support* (R46), *Increasing Tax-free Incentive Policy Support* (R47). It shows that these responsibilities have connections with most responsibilities in air pollution control. The network scale of the general network is 61 responsibilities. The network density is 1, and the degree of centrality of all responsibilities is 60, which is a fully connected network. It shows that there is a connection between each two responsibilities, that is, all departments have the situation of undertaking two responsibilities. The difference in different pairs of responsibility connections is mainly due to the different number of departments undertaking the two responsibilities. The responsibility connection is relatively well, which shows that after years of air pollution control practices, the Chinese municipal government has established a relatively close relationship of responsibility connection.

(2) The problems of the responsibility collaboration network in air pollution control.

In order to reveal the problem, it is necessary to analyse the order parameter of responsibility connection.

Therefore, this study analyses the correlation between the frequency of responsibility collaborations and effectiveness of air pollution control. The results are shown in **table II**.

From the perspective of collaboration, there are 436 pairs of responsibility connection and air pollution control efficiency that have a significant correlation (**Table II**). Among them, 431 pairs of responsibility connection are significantly positively correlated with the effectiveness of air pollution control, indicating that with the increase in the frequency of departments undertaking certain two responsibilities, the efficiency of air pollution control has been improved, and there are responsibility collaborations. In addition, there are five pairs of responsibility connection that are significantly negatively correlated with the efficiency of air pollution control, showing that as the frequency of departments increases, the efficiency of air pollution control decreases and there are conflicts of interests and costs between responsibilities, and the departments involved need to be integrated. Among them, *Development of Intermodality* (R21), *Carrying Out Various Forms of Publicity and Education* (R61), *Increasing Economic Policy*

TABLE II. CORRELATION ANALYSIS TABLE OF RESPONSIBILITY CONNECTION AND AIR POLLUTION CONTROL EFFICIENCY.

Responsibility collaboration	Correlation coefficient	P value	Responsibility collaboration	Correlation coefficient	P value
R1-R55	0.355	0.046	R20-R61	0.351	0.049
R2-R55	0.355	0.046	R21-R55	0.447	0.01
R4-R32	0.363	0.041	R21-R56	0.578	0.001
R5-R55	0.355	0.046	R21-R57	0.473	0.006
R6-R55	0.355	0.046	R21-R58	0.473	0.006
R7-R55	0.355	0.046	R21-R59	0.473	0.006
R8-R55	0.426	0.015	R21-R60	0.496	0.004
R11-R55	0.415	0.018	R21-R61	0.473	0.006
R11-R56	0.451	0.01	R22-R56	0.384	0.03
R11-R57	0.424	0.016	R22-R60	0.396	0.025
R11-R58	0.355	0.046	R25-R55	0.416	0.018
R11-R59	0.355	0.046	R26-R55	0.355	0.046
R11-R61	0.424	0.016	R27-R55	0.355	0.046
R12-R48	0.397	0.025	R28-R56	0.376	0.034
R12-R49	0.397	0.025	R31-R55	0.431	0.014
R12-R50	0.397	0.025	R31-R56	0.541	0.001
R12-R51	0.446	0.011	R31-R57	0.46	0.008
R12-R56	0.397	0.025	R31-R61	0.467	0.007
R12-R57	0.397	0.025	R32-R34	0.433	0.013
R12-R58	0.397	0.025	R32-R55	0.367	0.039
R12-R59	0.397	0.025	R32-R57	0.419	0.017
R12-R60	0.37	0.037	R32-R61	0.419	0.017
R12-R61	0.397	0.025	R35-R55	0.364	0.04
R13-R32	0.36	0.043	R36-R55	0.355	0.046
R14-R57	0.364	0.041	R38-R55	0.355	0.046
R14-R61	0.364	0.041	R40-R55	0.355	0.046
R15-R55	0.355	0.046	R44-R55	0.363	0.041
R19-R55	0.42	0.017	R46-R55	0.355	0.046
R19-R56	0.525	0.002	R48-R55	0.355	0.046
R19-R57	0.46	0.008	R49-R55	0.355	0.046
R19-R58	0.46	0.008	R52-R55	0.373	0.036
R19-R59	0.46	0.008	R53-R55	0.355	0.046
R19-R60	0.402	0.22	R54-R55	0.355	0.046
R19-R61	0.46	0.008	R55-R58	0.355	0.046
R20-R55	0.354	0.047	R55-R59	0.355	0.046
R20-R56	0.399	0.024	R2-R33	-0.349	0.05
R20-R57	0.351	0.049	R7-R33	-0.364	0.04
R20-R58	0.351	0.049	R15-R33	-0.366	0.04
R20-R59	0.351	0.049	R27-R33	-0.437	0.012
R20-R60	0.371	0.037	R33-R38	-0.435	0.013

