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Identifying Waste Supply Chain Coordination Barriers with Fuzzy MCDM

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Abstract: The stability and efficiency of the waste supply chain (WSC) is related to the urban environment. This study constructed a framework of barriers to coordinating the WSC based on four perspectives: the costs and benefits, mechanisms involved, behaviors of the subjects, and technologies and standards used. We used an analytic network process based on the fuzzy decision-making trial and evaluation laboratory to calculate the centrality and weight of each barrier factor, and we determined the critical barriers to coordination by combining their results. A causality diagram of the barriers was drawn, and a scheme of coordination of the WSC was designed based on a closed-loop supply chain around the critical barriers. The results show that contradictions in benefits between subjects, contradictions between economic and social benefits, excessive subsidies, the failure of the market mechanism, the lack of a mechanism for supervision, and blocked information and distrust among the subjects are the five most critical barriers to the coordination of the WSC, with excessive subsidies the root cause of the lack of coordination. The subsidy for direct waste disposal should be used to reduce the cost of the operation of the WSC, waste recycling should be improved, an information-sharing platform should be built, and the cost of recyclable waste for manufacturers should be reduced to improve the efficiency of the WSC.

Keywords: WSC; supply chain coordination; critical barriers; analytic network process; decision-making trial and evaluation laboratory

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1. Introduction

The 21st century is prominent for competition among supply chains [1]. In the current environment of market competition, enterprises are paying increasing attention to the core competitiveness of their supply chains. Due to the distrust and asymmetry of information among the subjects in it, the supply chain needs to be coordinated to maintain stable and efficient operation and to maximize its overall benefits [2]. The current research on supply chain coordination has mainly focused on the problem of "double marginal benefits" that arises owing to decentralized decision making by subjects in the supply chain such that they prioritize the maximization of their own profits. Some scholars have used models in operational research, such as multiobjective programming and the newsboy model, to design contracts for the supply chain. They have designed revenue-sharing contracts, repurchasing contracts, and contracts pertaining to the flexibility of the quantities of goods for different products and scenarios of the supply chain [3]. Others have used game theory to study the strategic balance between subjects under different coordination mechanisms [4]. Previous researchers have provided a theoretical basis for examining supply chain coordination, but they usually make strict assumptions, such as abstracting from a complex supply chain to a simple one consisting of suppliers, wholesalers, and retailers, and assuming that the subjects in the supply chain are completely rational [5]. In practice, however, the structure of the supply chain is becoming increasingly complex with the development of the personalized requirements of consumers and the complexity of business models. There are many subjects in the supply chain, the relationships between them are complex, and they usually do not make completely rational decisions under various constraints. In such cases, many of the assumptions made in previous studies become untenable.

The waste supply chain (WSC) refers to a complex network that is composed of waste producers, recycling organizations, waste utilization enterprises, management departments of the government, financial institutions, and other organizations that are involved in the process of waste collection, recycling, disposal, and reuse [6]. Owing to the current environmental regulations and short lifecycles of products, the WSC has attracted interest from many researchers [7,8]. An efficient WSC can help reduce urban waste pollution and enhance the reuse value of waste. The WSC is a continuation of the forward supply chain of goods, and it forms a closed loop for the circulation of commodities. However, the forward supply chain and WSC are managed separately for most commodities in practice. A large number of valuable waste products are disposed of as garbage to be buried or incinerated, which leads to the waste of resources and damages the urban environment. The WSC is difficult to coordinate because it has a low added value, is tied to the features of public utilities, is significantly influenced by local policies, and lacks explicit core enterprises [9].

Coordinating the WSC is a popular subject of the research on supply chain management. Some scholars have claimed that implementing extended producer responsibility (EPR) with regard to household electrical appliances and the automobile industry could help improve the efficiency of the WSC. However, ERP has only a weak effect on low-value waste products, such as domestic and construction waste [10]. Others have claimed that the participation of third-party institutions could improve waste recycling and disposal to reduce the cost of the WSC based on the scale effect. The successes of Germany's Duales System Deutschland and Brazil's CEMPRE verify this view [11,12]. However, the introduction of third-party institutions leads to an increase in government subsidies and, thus, financial pressure on the government and regulatory difficulties. Researchers have also investigated the government's reward and punishment mechanisms, supply chain contracts, and other models of coordinating the supply chain [13]. Scholars have made some achievements in coordinating the WSC, but the existing research is focused on the cooperation among multiagents and government policy incentives, and obviously the results are not in line with the complex operating environment of the WSC. The differences in economic development and modes of waste disposal among countries imply that the WSC cannot be coordinated by applying a unified template, and there is a research gap in the detailed classification of the barriers in coordinating the WSC and the identification and importance ranking of the barriers in combination with the empirical situations of cities.

In the current study, we explore answers to the following research questions: What are the problems in coordinating the WSC? How do we identify the critical barriers to coordinating the WSC based on the situation at hand? How do we design the mechanism of coordination of the WSC according to the critical barriers to it? Solving these problems will help coordinate the WSC from the perspective of integrating the supply chain to prevent the contradictions in benefits that arise owing to decentralized decision making by the subjects in light of only a single barrier. Scholars usually use optimization design employing algorithms and machine learning to solve similar problems [14–16]. Such methods show good performances on large samples. The WSC is an imperfect system at present, and there are not enough samples in practice. Therefore, the construction and classification identification of a hindering-factor-system framework should be carried out first. We combined triangular fuzzy numbers with a decision-making trial and evaluation laboratory (DEMATEL)-based analytical network process (DEMATEL-based ANP (DANP for short)) to determine the weight of each barrier to the WSC and draw the corresponding causality diagram.

The study used the revised DANP method, rather than traditional DANP. The revised DANP method has the following characteristics. First, when identifying the key factors, the importance generated by the DEMATEL and the relative weight generated by the DANP are also considered. Second, when drawing the influence relationship between any two factors, only the largest influence relationship is retained, which greatly simplifies the cause-and-effect diagram and helps to analyze the dependency relationship between the key factors. Third, the method establishes a comprehensive and systematic evaluating index of the WSC coordination barriers, and it can help to ensure that the mechanism of coordination matches the characteristics of the WSC, and to realize the efficient collaboration among the parties involved.

The remainder of this paper is organized as follows. Section 2 provides a literature review, including the results of research on WSC coordination from four perspectives. This was used to construct a prototype of the decision structure of the system of barriers to coordinate the WSC. Section 3 introduces the proposed fuzzy DANP method, and Section 4 uses it to identify the critical barriers to coordinating the WSC, and discusses the implications of the results for waste management, and Section 5 summarizes the conclusions.

2. Literature Review

The current research on the waste supply chain has mainly focused on the following aspects: the design of the network of the WSC [7,17–20], assessments of its performance [21–25], and its coordinated development [26–30]. The coordination of the WSC is now the focus of the current research and practice in the area, and barriers to it are crucial in this regard. We draw on the literature in the area to propose four major barriers to the coordination of the WSC: the costs and benefits, the mechanisms involved, the behaviors of the subjects, and the technologies and standards used.

2.1. Barriers to Coordinating WSC

2.1.1. Costs and Benefits

The costs and benefits of the WSC represent financial problems that must be solved to ensure its development. Because enterprises are profit-driven, high costs and low benefits are the main barriers to the operation of the WSC. Scholars have identified problems related to the costs and benefits of waste recycling. Jnr et al. claimed that waste with little or no value generally ends up in uncontrolled and illegal landfills [31]. Tsai et al. found that some secondary markets do not consider solid wastes to be a valuable resource owing to the high cost of recycling them and the low returns from this practice [32]. Ghaffar et al. found that the costs of recycling and the secondary manufacture of products are high such that they impose pressure on enterprises in terms of making profits [33]. To balance corporate profits with social responsibility, the government coordinates the WSC through subsidies [34]. Hong et al. showed that government subsidies play an important role in encouraging the flow of recycled waste when dealing with end-of-life electronic products [35]. However, some researchers have questioned the current status of the waste subsidies in China. Sun et al. claimed that if the subsidy is high, then enterprises enter the market with profits in hand and withdraw once the subsidy has been eliminated [36]. The scale of benefits to the enterprise is important for the development of the WSC because it can achieve real profits after the elimination of subsidies. However, Tian found that most enterprises that engage in recycling supply chain waste are small, independent, and decentralized. The current recycling market has not yet formed economies of scale [37], and this is a barrier to the coordinated operation of the WSC. In addition, economic benefits often lead to negative pressure on social development. Araee et al. claimed that the contradiction between economic growth and sustainable social development greatly hinders waste management [38].

The above literature shows that enterprises engaged in the WSC are profit-driven, and that the costs and benefits thus influence their performances in the supply chain.

2.1.2. Mechanism

The mechanism in this context refers to the mode of operation according to which the government and market coordinate the relationships between all the parts of the WSC. The market mechanism allocates resources through competition and exchange. Gangolells et al. noted that an imbalance between the demand and supply in the recycling and reuse market is an important factor that hinders the development of recycled materials [30]. It causes the market mechanism to malfunction such that it cannot promote the smooth operation of the WSC. Because enterprises are profit-driven, the market mechanism alone cannot enable low-value recyclables to enter the recycling channel [36]. Bao et al. claimed that government-led and market-driven interventions can help expand the space for recycled products [39]. Many studies have found that incentives, subsidies, and penalties increase the rate of the collection of recyclables and promote the development of the WSC [40–42]. Sun et al. claimed that the efficiency of recycling low-value products is poor owing to a lack of effective reward and punishment mechanisms, as well as inadequate supervision [36]. Enterprises and residents generally have a poor awareness of environmental protection. Bao et al. noted that the public has an inadequate understanding of recycled products and harbors concerns about their quality [39]. Ghaffar et al. claimed that government intervention can promote the development of the recycling industry, and that extensive publicity of the practice helps the operation of the WSC [33]. Li found that the government had not adequately publicized the recycling of waste products, nor had it sufficiently educated the public on the issue [43]. This has led to a lack of awareness among enterprises and the public regarding resource recovery and recycling, and, in turn, has hindered the operation and development of the WSC.