Support (R46), *Encouraging Departmental Participation and Coordination* (R56), which are responsibilities with very strong positive externalities and can have a positive impact on other responsibilities, have the most positive correlations. Strengthening collaborations with these responsibilities can improve the effectiveness of air pollution control. There is the most negative correlation in the collaborations involving *Straw Utilization* (D33). The fundamental reason is the lack of market mechanisms, and the straw

procurement and storage system is extremely imperfect. Strengthening collaborations with this responsibility will reduce the effectiveness of air pollution control. Due to the large amount of data, in **table II**, this study only displays those order parameters that are related to administrative system reform.

To reveal the problem of responsibility collaboration in air pollution control the municipal level, it is necessary to analyse the core network of responsibility connection based on order parameter.

In **table II**, there are 75 pairs of responsibility connection that are significantly positively correlated with the effectiveness of air pollution control. But in **figure 2**, there is no connection for these responsibility collaborations, indicating that collaborations of these responsibilities have defects, and the administrative system should be reformed. Among them, it is the most obvious that the lack of collaborations in *Stepping Up Inspection on Ecological and Environmental Protection* (R55). The municipal government should add more departments to strengthen ecological and environmental protection inspection when undertaking other responsibilities, which can improve the effectiveness of air pollution control. In **table 2**, there are five pairs of responsibility connection that are significantly negatively related to the effectiveness of air pollution control. However, in **figure 2**, there are connection for these responsibilities, indicating that there are serious inconsistencies between the interests and costs of the departments taking part in these responsibilities, and the departments participating in responsibilities should be integrated. Among them, *Straw Utilization* (R33) is most obvious. It shows that most departments only pay costs for participating in this responsibility, and it is difficult to get benefits from other responsibilities. Therefore, the enthusiasm for participation is poor, and the contradictions are more prominent. We should focus on strengthening the integration of departments participating in this responsibility and related responsibilities to improve the effectiveness of air pollution control.

Analysis on the responsibilities of municipal government departments in air pollution control

Although the above analysis reveals the major problem of inter-departmental collaborations and responsibility collaborations in air pollution control of municipal governments, it does not make clear how to strengthen or reduce inter-departmental collaborations and responsibility collaborations. This involves the refinement of governance mechanism. Only through the refinement of the governance mechanism can the collaborative mechanism be more effective. And only by further clarifying the order parameters of inter-departmental collaborations and responsibility collaborations can the departmental responsibilities be scientifically and rationally optimized. This research first analyses the department-responsibility network of the municipal government's air pollution control, and then optimizes the departments' responsibilities based on detailed structural laws.

Status analysis of department-responsibility network for air pollution control in municipal governments

Figure 3 shows the status of the department-responsibility core network for air pollution control in municipal governments where the frequency of co-occurrence between departments and responsibilities exceeds the threshold. The department-responsibility core network has a network size of 17 departments and 55 responsibilities, while the general network has a network size of 43 departments and 61 responsibilities. The department-responsibility core network reduces most departments while retaining most of responsibilities compared with the general network, indicating that responsibilities of the municipal government plan are more comprehensive but vary greatly in the provisions of departments. From the perspective of the importance of government departments, *Department of Ecology and Environment* (D7), *Department of development and reform* (D9), *Department of industry and information technology* (D10) and *Department of transport* (D17) in the core network have the largest point centrality, while in the general network, *Department of Ecology and Environment* (D7), *Department of housing and urban-rural development* (D16), *Department of industry and information technology* (D10) and *Department of development and reform* (D9) have the largest point centrality, indicating that the department-responsibility core network and the general network have a high consistency in the main government departments. *Department of Ecology and Environment* (D7), *Department of development and reform* (D9), *Department of industry and information technology* (D10) and *Department of transport* (D17) in the municipal government's air pollution control, both in frequency of responsibilities and types of responsibilities, the point centrality is quite different in the two networks, respectively: 44, 25, 21, 14 and 61, 59, 52, and 51. It indicates that, except for *Department of Ecology and Environment* (D7), although the other departments have a variety of responsibilities, they only undertake a few high-frequency responsibilities. From the point of the importance of responsibility, in the core network, *Elimination of Old Vehicles* (R23), *Diesel Truck Pollution Control* (R36), *VOCs Remediation* (R38) and *Strengthening High-polluting Vehicles and Oil Quality Law Enforcement* (R54) have the largest point centrality, at 20, 18, 17, 17, 17, 17, indicating that the department-responsibility core network and general network are very inconsistent in the main responsibilities, and the point centrality gap is large. Although more departments participate in the

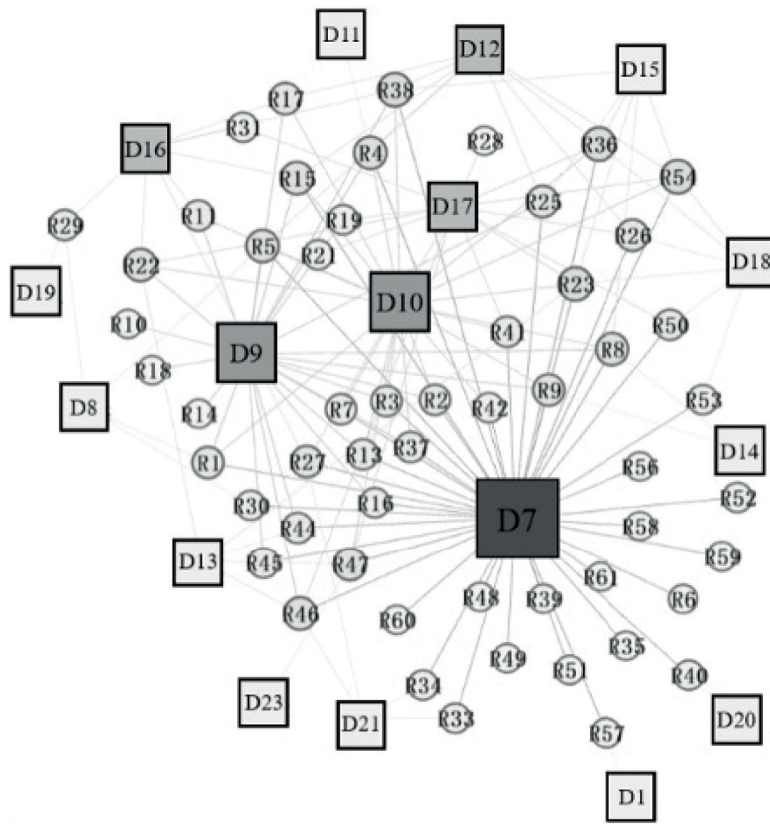


Fig 3. The department-responsibility core network for air pollution control in municipal governments.

responsibilities, there are only fewer high-frequency departments.