2.1.3. Subject Behaviors

The behaviors of subjects refers to the actions of the participants in the operation of the WSC, and it focuses on the problems caused by them. Core enterprises play an important role in the supply chain in terms of organizing and coordinating to promote its development. Tian noted that recycling enterprises in the traditional supply chain are mainly independent, have limited space for profit, operate at a small scale, lack influence in terms of the overall supply chain, and cannot coordinate its operation [37]. The manufacturer is an important part of the WSC that determines whether a fully closed loop can be formed for a product. EPR is an environmental policy that extends the responsibility of manufacturers to the postconsumption stage [44]. EPR encourages manufacturers to enhance their resource efficiency and promote reverse supply chain operations through green innovation [45]. Marco claimed that the implementation of EPR can significantly improve the rate of waste collection, but it remains low in developed and developing countries [46]. In addition to the above subjects, advanced recycling technologies are indispensable for recycling waste. Bao et al. claimed that more research and development are needed to improve the quality of recycled products and eliminate public concerns regarding the issue [39]. However, research and development often rely on the enterprises themselves. Sun et al. claimed that universities and other scientific research institutions are not intimately involved in research on and the development of waste recycling technologies [36], where this is not conducive to the long-term operation of the WSC. Innovative technologies require not only scientific research teams, but also large investments of capital that are not possible for most recycling enterprises. Wang found that financial institutions are unwilling to help enterprises develop due to uncertainties regarding the return on investment [47]. This hinders the recovery, reproduction, and sale of secondary raw materials. Ghaffar et al. claimed that the largest barrier to the operation of the WSC is posed by logistics, accounting for 41% of the overall hindrance, followed by cost (29%) [33]. If the many subjects involved in the WSC can cooperate, then they can promote its development. Aid et al. claimed that management may not be able to identify opportunities for cooperation and make use of them because of an unwillingness to cooperate, distrust regarding the goals of cooperation, and doubts regarding the fairness of the system [48]. Information sharing has significant potential for increasing the recycling of waste; the efficient operation of the supply chain cannot be achieved without the effective flow of information. Sakr et al. noted that barriers to the WSC arise in cases of a lack of information for action, uncertainties in the available knowledge, and ambiguity in the information on the market supply [49].

The above literature shows that manufacturers, recycling enterprises, scientific research institutions, financial institutions, and other subjects influence the operation of the WSC. These subjects should thus be encouraged to cooperate with one another to promote the efficient operation of the WSC.

2.1.4. Technologies and Standards

Technologies and standards refer to those used for the classification, recovery, and disposal of waste during recycling and treatment. The classification of waste is a recently developed method to manage the problem of the “garbage siege” [50], and it can promote the recycling of waste [51,52]. China has long implemented the classification of garbage, beginning with a pilot project that started with 8 participating cities in 2000, which had increased to 237 cities by 2019 [53]. However, this has had no significant effect on improving the WSC. According to Jin et al., more than 60% of urban residents in China do not regularly separate their garbage [54]. Sz et al. found that the infrastructure for garbage classification is problematic, and that the lack of service convenience significantly affects the behavior of residents in terms of separating waste [55]. Bui et al. found that improper garbage classification makes recycling more complicated [56], and Shamshad et al. claimed that the effectiveness of garbage classification is influenced by the standards used. The standardized definition is broad and increases the difficulty of waste classification [57]. Delufa et al. found that the sorted garbage was mixed with loading and transportation in some areas [58]. The recycling and processing of waste can help realize resource recycling. Chien et al. claimed that the infrastructure for waste treatment is deficient and affects recycling and processing [59]. Um et al. claimed that the standards for waste recycling and the purposes of recycling are unclear and have made the public suspicious of recycled products [60]. A total of 52% of China’s urban waste is stored in landfills, 45% is incinerated, and only 3% is composted. Prajapati et al. found that developing countries lack relevant financial resources and waste disposal technology [61]. Shamshad et al. claimed that China’s efficiency of resource recovery is significantly lower than those of developed countries owing to its different methods of waste treatment [57].

According to the above, deficiencies persist in the standardization of classification and the transportation of waste. Unified standards for recycling products remain elusive, the recycling and processing technologies require improvement, and the infrastructure for the processing and disposal of waste products is immature. All these factors limit the operation of the WSC.

2.2. Initial Set of Barriers

We identified the barriers to the operation of the WSC, and we integrated them based on the above literature review. We classified them according to their definitions and deleted redundant factors/barriers according to the meaning of each. We finally obtained an initial set of four barriers: (i) the costs and benefits, (ii) the mechanisms involved, (iii) the behaviors of subjects, and (iv) the technologies and standards used. A detailed description of each is provided in Table 1.

Table 1. Initial set of barriers.

Aspect	Barrier Factor	Reference
Costs and benefits	Contradiction in benefits between subjects	[62]
	Contradiction between economic and social benefits	[38]
	Excessive subsidies	[36]

Table 1. *Cont.*

Aspect	Barrier Factor	Reference
	No economies of scale Uncertain financial profit	[63] [48]
	High transaction costs	[39,48,64]
	Market instability	[48]
	Low recycling value	[36,62]
Mechanisms	Failure of market mechanism	[65]
	Lack of supervision mechanism	[39,66]
	Lack of environmental awareness	[39,62]
Subjects’ behaviors	Information blockage and distrust among subjects	[32,48,62,67]
	Inadequate participation of scientific research and financial institutions	[36,47]
	Manufacturers have not implemented EPR	[33,46,68]
	Lack of core enterprises in supply chain	[37]
	Lack of logistics channels	[33]
Technologies and standards	Irregular garbage classification and transportation	[56–58,62]
	Inconsistent standards for recycled products	[32,39,60]
	Incomplete recycling and processing technologies	[33,48,57,61]
	Inadequate recycling and processing infrastructure	[61,69,70]

3. Proposed Method

The identification of the barriers to coordinating the WSC is a typical MCDM problem. There are many methods of MCDM, and the DEMATEL and ANP are representative [71]. They have been widely used in many fields of research [72–76]. The DEMATEL is used to identify the relationships between factors, while the ANP can prioritize certain factors. Researchers often use both to solve MCDM problems. Mohammad et al. used the fuzzy DANP to identify and assess the main factors influencing the risks to oil and gas projects under uncertain conditions [77]. Reza et al. used the DANP to determine the barriers to information technology in the sugarcane supply chain and determined the relevant priorities [78]. Nistha et al. used the DANP to study barriers to the adoption and development of food banks in India [79], and Reza et al. used the fuzzy DANP to study the key factors that influence the success of sustainable project management in the construction industry [80]. Subrata et al. aimed to address shortcomings using an integrated DEMATEL–ANP model to select the influencing factors and assess the ecological security of the Kolkata Metropolitan Area (KMA) [81]. Rao implemented Taiwan’s High Speed Rail Corporation as a case study and applied the DEMATEL–ANP-based method (DANP) to analyze and standardize the discrete indicator and synthetic performance indices using critical indicators [82]. Sezin et al. applied the MCDM approach to use the DEMATEL technique, integrated with an ANP, for selecting the most appropriate renewable energy resources in Turkey from an investor-focused perspective [83]. Chen used the DEMATEL–ANP method and considered the interrelationships and effects among the evaluation dimensions and criteria to precisely rank and select criteria [84].

Because the coordination of the WSC is hindered by many factors that are correlated, and given the main problem considered in this paper, we use the fuzzy DANP here.

Many organizations use group-based decision making to obtain satisfactory solutions to complex socioeconomic issues. However, many evaluations provided by experts or decisionmakers are vague and based on their subjective experiences. Moreover, the language used for assessment is based on qualitative criteria rather than quantitative values, and this makes further calculations and analyses challenging. We apply fuzzy set theory here to quantify the subjective judgments of the experts. This solves the problem of the deficiencies of human judgement by converting linguistic expressions into fuzzy numbers [85].

Many studies have reviewed some of the important definitions and methods of the calculation of fuzzy set theory [86–88]. By applying triangular fuzzy numbers to the DEMATEL, the traditional scores provided by the experts could be improved by scaling them to the interval of the fuzzy numbers, and the initial matrix of direct impacts was processed by using triangular fuzzy numbers to improve the accuracy of the DEMATEL. We then applied converting fuzzy data into crisp scores (CFCS) to defuzzify the total-relation matrix. Following this, we obtained the relationships between the causes and effects in the WSC by using the fuzzy DEMATEL. We used the total-relation matrix to generate a supermatrix for the ANP, and we obtained the weight of each criterion/factor/barrier. Finally, we identified the critical barriers to the WSC according to a comprehensive ranking of the factors. A general view of the fuzzy DANP method is shown in Figure 1.