Optimization of departmental responsibilities for air pollution control in municipal governments

Since the department is involved in specific responsibilities, the order parameters of the department should be calculated in the specific responsibilities, that is, the co-occurrence of the department and the air pollution control efficiency need to be analysed in different responsibilities, in order to make the collaborative mechanism construction more detailed. In the same way, the relationship of responsibilities is also based on specific government departments. Only when the responsibility collaboration is established on the basis of which government departments can it be strengthened in a targeted manner. On the basis of the above analysis, departmental responsibilities of the municipal government can be optimized. Due to the space, this study only shows the refinement order parameters related to the optimization of departmental responsibilities, as shown in **table III**.

From the perspective of collaborative relationship, the relevant analysis of inter-departmental collaborations and air pollution control efficiency in the

responsibilities shows that there are 63 types of inter-departmental collaborations in 43 responsibilities that have a significant correlation with the air pollution control efficiency, and the number is higher than that of the direct inter-departmental collaborations in **table I**. The results indicate that inter-departmental collaborative mechanism is actually established on the basis of inter-departmental collaborations in responsibilities. Among them, the order parameters of 47 types of departments are positive, indicating that the collaborative mechanism of these departments should be strengthened to improve the air pollution control efficiency. On the other hand, the order parameters of six departments are negative, indicating that the integration between departments should be strengthened to improve the air pollution control efficiency. There are both positive and negative values for the order parameters of 10 departments, which means that the collaborative mechanism should be strengthened in the responsibilities with positive order parameters, and the integration between departments should be strengthened in the responsibilities with negative order parameters.

Since the order parameter is not a number, but a set of numbers, representing the multidimensionality of

the internal order of the system, this study optimizes responsibilities of government departments from the perspective of the inter-departmental collaboration and responsibility collaboration. The inter-departmental collaboration perspective mainly optimizes the department-responsibility network according to different responsibilities, and the responsibility collaboration perspective mainly optimizes the department-responsibility network according to different departments. Specifically, as shown in **table III**, when the order parameter of the department in the responsibility is positive, if the two departments and responsibilities in **figure 3** are both connected, it means that the insufficient responsibility of the department is not obvious. If there is no connection between any department and a certain responsibility, it indicates that the department has insufficient responsibility, resulting in less responsibility collaborations. The departments should be strengthened to undertake this responsibility to optimize the department-responsibility network. In the case where the order parameter of the responsibility in **table II** is positive, if all the government departments involved in **figure 3** are connected to the two responsibilities, it indicates that the insufficient responsibility of the department is not obvious; if there is no connection between any government department and a certain responsibility, it indicates that the government department has insufficient responsibility for that, resulting in less responsibility collaborations. The government department should be strengthened to undertake this responsibility to optimize the department-responsibility network. From the above analysis, we can see that there may be many departments involved in the responsibility collaborations. To avoid noise, this study selects departments that undertake two responsibilities in more than 5% of the samples.

If the order parameter of department and responsibility is negative, when two departments have connections with responsibilities and departments have connections with both two responsibilities, as long as one of the departments is exempted from assuming responsibilities or the department is exempted from undertaking one of the responsibilities can meet the requirements, but the specific responsibilities of government departments that should be exempted are not clear. It needs to further combine the positive sequence parameters of departments and responsibilities to make judgments. The study finds that for every two options that may need to be exempted from departments' responsibilities, it can be determined from the positive sequence parameters and derivation that one of them needs to be strengthened by government

departments, so that the specific government department's responsibility which needs to be exempted can be determined through the exclusion method. It shows that, to solve the problem of collaborations, scientific and rational allocation of departmental responsibilities can be derived and clarified. According to the above analysis, the optimization results of government departments' responsibilities are shown in **table IV**.