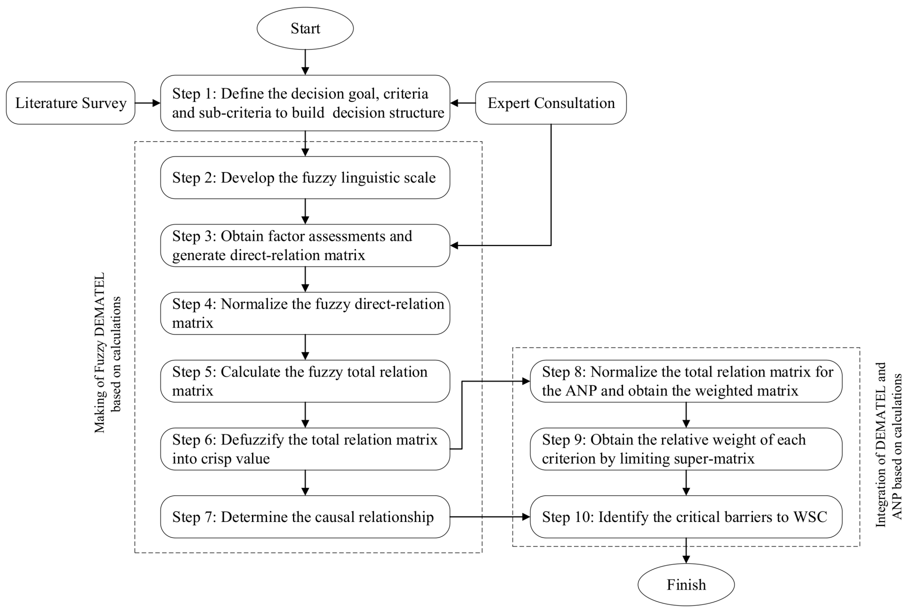

Figure 1. General view of fuzzy DANP method.

The computational steps of the fuzzy DANP are as follows:

Step 1: Define the decision goal, criteria, and subcriteria of the assessment model for the barrier factors. The assessment criteria are obtained through a literature review and expert experience and expertise. As a result, the formal decision structure is determined;

Step 2: Develop the fuzzy linguistic scale.

Linguistic variables receive values defined by linguistic terms, which are words or sentences in a natural or artificial language. Define $\widetilde{Z} = (l, m, u)$ on X as a triangular fuzzy number (TFN) and its membership function ($\mu_{\widetilde{A}}(x) : X \to [0,\ 1]$) follows Equation (1):

$$\mu_{\widetilde{A}}(x) = \begin{cases} \frac{x-l}{m-l},\ l \leq x \leq m \\ \frac{u-x}{u-m},\ m \leq x \leq u \\ 0,\ else \end{cases} \tag{1}$$

This study used five linguistics with respect to the fuzzy-level scale, as in Table 2, to evaluate the factors that influence each other. To obtain the interrelationships of each criterion, we consulted the experts and then converted the linguistic variables into a fuzzy linguistic scale;

Step 3: Obtain factor assessments from the team of decisionmakers.

Table 2. Fuzzy linguistic scale.

Linguistic Variable	Influence Score	Triangular Fuzzy Numbers (TFNs)
No influence (NO)	0	(0, 0.1, 0.3)
Very low influence (VL)	1	(0.1, 0.3, 0.5)
Low influence (L)	2	(0.3, 0.5, 0.7)
High influence (H)	3	(0.5, 0.7, 0.9)
Very high influence (VH)	4	(0.7, 0.9, 1.0)

Assume there are n assessment factors to consider, let $i, j = 1, 2, \ldots, n$, and suppose we have K experts. The expert decisionmakers are invited to give pair-wise comparisons. They are asked to evaluate the interrelationship of each factor by using five scores in linguistic variables: 0 (no influence); 1 (very low influence); 2 (low influence); 3 (high influence); 4 (very high influence). The fuzzy linguistic scale in Table 2 is then used to develop $\widetilde{Z}_{11}^{k}, \widetilde{Z}_{12}^{k}, \cdots \widetilde{Z}_{nn}^{k}$. Thus, the fuzzy matrix ($\widetilde{Z}_{(k)}$) is the initial direct-relation fuzzy matrix of expert decisionmaker k, and it follows Equation (2):

$$\widetilde{Z}_{(k)} = \begin{bmatrix} 0 & \widetilde{Z}_{21}^{(k)} & \cdots & \widetilde{Z}_{1n}^{(k)} \\ \widetilde{Z}_{21}^{(k)} & 0 & \cdots & \widetilde{Z}_{2n}^{(k)} \\ \vdots & \vdots & \ddots & \vdots \\ \widetilde{Z}_{n1}^{(k)} & \widetilde{Z}_{n2}^{(k)} & \cdots & 0 \end{bmatrix} \tag{2}$$

where $\widetilde{Z}_{ij}^{(k)} = \left(l_{ij}^{(k)}, m_{ij}^{(k)}, u_{ij}^{(k)}\right)$ means the degree of factor i that affects factor j from the fuzzy questionnaires (k ($k = 1, 2, \ldots, K$)). Then, the arithmetic mean of all the experts' assessments is calculated to generate the direct-relation matrix: $\widetilde{Z}$, $\widetilde{Z} = [\widetilde{z}_{ij}]_{n\times n}$. $\widetilde{Z}$ shows the direct effects that a factor exerts on and receives from other factors;

Step 4: Normalize the direct-relation fuzzy matrix.

The normalized direct-relation fuzzy matrix can be obtained using Equation (3):

$$\widetilde{x}_{ij} = \frac{\widetilde{z}_{\mathrm{ij}}}{r} = \left(\frac{l_{ij}}{r}, \frac{m_{ij}}{r}, \frac{u_{ij}}{r}\right) \tag{3}$$

where $r = \max\limits_{i,j}\left\{\max\limits_{i}\sum\limits_{j=1}^{n} u_{ij}, \max\limits_{j}\sum\limits_{i=1}^{n} u_{ij}\right\}$ $i, j \in \{1, 2, 3, \ldots, n\}$.

Then, we obtain the normalized direct-relation fuzzy matrix: $\widetilde{X}$, $\widetilde{X} = [\widetilde{x}_{\mathrm{ij}}]_{n\times n}$;

Step 5: Calculate the total-relation fuzzy matrix.

After normalizing the direct-relation matrix, the total-relation matrix (T) can be obtained by Equation (4):

$$\widetilde{T} = \lim_{W\to+\infty}\left(\widetilde{X}^1 \oplus \widetilde{X}^2 \oplus \ldots \oplus \widetilde{X}^W\right) = X(1-X)^{-1} \tag{4}$$

The normalized matrix is subtracted from the identity matrix (I). Then, the reverse matrix of this is calculated, and finally the normalized matrix is multiplied by the resulting matrix [89]. If each factor of the total-relation fuzzy matrix is expressed as $\widetilde{t}_{\mathrm{ij}} = \left(l''_{ij}, m''_{ij}, u''_{ij}\right)$ (a TFN belongs to $\widetilde{T}$), then the matrices $\left[l''_{ij}\right]$, $\left[m''_{ij}\right]$, and $\left[u''_{ij}\right]$ can be calculated by Equations (5)–(7), respectively:

$$\left[l''_{ij}\right] = x_l \times (I - x_l)^{-1} \tag{5}$$

$$\left[m''_{ij}\right] = x_m \times (I - x_m)^{-1} \tag{6}$$

$$\left[u''_{ij}\right] = x_u \times (I - x_u)^{-1} \tag{7}$$

Step 6: Defuzzify the total-relation matrix into a crisp value.

This study applies the CFCS method developed by Opricovic and Tzeng [90]. The CFCS method is used to obtain a crisp value of the total-influence matrix. The steps are carried out as follows:

The total-relation fuzzy matrix can be normalized by Equations (8)–(11):

$$l_{ij}^{n} = \frac{\left(l_{ij}^{t} - min\ l_{ij}^{t}\right)}{\Delta_{min}^{max}} \tag{8}$$

$$m_{ij}^{n} = \frac{\left(m_{ij}^{t} - min\ l_{ij}^{t}\right)}{\Delta_{min}^{max}} \tag{9}$$

$$u_{ij}^{n} = \frac{\left(u_{ij}^{t} - min\ l_{ij}^{t}\right)}{\Delta_{min}^{max}} \tag{10}$$

$$\Delta_{min}^{max} = max\ u_{ij}^{t} - min\ l_{ij}^{t} \tag{11}$$

where $max\ u_{ij}^{t}$ and $min\ l_{ij}^{t}$ refer to the largest upper bound and smallest lower bound in each column of the matrix ($\widetilde{T}$), respectively.

The upper (l_{ij}^{s}) and lower bounds (u_{ij}^{s}) of the normalized values are calculated by Equations (12) and (13), respectively:

$$l_{ij}^{s} = \frac{m_{ij}^{n}}{\left(1 + m_{ij}^{n} - l_{ij}^{n}\right)} \tag{12}$$

$$u_{ij}^{s} = \frac{u_{ij}^{n}}{\left(1 + u_{ij}^{n} - l_{ij}^{n}\right)} \tag{13}$$

The total normalized crisp values with respect to the upper and lower bounds are calculated by Equation (14):

$$T_{ij} = \frac{\left[l_{ij}^{s}\left(1 - l_{ij}^{s}\right) + u_{ij}^{s} \times u_{ij}^{s}\right]}{\left[1 - l_{ij}^{s} + u_{ij}^{s}\right]} \tag{14}$$

Step 7: Determine the causal relationship.