From **table IV**, it can be found that there are 145 departments in municipal government's air pollution control that have insufficient responsibilities, consisting of government departments and 49 responsibilities. There are three departments that have too many responsibilities, consisting of three government departments and three responsibilities. Analysed from the perspective of the department, among insufficient responsibilities of departments, *Department of Finance* (D13) needs to strengthen 18 responsibilities, and *Department of Housing and Urban-Rural Development* (D16), *Department of Ecology and Environment* (D7), *Department of Industry and Information Technology* (D10), *Department of Transport* (D17), *Department of Public Security* (D18) and *Department of Development and Reform* (D9) respectively has 16, 15, 15, 13, 11, 10 responsibilities to strengthen, of which Department of Finance, Department of Ecology and Environment, Department of Industry and Information Technology, and Department of Development and Reform belong to comprehensive management departments, with a total of 58 items. Department of Housing and Urban-Rural Development, Department of Transport and Department of Public Security belong to specialized management departments, with a total of 40 items, which together account for the majority of insufficient responsibilities of departments, indicating that comprehensive management departments should be mainly strengthened to assume responsibilities, while specialized management departments should also be strengthened. This is due to the multi-source and complexity of air pollution, leading to many problems that cannot be solved by the non-comprehensive management department. Therefore, it is necessary to strengthen comprehensive management departments to assume responsibilities. In addition, air pollution control requires specialized management. Specialized management departments have greater advantages in technology and management. Therefore, specialized management departments need to be strengthened to assume responsibilities. When the departments assume too many responsibilities, Department of Ecology and Environment should be exempted from straw

[illegible]

TABLE IV. DEPARTMENT RESPONSIBILITY OPTIMIZATION SUGGESTION.

Department	Optimization	Responsibility
D7	Strengthen	R11, R12, R14, R17, R18, R19, R20, R21, R22, R28, R31, R32, R34, R43, R55
	Cancel	R33
D8	Strengthen	R2, R3, R7, R11, R19, R21, R22, R35, R38
D9	Strengthen	R6, R12, R20, R35, R36, R42, R47, R52, R54, R60
D10	Strengthen	R6, R12, R14, R16, R18, R19, R21, R22, R25, R26, R35, R45, R46, R47, R60
D11	Strengthen	R2, R3, R5, R54
	Cancel	R4
D12	Strengthen	R2, R13, R22, R27, R37, R43, R46, R47
D13	Strengthen	R3, R4, R8, R11, R15, R18, R19, R21, R22, R25, R26, R31, R35, R36, R38, R45, R47, R53
D15	Strengthen	R1, R2, R19, R21, R22, R26, R35, R43
D16	Strengthen	R2, R4, R5, R13, R16, R18, R22, R30, R32, R35, R36, R37, R41, R43, R46, R47
D17	Strengthen	R3, R4, R7, R25, R26, R35, R38, R40, R42, R43, R44, R45, R48
D18	Strengthen	R5, R19, R21, R22, R25, R26, R27, R31, R35, R38, R41
D21	Strengthen	R35, R42, R47
	Cancel	R27
D31	Strengthen	R21, R22
D22	Strengthen	R46, R47
D29	Strengthen	R46, R47
D23	Strengthen	R46
D1	Strengthen	R61
D3	Strengthen	R58, R59, R61
D27	Strengthen	R1, R2, R3, R17

utilization, Department of Emergency Management should be exempted from elimination of backward and excess production capacity, and Department of Agriculture and Rural Affairs should be exempted from prevention and control of exhaust pollution from mobile machinery, indicating that a few departments have taken on too many responsibilities.