The next step is to calculate the sum of each row and each column of the total-relation matrix (T). The sum of the rows (D) and columns (R) can be calculated through Equations (15) and (16), respectively:

$$D = \sum_{j=1}^{n} T_{ij} \tag{15}$$

$$R = \sum_{i=1}^{n} T_{ij} \tag{16}$$

Then, the values of $D + R$ and $D - R$ can be calculated by the D and R, where $D + R$ represents the degree of importance of factor i in the entire system, and $D - R$ represents the net effects that factor i contributes to the system;

Step 8: Normalize the total-relation matrix for the ANP and obtain the weighted matrix.

The ANP is used to calculate the weight of each criterion. According to a previous study [91], the total-relation matrix of the DEMATEL can be treated as an unweighted supermatrix for the ANP. Therefore, a weighted matrix (W) can be obtained by normalizing the T. In the weighted matrix, the numbers in each column sum to 1;

Step 9: Obtain the relative weight of each criterion by limiting the supermatrix.

The global weight of each factor can be obtained by multiplying the W by itself several times until a limiting supermatrix (W^*) is derived. The weights are obtained from the corresponding columns of the limiting supermatrix;

Step 10: Identify the critical barriers to the WSC.

Because the relative weights represent the importance of each criterion, we identified the critical barriers according to the weights obtained by the fuzzy DANP method.

4. Results and Discussion

4.1. Determining Formal DECISION Structure

In this study, identifying the WSC coordination barriers was considered an MCDM problem. Thus, determining the criteria in the evaluating structure was the first task to solve. We conducted a systematic literature review, analyzing and summarizing the restrictive factors listed in Table 1. The factors are typically classified into four aspects: costs and benefits, mechanisms, the subjects' behaviors, and technologies and standards. Therefore, we proposed the prototype decision structure by selecting and integrating the criteria for assessment.

We selected an expert panel consisting of five experts: two government officials, one general manager in a waste management company, one technical director in a large-scale recycling facility, and one senior research fellow specializing in the research of waste recycling performance assessment. We interviewed the experts with consideration to the following points. First, we needed to understand the resistance to ecological synergy in the WSC. We used subjective evaluations to obtain the reasons for the restricted development of the WSC based on interviews with the experts, and we then identified the likely barriers. Second, we needed to identify the specific effects of the implementation of the relevant policies by the government at all levels to support the WSC, including financial subsidies, administrative regulations, and industry standards, to deduce the key factors and incorporate them into the index of assessment. Third, we needed to clarify the overall process and critical nodes of the WSC. Finally, we needed to understand the complex relationships among the multiple actors involved in the WSC, as well as the mechanism of collaborative governance among multiple agents. This was an essential complement to the construction of the index of assessment. Then, we used the Delphi method with a series of open-ended questionnaires distributed to each expert, and we finally formed the formal decision structure with a reliable consensus among the experts. The experts agreed that it was reasonable to categorize the goals of decision making into four primary aspects and to take into account each criterion. We adopted the experts' suggestions and decided on the index to identify the barriers to the WSC, as shown in Table 3. The experts' professional backgrounds are specified in Table 4.

Table 3. Decision structure to identify barriers to WSC.

Aspect	Barrier
Costs and benefits	Contradiction in benefits between subjects (F1)
	Contradiction between economic benefits and social benefits (F2)
	Excessive subsidies (F3)
	No economies of scale (F4)
Mechanisms	Failure of market mechanism (F5)
	Lack of supervision mechanism (F6)
	Lack of uniform waste recycling standards (F7)
	Lack of environmental awareness (F8)

Table 3. *Cont.*

Aspect	Barrier
Subjects' behaviors	Information blockage and distrust among subjects (F9)
	Inadequate participation of scientific research and financial institutions (F10)
	Manufacturers have not implemented EPR (F11)
	Lack of core enterprises in supply chain (F12)
	Lack of logistics channels (F13)
Technologies and standards	Irregular garbage classification and transportation (F14)
	Lack of experienced human resources (F15)
	Inadequate recycling and processing infrastructure (F16)

Table 4. Professional backgrounds of five selected experts.

Expert	Organization	Position	Duty	Seniority (Years)
1	Ministry of Ecology and Environment	Department Director	Developing waste recycling and processing regulations and standards	20
2	Inspection Bureau of Ecology and Environment	Deputy Director	Supervising and examining waste disposal and recycling	12
3	A waste management company	General Manager	Implementing waste collection and reuse projects	15
4	A large-scale waste recycling facility	Technical Director	Waste treatment technology development and application	13
5	A waste recycling research institute	Senior Research Fellow	Engaged in research on waste-recycling performance assessment	18

4.2. Identifying Critical Barriers to Coordinating WSC

By literature review and based on the experts' practical experience, we defined the potential barriers to coordinating the WSC. Previous studies and expert advice have proposed that the various criteria that describe the barriers have a connection network, which incorporates an interrelationship rather than a hierarchy. For instance, barriers about costs and benefits, such as the contradiction in benefits between subjects and the contradiction between economic benefits and social benefits, are usually interrelated. Therefore, it is reasonable to assume that the criteria within the WSC coordination are interactive. To analyze the interrelationships between the criteria, we applied the fuzzy DANP to identify the barriers restricting the WSC. First, we conducted the survey to gather the experts' opinions. We collected the experts' perceptions on the interdependent influences of the barrier factors to coordinating the WSC. The experts' viewpoints on the criteria and subcriteria were gathered via one-on-one interviews and the filling out of questionnaires with the linguistic terms. Then, we converted the linguistic terms into TFNs, defined by Equation (1). We calculated the initial fuzzy matrix of direct relations by using Equation (2), as shown in Table A1. The normalized matrix of direct relations was obtained by Equation (3), as shown in Table A2. The fuzzy matrix of total relations was obtained by Equations (4)–(7), as shown in Table A3. The crisp value of this matrix was obtained by Equations (8)–(14), as shown in Table 5. The degrees of centrality and causality of each criterion are shown in Table 6, according to Equations (15) and (16), respectively.

Table 5. DEMATEL total-relation matrix.

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16
F1	0.05	0.121	0.055	0.139	0.106	0.052	0.058	0.048	0.085	0.064	0.073	0.081	0.063	0.074	0.054	0.049
F2	0.107	0.051	0.049	0.127	0.098	0.067	0.054	0.069	0.074	0.057	0.059	0.063	0.058	0.082	0.062	0.051
F3	0.1	0.101	0.023	0.097	0.081	0.041	0.041	0.062	0.068	0.048	0.051	0.066	0.045	0.047	0.042	0.04
F4	0.05	0.056	0.029	0.035	0.051	0.036	0.033	0.031	0.037	0.037	0.038	0.045	0.048	0.047	0.041	0.038
F5	0.092	0.1	0.038	0.093	0.036	0.037	0.057	0.052	0.06	0.04	0.063	0.078	0.041	0.064	0.048	0.043
F6	0.07	0.074	0.061	0.076	0.06	0.023	0.056	0.052	0.048	0.039	0.08	0.055	0.039	0.086	0.044	0.053
F7	0.055	0.072	0.039	0.086	0.056	0.057	0.02	0.041	0.044	0.032	0.046	0.041	0.037	0.079	0.034	0.04
F8	0.043	0.049	0.032	0.055	0.047	0.047	0.03	0.018	0.047	0.037	0.053	0.038	0.033	0.051	0.048	0.034
F9	0.097	0.084	0.033	0.104	0.075	0.035	0.039	0.036	0.029	0.035	0.065	0.077	0.047	0.051	0.036	0.038
F10	0.055	0.066	0.042	0.088	0.046	0.033	0.036	0.049	0.037	0.02	0.052	0.066	0.037	0.059	0.059	0.068
F11	0.041	0.047	0.026	0.066	0.032	0.027	0.026	0.035	0.029	0.027	0.017	0.03	0.027	0.032	0.028	0.027
F12	0.052	0.065	0.029	0.086	0.053	0.034	0.03	0.031	0.055	0.03	0.039	0.023	0.038	0.048	0.038	0.031
F13	0.044	0.053	0.027	0.084	0.038	0.028	0.028	0.029	0.034	0.028	0.036	0.032	0.016	0.052	0.029	0.029
F14	0.046	0.045	0.026	0.072	0.037	0.028	0.035	0.028	0.03	0.027	0.046	0.031	0.028	0.02	0.032	0.028
F15	0.036	0.045	0.027	0.065	0.033	0.028	0.028	0.036	0.03	0.046	0.032	0.031	0.028	0.041	0.016	0.05
F16	0.074	0.095	0.032	0.114	0.058	0.034	0.037	0.053	0.042	0.034	0.06	0.039	0.035	0.056	0.039	0.021

Table 6. Total-relation matrix analysis.

Rank	Barrier	Influence Degree (D)	Influenced Degree (R)	Center Degree ($D + R$)	Cause Degree ($D - R$)	Factor Type
1	F2	1.128	1.124	2.252	0.004	Cause factor
2	F1	1.172	1.012	2.184	0.160	Cause factor
3	F4	0.652	1.387	2.039	−0.735	Effect factor
4	F5	0.942	0.907	1.849	0.035	Cause factor
5	F9	0.881	0.749	1.630	0.132	Cause factor
6	F6	0.916	0.607	1.523	0.309	Cause factor
7	F3	0.953	0.568	1.521	0.385	Cause factor
8	F12	0.682	0.796	1.478	−0.114	Effect factor
9	F16	0.823	0.64	1.463	0.183	Cause factor
10	F14	0.559	0.889	1.448	−0.330	Effect factor
11	F10	0.813	0.601	1.414	0.212	Cause factor
12	F7	0.779	0.608	1.387	0.171	Cause factor
13	F8	0.662	0.670	1.332	−0.008	Effect factor
14	F11	0.517	0.810	1.327	−0.293	Effect factor
15	F15	0.572	0.650	1.222	−0.078	Effect factor
16	F13	0.587	0.620	1.207	−0.033	Effect factor

The center degree ($D + R$) is the sum of the degree of influence (D) and the degree of having been influenced (R). It expresses the comprehensive influence of the barriers on one another. The cause degree ($D - R$) reflects their net influence [92]. We ranked the factors by their degrees of centrality in descending order. The positive and negative values of the degrees of causality represent the cause factors (greater than zero) and effect factors (less than zero), respectively. The contradiction in benefits between subjects (F1), the contradiction between economic and social benefits (F2), excessive subsidies (F3), the failure of the market mechanism (F5), the lack of a mechanism for supervision (F6), the lack of uniform standards for waste recycling (F7), inadequate participation by scientific research and financial institutions (F10), and incomplete recycling and processing technologies (F16) were the cause factors that significantly influenced the other factors. The lack of economies of scale (F4), environmental awareness (F8), the implementation of EPR by manufacturers (F11), core enterprises in the supply chain (F12), and experienced human resource officers (F15), as well as irregular garbage classification and transportation (F14), were the effect factors. This implies that the group of effect factors (F4, F8, F11, F12, F14, and F15) can be improved, while the group of cause factors (F1, F2, F3, F5, F6, F7, F10, and F16) can increase development.

The three highest-ranking cause factors were the degrees of centrality of the contradiction between economic and social benefits (F2), the contradiction in benefits between subjects (F1), and the failure of the market mechanism (F5). However, given the degrees of causality, the most important criterion restricting the WSC was excessive subsidies (F3). Therefore, it is essential to reasonably adjust them to reduce the barriers to the WSC.

The three highest-ranking effect factors were the degrees of centrality of the lack of economies of scale (F4), lack of environmental awareness (F8), and inadequate participation by scientific research and financial institutions (F10). However, the effect factors were all influenced by the cause factors, and thus they did not function as influential factors in the analysis of the chain of cause and effect.

The weighted supermatrix was generated by normalizing the total-relation matrix, and the limiting supermatrix was obtained by a subsequent weighted supermatrix, as shown in Table A4. The numbers in Table A5 represent the relative weights of the criteria in the evaluation of the barriers to the WSC. For example, 0.092 represents the weight of F1. The factor weights obtained by the limiting supermatrix are shown in Table 7.

Table 7. Weights obtained by limiting supermatrix.

Aspect	Barrier	Weight	Rank
Costs and benefits (A1) 0.311	Contradiction in benefits between subjects (F1)	0.092	1
	Contradiction between economic and social benefits (F2)	0.090	2
	Excessive subsidies (F3)	0.076	3
	No economies of scale (F4)	0.053	12
Mechanisms (A2) 0.262	Failure of market mechanism (F5)	0.074	4
	Lack of supervision mechanism (F6)	0.073	5
	Lack of uniform waste recycling standards (F7)	0.062	9
	Lack of environmental awareness (F8)	0.053	11
Subjects' behaviors (A3) 0.272	Information blockage and distrust among subjects (F9)	0.068	6
	Inadequate participation of scientific research and financial institutions (F10)	0.064	7
	Manufacturers have not implemented EPR (F11)	0.041	16
	Lack of core enterprises in supply chain (F12)	0.054	10
	Lack of logistics channels (F13)	0.045	14
Technologies and standards (A4) 0.154	Irregular garbage classification and transportation (F14)	0.044	15
	Lack of experienced human resources (F15)	0.046	16
	Inadequate recycling and processing infrastructure (F16)	0.063	8

The weights of the barriers to the WSC were as follows: A1 = 0.311; A3 = 0.272; A2 = 0.262; A4 = 0.154. They show that the costs and benefits (A1) had the largest weight, which means that the measures surrounding them need to be optimized most urgently.

The ranking of the barriers to the WSC in terms of the degree of centrality were obtained by using the fuzzy DEMATEL, and the weight of each barrier was calculated by using the DANP. Following this, the importance of the factors was sorted by adding the ranks of the fuzzy DEMATEL center degrees and DANP weights, representing the comprehensive ranks. Table 8 shows that the team of experts solicited for this study suggested the first six items in the ranking as critical barriers: contradictions in benefits between subjects (F1), contradictions between economic and social benefits (F2), excessive subsidies (F3), the failure of the market mechanism (F5), lack of supervision (F6), and information blockage and distrust among the subjects (F9). A causal diagram of the critical barriers based on the total-relation matrix is shown in Figure 2. Excessive subsidies (F3) formed the source of all the barriers because they had the highest degree of causality. These factors have led to a contradiction in benefits between subjects (F1), a contradiction between economic and social benefits (F2), the failure of the market mechanism (F5), and information blockage and distrust among subjects (F9). We also found that mitigating the contradiction between economic and social benefits (F2) could help improve the lack of a mechanism of supervision (F6).

Table 8. Rankings of barriers.

Barriers	Fuzzy DEMATEL Center Degree	DANP Weight	Comprehensive Rank
F1	2	1	2
F2	1	2	1
F3	7	3	4
F4	3	12	7
F5	4	4	3
F6	6	5	5
F7	12	9	11
F8	13	11	12
F9	5	6	6
F10	11	7	9
F11	14	16	14
F12	8	10	10
F13	16	14	15
F14	10	15	13
F15	15	16	16
F16	9	8	8

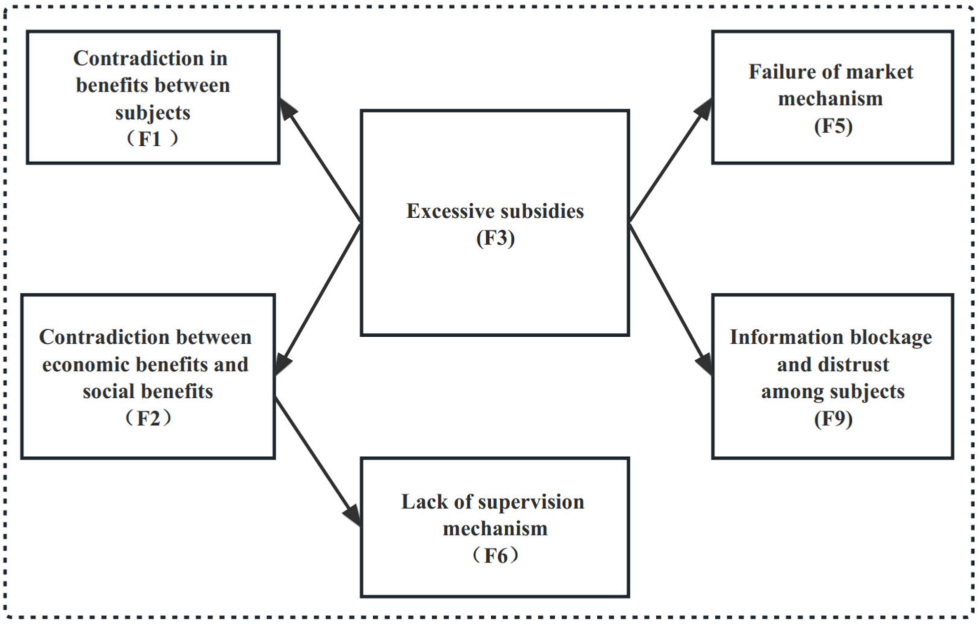

Figure 2. Causal diagram of critical barriers.

4.3. Discussion and Implications

Excessive subsidies are the root cause of the barriers to coordinating the WSC. Owing to its low added value, the cost of the WSC is greater than the income gleaned from it; thus, the actors in the supply chain are unwilling to participate in it. The WSC is closely related to the urban environment such that the relevant government departments need to guarantee its stability through subsidies. Such subsidies are mainly used to ensure the smooth operation of waste disposal institutions and to provide workers' wages. However, excessive subsidies have a significant negative effect on the process. First, subsidies exert great pressure on the government's finances [36]. Second, excessive subsidies motivate waste disposal organizations to obtain them rather than engage in high-quality waste disposal by investing in state-of-the-art waste disposal technology. This means that the manufacturers that are upstream of the WSC are less willing to purchase waste recyclables, and the market mechanism consequently fails [36]. Third, some institutions for waste disposal engage in dishonest behaviors, such as false reporting related to disposal, and these damage the interests of the government and manufacturers while breeding distrust among the actors involved in the supply chain [93]. Fourth, the government needs to attend to the urban environment as well as to the economic benefits of waste disposal. The concerns of the various parties involved in the process are inconsistent, and subsidies will aggravate this contradiction such that this will render the government unable to adequately supervise waste disposal institutions [94].

To eliminate the barriers to the coordination of the WSC, we propose that the government gradually reduce its direct subsidies for waste management institutions and to instead offer subsidies for the following four areas: reducing the operating costs of the supply chain, improving the value of waste recycling, building an information-sharing platform for the supply chain, and reducing the cost of recyclables for manufacturers.