Analyzed from the perspective of the responsibility, among insufficient responsibilities, *Promoting New-energy Vehicles*(R22) and *Air Pollution Control in Autumn and Winter* (R35) need to increase 9 government departments, which are the most. There are 8 government departments to be *Increasing Tax-free Incentive Policy Support*(R47), 7 government departments in *Development of Intermodality* (R21),

and 6 government departments in *Adjusting regional industrial layout* (R2), *Optimizing Freight Structure* (R19) and *Increasing Economic Policy Support* (R46). Among them, promoting new-energy vehicles, increasing tax-free incentive policy support, development of inter-modality, optimizing freight structure, and increasing economic policy support belong to the government's guiding responsibilities, and carrying out Air Pollution Control in Autumn and Winter and adjusting regional industrial layout are government supervision responsibilities. In general, there are 81 departments that need to increase government supervision responsibilities, 60 departments that need to increase government guidance responsibilities, and four departments that need to increase social

management responsibilities. The insufficiency of departments responsible for government supervision is the most obvious. The departments responsible for government supervision should be mainly increased, and departments should also be increased for government guidance responsibilities to improve the effectiveness of air pollution control. There are too many departments responsible for the *Straw Utilization* (R33), *Elimination of Backward and Excess Production Capacity* (R4), and *Prevention and Control of Exhaust Pollution from Mobile Machinery* (R27), so each need to be exempted from a department. Since these responsibilities are government supervision responsibilities, it shows that a small number of government supervision responsibilities also have too many departments. The situation requires a specific analysis of specific circumstances, through targeted exemption of departments from taking on excessive supervision responsibilities, strengthening the dominant position of enterprises, and establishing and perfecting market-oriented operating mechanisms to enhance the effectiveness of air pollution control.

DISCUSSION

For inter-departmental collaboration, firstly, a clear division of the responsibility is the prerequisite for the establishment of the inter-departmental collaborative mechanism. Inter-departmental collaboration actually refers to the effective joint actions of the departments. When the division of the responsibility is not clear, even whether one should act is still doubtful, and there is no way to talk about effective joint action. Secondly, the order parameters of departments are the structural laws of inter-departmental collaborations formed by self-organizing movements within the system under influence of environmental factors such as culture, system, organization, mechanism, and technology. The existing inter-departmental collaborations are constantly changing under control of structural laws. Some of the order parameters promote inter-departmental collaborations, while some promote departmental integration. Due to the fragmentation of China, it is impossible to establish a long-term and efficient inter-departmental collaborative mechanism, which can only be solved by the bureaucratic collaborative mechanism. In this way, with the refinement of the government's division of labour, it will inevitably cause the improvement of government management levels and the expansion of institutions, leading to inefficiency and rising costs. As a last resort, it is necessary to carry out

institutional reforms through integrated means, resulting in the 8 large-scale government institutional reforms that China has experienced since the reform and opening up to fall into a streamlined-expansion cycle. Therefore, only through the self-organizing movement within the system to establish a collaborative mechanism, and through the adjustment of environmental factors to artificially indirectly control the collaborative mechanism, can we fundamentally jump out of the streamlined-expansion cycle. Thirdly, through the correlation analysis between departmental co-occurrence and governance effects, order parameters are obtained, the inter-departmental collaborative mechanism is constructed according to order parameters, and the current situation of order parameters and departmental co-occurrences are analysed to find out the difficulties of the slaving principle, that is, the administrative system problem existing in inter-departmental collaborations. Fourthly, the optimization of the departmental responsibility is to solve the problem of the administrative system reform of inter-departmental collaborative mechanism, mainly due to the excessive or lack of the responsibility of a certain department, and the exemption or increase of the responsibility of this department is to optimize them in a scientific and reasonable manner, which is conducive to enhancing the role of inter-departmental collaborative mechanism. Fifthly, the order parameter of departments changes with changes in environmental factors, the inter-departmental collaborations change with changes in departmental order parameters, and the optimization of departmental responsibilities changes with changes in inter-departmental collaborations. In other words, these three are all processes of dynamic adjustment. Since the internal order of the system is multi-dimensional, the analysis of the order parameters of responsibilities is similar to that of inter-departmental collaborations, so they won't be repeated here.