(1) The operating costs of the supply chain and the value of waste recycling can be reduced and improved, respectively, at the same time. This would prevent subsidies from being the only link between the government and waste disposal institutions. This result is consistent with those reported by Zhang et al. [95] and Sun et al. [36], who verified the role of reducing the operating costs of the supply chain in improving the value of the coordination in the WSC. Furthermore, our results show that reducing the operating costs of the supply chain and improving the value of waste recycling complement each other and imply specific measures of implementation. The measures

to reduce the operational cost of the supply chain include improving the social awareness of green recycling and encouraging urban residents to better classify lean waste, guiding enterprises to expand the scope of their EPR implementation, and reducing the rents and other costs of waste disposal sites. Measures to enhance the value of waste recycling include purchasing advanced disposal equipment for waste disposal institutions and building a special research fund for waste recycling technology;

(2) An information-sharing platform can make the flow of waste recyclables in the WSC more transparent, facilitate supervision, better match the supply of waste recyclables with the demand for them, and smooth the business between subjects to solve the problem of the information blockage and distrust among them;

(3) The cost of waste recyclables is higher than that of new raw materials, and this is why manufacturers do not participate in the WSC. If recyclable waste cannot be circulated in the supply chain, then the market mechanism loses its function. Past research has claimed that the implementation of EPR depends on regulation by the government [96,97], but most waste has a low value, and mandatory EPR interferes considerably with the normal production and operation of enterprises. Therefore, we suggest that the government reduce the cost of waste recyclables by reducing tax rates to stimulate the participation of manufacturers and implement flexible EPR on some wastes.

In addition to changing the subsidies, the coordination of the WSC can be improved by encouraging scientific research and financial institutions to participate in the supply chain [36,47]. Scientific research institutions can conduct targeted research on advanced waste disposal technologies to enhance the value of waste recyclables in the WSC and make them more suitable for the market demand. Financial institutions can provide the capital needed by third-party waste disposal institutions to satisfy the entry threshold of the waste industry. This would be conducive to forming a positive environment that ensures continual improvements in the efficiency of the WSC.

5. Conclusions

In light of the problem of coordinating the waste supply chain, this study used MCDM to identify the critical barriers in this area, and it proposes a method that provides theoretical support to the government for the implementation of an efficient mechanism of incentives to promote the better use of wastes by large enterprises. The main conclusions are as follows:

(1) We used the literature and opinions of experts in the area to classify the barriers to the coordination of the WSC from four perspectives: the costs and benefits, mechanisms, behaviors of the subjects, and technologies and standards;

(2) We used the fuzzy DEMATEL to calculate the centrality rankings of the barriers, and we used the ANP to determine their weights. We used their combination to determine the importance of all the barriers. We thus identified a contradiction in benefits between subjects, a contradiction between economic and social benefits, excessive subsidies, the failure of the market mechanism, a lack of supervision, and information blockage and distrust among the subjects as the six most critical barriers to the WSC;

(3) We drew a causal diagram of the critical barriers mentioned above, and we designed a solution to the problem of supply chain coordination according to excessive subsidies, as this is the root cause hindering its development. We concluded that the operating costs of the supply chain need to be reduced, the value of waste recycling needs to be improved, an information-sharing platform for the supply chain needs to be built, and the cost of waste recyclables for manufacturers needs to be reduced to ensure the overall development of the WSC.

Because of the public welfare of the WSC, it is unable to fully rely on the market mechanism for its coordination. In this paper, we identified the critical barriers to the WSC. However, there are limitations that deserve further attention. First, this paper focused on the current state of the WSC. With the improvement in the supply chain, more entities will participate in the WSC, such as financial and scientific research institutions, and how to ensure the balance of interests among multiple subjects should be considered in the future. Second, advanced waste disposal technologies will play an important role in WSC coordination, but this study did not pay attention to the potential impact of interdisciplinary technology on WSC coordination.

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Appendix A

Table A1. Initial direct-relation matrix.

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16
F1	(0.000,0.000,0.000)	(0.580,0.780,0.940)	(0.120,0.300,0.500)	(0.660,0.860,0.980)	(0.500,0.700,0.880)	(0.080,0.220,0.420)	(0.120,0.300,0.500)	(0.020,0.140,0.340)	(0.340,0.540,0.720)	(0.200,0.380,0.580)	(0.220,0.380,0.580)	(0.260,0.460,0.660)	(0.180,0.340,0.540)	(0.180,0.340,0.540)	(0.080,0.220,0.420)	(0.060,0.180,0.380)
F2	(0.500,0.700,0.860)	(0.000,0.000,0.000)	(0.060,0.220,0.420)	(0.540,0.740,0.900)	(0.440,0.620,0.780)	(0.240,0.420,0.620)	(0.100,0.260,0.460)	(0.260,0.420,0.620)	(0.240,0.420,0.620)	(0.140,0.300,0.500)	(0.060,0.220,0.420)	(0.100,0.260,0.460)	(0.140,0.300,0.500)	(0.280,0.460,0.660)	(0.180,0.340,0.540)	(0.080,0.220,0.420)
F3	(0.480,0.660,0.820)	(0.420,0.620,0.800)	(0.000,0.000,0.000)	(0.260,0.460,0.660)	(0.280,0.460,0.660)	(0.020,0.140,0.340)	(0.020,0.140,0.340)	(0.180,0.380,0.580)	(0.200,0.380,0.580)	(0.080,0.220,0.420)	(0.060,0.180,0.380)	(0.180,0.340,0.540)	(0.040,0.180,0.380)	(0.000,0.100,0.300)	(0.020,0.140,0.340)	(0.020,0.140,0.340)
F4	(0.060,0.220,0.420)	(0.100,0.260,0.460)	(0.000,0.100,0.300)	(0.000,0.000,0.000)	(0.120,0.260,0.460)	(0.040,0.180,0.380)	(0.020,0.140,0.340)	(0.000,0.100,0.300)	(0.020,0.140,0.340)	(0.040,0.180,0.380)	(0.020,0.140,0.340)	(0.080,0.220,0.420)	(0.140,0.300,0.500)	(0.060,0.220,0.420)	(0.060,0.220,0.420)	(0.060,0.180,0.380)
F5	(0.380,0.580,0.760)	(0.420,0.620,0.820)	(0.020,0.140,0.340)	(0.240,0.420,0.600)	(0.000,0.000,0.000)	(0.000,0.100,0.300)	(0.200,0.340,0.540)	(0.080,0.260,0.460)	(0.160,0.300,0.500)	(0.020,0.140,0.340)	(0.160,0.340,0.540)	(0.320,0.500,0.700)	(0.020,0.140,0.340)	(0.160,0.300,0.500)	(0.080,0.220,0.420)	(0.040,0.180,0.380)
F6	(0.160,0.340,0.540)	(0.180,0.340,0.540)	(0.240,0.420,0.620)	(0.100,0.260,0.460)	(0.080,0.260,0.460)	(0.000,0.000,0.000)	(0.180,0.340,0.540)	(0.100,0.260,0.460)	(0.040,0.180,0.380)	(0.020,0.140,0.340)	(0.360,0.540,0.720)	(0.100,0.260,0.460)	(0.020,0.140,0.340)	(0.400,0.580,0.760)	(0.060,0.180,0.380)	(0.160,0.300,0.500)
F7	(0.060,0.220,0.420)	(0.200,0.380,0.580)	(0.060,0.180,0.380)	(0.260,0.460,0.660)	(0.120,0.260,0.460)	(0.200,0.380,0.580)	(0.000,0.000,0.000)	(0.040,0.180,0.380)	(0.060,0.180,0.380)	(0.000,0.100,0.300)	(0.040,0.180,0.380)	(0.020,0.140,0.340)	(0.020,0.140,0.340)	(0.360,0.540,0.740)	(0.000,0.100,0.300)	(0.060,0.180,0.380)
F8	(0.020,0.140,0.340)	(0.060,0.180,0.380)	(0.020,0.140,0.340)	(0.040,0.180,0.380)	(0.080,0.220,0.420)	(0.120,0.300,0.500)	(0.000,0.100,0.300)	(0.000,0.000,0.000)	(0.080,0.260,0.460)	(0.040,0.180,0.380)	(0.120,0.300,0.500)	(0.020,0.140,0.340)	(0.020,0.140,0.340)	(0.100,0.260,0.460)	(0.140,0.300,0.500)	(0.020,0.140,0.340)
F9	(0.460,0.660,0.860)	(0.260,0.460,0.660)	(0.000,0.100,0.300)	(0.380,0.580,0.780)	(0.240,0.420,0.620)	(0.000,0.100,0.300)	(0.020,0.140,0.340)	(0.000,0.100,0.300)	(0.000,0.000,0.000)	(0.000,0.100,0.300)	(0.200,0.380,0.580)	(0.320,0.500,0.700)	(0.080,0.220,0.420)	(0.060,0.180,0.380)	(0.000,0.100,0.300)	(0.020,0.140,0.340)
F10	(0.060,0.220,0.420)	(0.100,0.300,0.500)	(0.080,0.220,0.420)	(0.260,0.460,0.660)	(0.020,0.140,0.340)	(0.000,0.100,0.300)	(0.020,0.140,0.340)	(0.120,0.260,0.460)	(0.000,0.100,0.300)	(0.000,0.000,0.000)	(0.100,0.260,0.460)	(0.240,0.420,0.620)	(0.020,0.140,0.340)	(0.160,0.300,0.500)	(0.220,0.380,0.580)	(0.340,0.500,0.680)
F11	(0.040,0.180,0.380)	(0.080,0.220,0.420)	(0.000,0.100,0.300)	(0.180,0.380,0.580)	(0.000,0.100,0.300)	(0.000,0.100,0.300)	(0.000,0.100,0.300)	(0.040,0.180,0.380)	(0.000,0.100,0.300)	(0.000,0.100,0.300)	(0.000,0.000,0.000)	(0.000,0.100,0.300)	(0.000,0.100,0.300)	(0.000,0.100,0.300)	(0.000,0.100,0.300)	(0.000,0.100,0.300)
F12	(0.060,0.220,0.420)	(0.180,0.340,0.540)	(0.000,0.100,0.300)	(0.300,0.500,0.700)	(0.080,0.260,0.460)	(0.020,0.140,0.340)	(0.000,0.100,0.300)	(0.000,0.100,0.300)	(0.160,0.340,0.540)	(0.000,0.100,0.300)	(0.020,0.140,0.340)	(0.000,0.000,0.000)	(0.040,0.180,0.380)	(0.080,0.220,0.420)	(0.040,0.180,0.380)	(0.000,0.100,0.300)
F13	(0.040,0.180,0.380)	(0.100,0.260,0.460)	(0.000,0.100,0.300)	(0.340,0.540,0.740)	(0.020,0.140,0.340)	(0.000,0.100,0.300)	(0.000,0.100,0.300)	(0.000,0.100,0.300)	(0.020,0.140,0.340)	(0.000,0.100,0.300)	(0.020,0.140,0.340)	(0.000,0.100,0.300)	(0.000,0.000,0.000)	(0.140,0.300,0.500)	(0.000,0.100,0.300)	(0.000,0.100,0.300)
F14	(0.060,0.220,0.420)	(0.040,0.180,0.380)	(0.000,0.100,0.300)	(0.220,0.420,0.620)	(0.020,0.140,0.340)	(0.000,0.100,0.300)	(0.060,0.180,0.380)	(0.000,0.100,0.300)	(0.000,0.100,0.300)	(0.000,0.100,0.300)	(0.120,0.260,0.460)	(0.000,0.100,0.300)	(0.000,0.100,0.300)	(0.000,0.000,0.000)	(0.020,0.140,0.340)	(0.000,0.100,0.300)
F15	(0.000,0.100,0.300)	(0.040,0.180,0.380)	(0.000,0.100,0.300)	(0.140,0.340,0.540)	(0.000,0.100,0.300)	(0.000,0.100,0.300)	(0.000,0.100,0.300)	(0.040,0.180,0.380)	(0.000,0.100,0.300)	(0.140,0.300,0.500)	(0.000,0.100,0.300)	(0.000,0.100,0.300)	(0.000,0.100,0.300)	(0.060,0.180,0.380)	(0.000,0.000,0.000)	(0.180,0.340,0.540)
F16	(0.220,0.420,0.620)	(0.420,0.620,0.820)	(0.000,0.100,0.300)	(0.540,0.740,0.920)	(0.100,0.260,0.460)	(0.000,0.100,0.300)	(0.020,0.140,0.340)	(0.120,0.300,0.500)	(0.020,0.140,0.340)	(0.000,0.100,0.300)	(0.160,0.340,0.540)	(0.000,0.100,0.300)	(0.000,0.100,0.300)	(0.120,0.260,0.460)	(0.020,0.140,0.340)	(0.000,0.000,0.000)