CONCLUSION

This study analyses collaborations in air pollution control in municipal governments, and reveals the problems of collaborations. Firstly, in the analysis of the order parameters of the departments, Department of Ecology and Environment, Department of Development and Reform involve the most positive correlations, indicating that strengthening the collaboration with comprehensive management departments can improve the effectiveness of air pollution

control. Department of Forestry and Grassland Administration has the most negative correlations, indicating that strengthening the collaboration with it will lead to a reduction in the effectiveness of air pollution control. In the disclosure of the problem of inter-departmental collaborations, Department of Ecology and Environment and Commission Office of Public Sectors Reform of Municipality, Department of Science and Technology and Department of Meteorological, Department of Justice and Municipal People's Procuratorate, Municipal Intermediate People's Court, Department of Education and Municipal Publicity Department of the CPC have problems with insufficient collaborations due to administrative system problems. Department of Forestry and Grassland Administration has a serious lack of integration with Department of Ecology and Environment and Department of Housing and Urban-Rural Development. Second, in the analysis of order parameters of responsibility collaborations, development of inter-modality, carrying out various forms of publicity and education, increasing economic policy support, and encouraging departmental participation and collaboration involve the most positive correlations, indicating that strengthening collaboration with the responsibilities of strongly positive externalities can improve the efficiency of air pollution control. Straw utilization involves the most negative correlations, indicating that strengthening collaboration with this responsibility will lead to a reduction in the effectiveness of air pollution control. In the disclosure of problems of responsibility collaborations, the lack of collaboration in carrying out stepping up inspection on ecological and environmental protection is the most obvious, indicating that more government departments should undertake other responsibilities while assuming stepping up inspection on ecological and environmental protection to improve the efficiency of air pollution control. The inconsistency between the interests and costs of participating government departments in the responsibility of straw utilization and other responsibilities is the most obvious, indicating that the integration of the government departments in this responsibility and other responsibilities should be strengthened.

Aiming at the collaboration problems existing in the air pollution control of the municipal government, this study optimizes the departmental responsibilities. First, from the perspective of government departments, the lack of responsibility for Department of Finance, Department of Housing and Urban-rural Development, Department of Ecology and Environment, Department of Industry and Infor-

mation Technology, Department of Transport, Department of Public Security and Department of Development and Reform is the most obvious, indicating that the comprehensive management departments should be mainly strengthened to assume responsibilities, while the specialized management departments should also be strengthened. Department of Ecology and Environment, Department of Emergency Management, Department of Agriculture and Rural Affairs each need to be exempted from a government responsibility, indicating that a small number of departments have taken on too many responsibilities. Second, from the perspective of the responsibility, departments that need to increase the responsibilities of promoting new-energy vehicles, air pollution control in autumn and winter, increasing tax-free incentive policy support, development of intermodality, adjusting regional industrial layout, optimizing freight structure, and increasing economic policy support are the most, indicating that the lack of government supervision responsibilities is the most obvious, and insufficiency of government departments responsible for guiding responsibilities is also obvious. Straw utilization, elimination of backward and excess production capacity, and prevention and control of exhaust pollution from mobile machinery need to be exempted from a government department, indicating that a small number of government supervision responsibilities also have too many departments, and it is necessary to exempt government departments from taking too much supervision responsibilities in order to improve the efficiency of air pollution control.

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APPENDIX

TABLE A1. ABBREVIATION OF RESPONSIBILITIES.