Table A2. Normalized direct-relation matrix.

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16
F1	(0.000,0.000,0.000)	(0.057,0.077,0.092)	(0.012,0.029,0.049)	(0.065,0.084,0.096)	(0.049,0.069,0.086)	(0.008,0.022,0.041)	(0.012,0.029,0.049)	(0.002,0.014,0.033)	(0.033,0.053,0.071)	(0.020,0.037,0.057)	(0.022,0.037,0.057)	(0.026,0.045,0.065)	(0.018,0.033,0.053)	(0.018,0.033,0.053)	(0.008,0.022,0.041)	(0.006,0.018,0.037)
F2	(0.049,0.069,0.084)	(0.000,0.000,0.000)	(0.006,0.022,0.041)	(0.053,0.073,0.088)	(0.043,0.061,0.077)	(0.024,0.041,0.061)	(0.010,0.026,0.045)	(0.026,0.041,0.061)	(0.024,0.041,0.061)	(0.014,0.029,0.049)	(0.006,0.022,0.041)	(0.010,0.026,0.045)	(0.014,0.029,0.049)	(0.028,0.045,0.065)	(0.018,0.033,0.053)	(0.008,0.022,0.041)
F3	(0.047,0.065,0.081)	(0.041,0.061,0.079)	(0.000,0.000,0.000)	(0.026,0.045,0.065)	(0.028,0.045,0.065)	(0.002,0.014,0.033)	(0.002,0.014,0.033)	(0.018,0.037,0.057)	(0.020,0.037,0.057)	(0.008,0.022,0.041)	(0.006,0.018,0.037)	(0.018,0.033,0.053)	(0.004,0.018,0.037)	(0.000,0.010,0.029)	(0.002,0.014,0.033)	(0.002,0.014,0.033)
F4	(0.006,0.022,0.041)	(0.010,0.026,0.045)	(0.000,0.010,0.029)	(0.000,0.000,0.000)	(0.012,0.026,0.045)	(0.004,0.018,0.037)	(0.002,0.014,0.033)	(0.000,0.010,0.029)	(0.002,0.014,0.033)	(0.004,0.018,0.037)	(0.002,0.014,0.033)	(0.008,0.022,0.041)	(0.014,0.029,0.049)	(0.006,0.022,0.041)	(0.006,0.022,0.041)	(0.006,0.018,0.037)
F5	(0.037,0.057,0.075)	(0.041,0.061,0.081)	(0.002,0.014,0.033)	(0.024,0.041,0.059)	(0.000,0.000,0.000)	(0.000,0.010,0.029)	(0.020,0.033,0.053)	(0.008,0.026,0.045)	(0.016,0.029,0.049)	(0.002,0.014,0.033)	(0.016,0.033,0.053)	(0.031,0.049,0.069)	(0.002,0.014,0.033)	(0.016,0.029,0.049)	(0.008,0.022,0.041)	(0.004,0.018,0.037)
F6	(0.016,0.033,0.053)	(0.018,0.033,0.053)	(0.024,0.041,0.061)	(0.010,0.026,0.045)	(0.008,0.026,0.045)	(0.000,0.000,0.000)	(0.018,0.033,0.053)	(0.010,0.026,0.045)	(0.004,0.018,0.037)	(0.002,0.014,0.033)	(0.035,0.053,0.071)	(0.010,0.026,0.045)	(0.002,0.014,0.033)	(0.039,0.057,0.075)	(0.006,0.018,0.037)	(0.016,0.029,0.049)
F7	(0.006,0.022,0.041)	(0.020,0.037,0.057)	(0.006,0.018,0.037)	(0.026,0.045,0.065)	(0.012,0.026,0.045)	(0.020,0.037,0.057)	(0.000,0.000,0.000)	(0.004,0.018,0.037)	(0.006,0.018,0.037)	(0.000,0.010,0.029)	(0.004,0.018,0.037)	(0.002,0.014,0.033)	(0.002,0.014,0.033)	(0.035,0.053,0.073)	(0.000,0.010,0.029)	(0.006,0.018,0.037)
F8	(0.002,0.014,0.033)	(0.006,0.018,0.037)	(0.002,0.014,0.033)	(0.004,0.018,0.037)	(0.008,0.022,0.041)	(0.012,0.029,0.049)	(0.000,0.010,0.029)	(0.000,0.000,0.000)	(0.008,0.026,0.045)	(0.004,0.018,0.037)	(0.012,0.029,0.049)	(0.002,0.014,0.033)	(0.002,0.014,0.033)	(0.010,0.026,0.045)	(0.014,0.029,0.049)	(0.002,0.014,0.033)
F9	(0.045,0.065,0.084)	(0.026,0.045,0.065)	(0.000,0.010,0.029)	(0.037,0.057,0.077)	(0.024,0.041,0.061)	(0.000,0.010,0.029)	(0.002,0.014,0.033)	(0.000,0.010,0.029)	(0.000,0.000,0.000)	(0.000,0.010,0.029)	(0.020,0.037,0.057)	(0.031,0.049,0.069)	(0.008,0.022,0.041)	(0.006,0.018,0.037)	(0.000,0.010,0.029)	(0.002,0.014,0.033)
F10	(0.006,0.022,0.041)	(0.010,0.029,0.049)	(0.008,0.022,0.041)	(0.026,0.045,0.065)	(0.002,0.014,0.033)	(0.000,0.010,0.029)	(0.002,0.014,0.033)	(0.012,0.026,0.045)	(0.000,0.010,0.029)	(0.000,0.000,0.000)	(0.010,0.026,0.045)	(0.024,0.041,0.061)	(0.002,0.014,0.033)	(0.016,0.029,0.049)	(0.022,0.037,0.057)	(0.033,0.049,0.067)
F11	(0.004,0.018,0.037)	(0.008,0.022,0.041)	(0.000,0.010,0.029)	(0.018,0.037,0.057)	(0.000,0.010,0.029)	(0.000,0.010,0.029)	(0.000,0.010,0.029)	(0.004,0.018,0.037)	(0.000,0.010,0.029)	(0.000,0.010,0.029)	(0.000,0.000,0.000)	(0.000,0.010,0.029)	(0.000,0.010,0.029)	(0.000,0.010,0.029)	(0.000,0.010,0.029)	(0.000,0.010,0.029)
F12	(0.006,0.022,0.041)	(0.018,0.033,0.053)	(0.000,0.010,0.029)	(0.029,0.049,0.069)	(0.008,0.026,0.045)	(0.002,0.014,0.033)	(0.000,0.010,0.029)	(0.000,0.010,0.029)	(0.016,0.033,0.053)	(0.000,0.010,0.029)	(0.002,0.014,0.033)	(0.000,0.000,0.000)	(0.004,0.018,0.037)	(0.008,0.022,0.041)	(0.004,0.018,0.037)	(0.000,0.010,0.029)
F13	(0.004,0.018,0.037)	(0.010,0.026,0.045)	(0.000,0.010,0.029)	(0.033,0.053,0.073)	(0.002,0.014,0.033)	(0.000,0.010,0.029)	(0.000,0.010,0.029)	(0.000,0.010,0.029)	(0.002,0.014,0.033)	(0.000,0.010,0.029)	(0.002,0.014,0.033)	(0.000,0.010,0.029)	(0.000,0.000,0.000)	(0.014,0.029,0.049)	(0.000,0.010,0.029)	(0.000,0.010,0.029)
F14	(0.006,0.022,0.041)	(0.004,0.018,0.037)	(0.000,0.010,0.029)	(0.022,0.041,0.061)	(0.002,0.014,0.033)	(0.000,0.010,0.029)	(0.006,0.018,0.037)	(0.000,0.010,0.029)	(0.000,0.010,0.029)	(0.000,0.010,0.029)	(0.012,0.026,0.045)	(0.000,0.010,0.029)	(0.000,0.010,0.029)	(0.000,0.000,0.000)	(0.002,0.014,0.033)	(0.000,0.010,0.029)
F15	(0.000,0.010,0.029)	(0.004,0.018,0.037)	(0.000,0.010,0.029)	(0.014,0.033,0.053)	(0.000,0.010,0.029)	(0.000,0.010,0.029)	(0.000,0.010,0.029)	(0.004,0.018,0.037)	(0.000,0.010,0.029)	(0.014,0.029,0.049)	(0.000,0.010,0.029)	(0.000,0.010,0.029)	(0.000,0.010,0.029)	(0.006,0.018,0.037)	(0.000,0.000,0.000)	(0.018,0.033,0.053)
F16	(0.022,0.041,0.061)	(0.041,0.061,0.081)	(0.000,0.010,0.029)	(0.053,0.073,0.090)	(0.010,0.026,0.045)	(0.000,0.010,0.029)	(0.002,0.014,0.033)	(0.012,0.029,0.049)	(0.002,0.014,0.033)	(0.000,0.010,0.029)	(0.016,0.033,0.053)	(0.000,0.010,0.029)	(0.000,0.010,0.029)	(0.012,0.026,0.045)	(0.002,0.014,0.033)	(0.000,0.000,0.000)