Responsibility	Abbreviation	Responsibility	Abbreviation	Responsibility	Abbreviation
Optimizing Industrial Layout	R1	Development of Intermodality	R21	Emergency Emission Reductions	R41
Adjusting Regional Industrial Layout	R2	Promoting New-energy Vehicles	R22	Staggered Production in Autumn and Winter	R42
Strictly Control of High Pollution and High Energy Consumption Industries	R3	Eliminating Old Vehicles	R23	Improving Laws, Regulations and Policies	R43
Elimination of Backward and Excess Production Capacity	R4	Ship Update and Upgrade	R24	Increasing Fiscal Expenditure	R44
Remediation of Pollution from Small-scale Enterprises	R5	Oil Quality Upgrade	R25	Expanding Channels for Investment and Fund-raising	R45
Promoting Industrial Pollution Discharge to Standard and Permit	R6	Motor Vehicle Pollution Control	R26	Increasing Economic Policy Support	R46
Industry Pollution Control Upgrade and Transformation	R7	Prevention and Control of Exhaust Pollution from Mobile Machinery	R27	Increasing Tax-free Incentive Policy Support	R47
Circular Transformation of Industrial Parks	R8	Promoting the Use of Shore Power by Ships and Aircraft Calling at Ports	R28	Building Ecological Environment Monitoring Network	R48
Cultivating Green Industry	R9	Implementing Wind-proof and Sand-fixing Greening Projects	R29	Construction of Automatic Monitoring System for Key Pollution Sources	R49
Promoting Winter Cleaning and Heating	R10	Open-pit Mine Renovation	R30	Enhancing Mobile Source Emission Supervision Capacity	R50
Building a Natural Gas Production, Supply, Storage and Marketing System	R11	Dust Control	R31	Controlling Monitoring Data Quality	R51
Rural Power Grid Upgrade	R12	Dust Reduction Assessment	R32	Improving the Basic Support of Science and Technology	R52
Total Coal Consumption Control	R13	Straw Utilization	R33	Strengthening Environmental Law Enforcement	R53
Development of Low-emission Coal-fired Power Generation and Clean Power Generation	R14	Agricultural Source Ammonia Emission Control	R34	Strengthening High-polluting Vehicles and Oil Quality Law Enforcement	R54
Renovation of Coal-fired Boilers	R15	Air Pollution Control in Autumn and Winter	R35	Stepping Up Inspection on Ecological and Environmental Protection	R55
Development of Combined Heat and Power and Central Heating	R16	Diesel Truck Pollution Control	R36	Encouraging Departmental Participation and Coordination	R56
Improving Energy Efficiency	R17	Remediation of Pollution in Industrial Furnaces	R37	Intensifying Evaluation and Accountability	R57
Development of Clean Energy and New Energy	R18	VOCs Remediation	R38	Promoting the Environmental Information Disclosure	R58
Optimizing Freight Structure	R19	Air Pollution Prevention and Control Cooperation	R39	Establishing the Mandatory Disclosure System of Environmental protection information	R59
Construction of Railway Freight Projects	R20	Linked Response to Heavy Pollution Weather	R40	Engaging the Public in Protecting the Environment	R60

TABLE AII. ABBREVIATION OF MUNICIPAL DEPARTMENTS.

Municipal Department	Abbreviation	Municipal Department	Abbreviation
Municipal Organization Department of the CPC	D1	Department of Transport	D17
Municipal Discipline Inspection Commission of the CPC & Supervisory Commission of the CPC	D2	Department of Public Security	D18
Municipal Publicity Department of the CPC	D3	Department of Forestry and Grassland Administration	D19
Municipal Intermediate People's Court	D4	Department of Meteorologic	D20
Municipal People's Procuratorate	D5	Department of Agriculture and Rural Affairs	D21
Department of Justice	D6	People's Bank of China	D22
Department of Ecology and Environment	D7	Department of Taxation	D23
Department of Natural Resources	D8	Department of Energy	D24
Department of Development and Reform	D9	Department of Education	D25
Department of Industry and Information Technology	D10	Department of Water Resources	D26
Department of Emergency Management	D11	Municipal Bureau of Big Data	D27
Department of Market Regulation	D12	Commission Office of Public Sectors Reform of Municipality	D28
Department of Finance	D13	Department of Financial Supervision	D29
Department of Science and Technology	D14	Department of Assets Supervision and Administration	D30
Department of Commerce	D15	Department of Railway Administration	D31
Department of Housing and Urban-Rural Development	D16		