Table A3. Fuzzy total-relation matrix.

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16
F1	(0.009,0.033,0.130)	(0.064,0.108,0.225)	(0.013,0.043,0.135)	(0.076,0.126,0.253)	(0.055,0.094,0.201)	(0.010,0.038,0.132)	(0.014,0.046,0.140)	(0.005,0.032,0.130)	(0.037,0.073,0.172)	(0.021,0.052,0.145)	(0.025,0.059,0.164)	(0.031,0.068,0.172)	(0.020,0.050,0.145)	(0.023,0.059,0.168)	(0.011,0.040,0.136)	(0.008,0.035,0.131)
F2	(0.055,0.095,0.204)	(0.009,0.034,0.136)	(0.008,0.036,0.126)	(0.063,0.112,0.241)	(0.049,0.086,0.189)	(0.025,0.055,0.147)	(0.012,0.042,0.134)	(0.027,0.057,0.153)	(0.027,0.061,0.161)	(0.016,0.045,0.136)	(0.011,0.045,0.148)	(0.015,0.049,0.152)	(0.016,0.046,0.139)	(0.033,0.069,0.177)	(0.020,0.050,0.145)	(0.010,0.038,0.132)
F3	(0.053,0.088,0.187)	(0.048,0.087,0.194)	(0.001,0.012,0.076)	(0.035,0.080,0.201)	(0.034,0.068,0.166)	(0.004,0.027,0.111)	(0.004,0.027,0.112)	(0.020,0.051,0.138)	(0.024,0.055,0.146)	(0.010,0.035,0.118)	(0.009,0.036,0.131)	(0.022,0.052,0.146)	(0.006,0.032,0.117)	(0.004,0.030,0.130)	(0.004,0.028,0.115)	(0.004,0.027,0.113)
F4	(0.008,0.036,0.124)	(0.012,0.041,0.135)	(0.000,0.017,0.087)	(0.003,0.021,0.108)	(0.013,0.038,0.122)	(0.004,0.025,0.096)	(0.003,0.021,0.093)	(0.001,0.018,0.093)	(0.003,0.024,0.102)	(0.004,0.025,0.096)	(0.003,0.025,0.105)	(0.009,0.032,0.112)	(0.014,0.037,0.108)	(0.007,0.034,0.118)	(0.006,0.030,0.103)	(0.006,0.026,0.099)
F5	(0.042,0.079,0.180)	(0.046,0.085,0.194)	(0.003,0.025,0.107)	(0.033,0.075,0.195)	(0.006,0.023,0.103)	(0.002,0.023,0.108)	(0.021,0.045,0.129)	(0.010,0.039,0.126)	(0.019,0.047,0.137)	(0.004,0.026,0.110)	(0.018,0.050,0.144)	(0.034,0.065,0.158)	(0.004,0.027,0.112)	(0.020,0.049,0.147)	(0.010,0.035,0.121)	(0.005,0.030,0.116)
F6	(0.020,0.055,0.158)	(0.023,0.058,0.166)	(0.024,0.051,0.131)	(0.017,0.058,0.179)	(0.011,0.045,0.143)	(0.001,0.012,0.077)	(0.019,0.045,0.127)	(0.011,0.039,0.125)	(0.006,0.033,0.124)	(0.003,0.025,0.108)	(0.037,0.068,0.159)	(0.012,0.041,0.134)	(0.003,0.026,0.110)	(0.042,0.074,0.168)	(0.007,0.030,0.116)	(0.017,0.041,0.125)
F7	(0.009,0.040,0.135)	(0.023,0.056,0.157)	(0.007,0.026,0.102)	(0.030,0.070,0.182)	(0.014,0.041,0.132)	(0.020,0.046,0.123)	(0.001,0.010,0.069)	(0.005,0.028,0.109)	(0.007,0.030,0.114)	(0.001,0.019,0.096)	(0.006,0.032,0.119)	(0.004,0.027,0.114)	(0.003,0.024,0.102)	(0.038,0.068,0.157)	(0.001,0.020,0.100)	(0.007,0.027,0.106)
F8	(0.004,0.028,0.118)	(0.008,0.033,0.128)	(0.002,0.021,0.091)	(0.006,0.038,0.144)	(0.009,0.034,0.119)	(0.012,0.036,0.108)	(0.001,0.018,0.090)	(0.001,0.009,0.065)	(0.008,0.035,0.113)	(0.004,0.025,0.097)	(0.013,0.040,0.121)	(0.003,0.025,0.106)	(0.002,0.021,0.094)	(0.011,0.037,0.122)	(0.014,0.037,0.111)	(0.003,0.022,0.096)
F9	(0.049,0.084,0.184)	(0.031,0.069,0.175)	(0.001,0.020,0.100)	(0.045,0.088,0.205)	(0.028,0.061,0.156)	(0.001,0.021,0.103)	(0.004,0.026,0.108)	(0.001,0.022,0.108)	(0.004,0.017,0.087)	(0.002,0.022,0.103)	(0.022,0.052,0.144)	(0.034,0.065,0.155)	(0.010,0.034,0.117)	(0.009,0.036,0.132)	(0.002,0.023,0.107)	(0.003,0.025,0.109)
F10	(0.008,0.040,0.137)	(0.013,0.050,0.153)	(0.008,0.030,0.107)	(0.031,0.072,0.186)	(0.004,0.030,0.123)	(0.001,0.020,0.099)	(0.003,0.023,0.102)	(0.013,0.037,0.118)	(0.001,0.023,0.109)	(0.001,0.010,0.070)	(0.011,0.039,0.127)	(0.025,0.053,0.141)	(0.003,0.024,0.104)	(0.018,0.044,0.136)	(0.023,0.048,0.128)	(0.034,0.059,0.136)
F11	(0.005,0.028,0.109)	(0.008,0.033,0.119)	(0.000,0.015,0.079)	(0.019,0.051,0.147)	(0.001,0.019,0.097)	(0.000,0.016,0.081)	(0.000,0.015,0.081)	(0.004,0.024,0.092)	(0.000,0.017,0.089)	(0.000,0.015,0.081)	(0.000,0.008,0.063)	(0.000,0.018,0.091)	(0.000,0.016,0.082)	(0.001,0.019,0.096)	(0.000,0.016,0.084)	(0.000,0.016,0.083)
F12	(0.008,0.037,0.128)	(0.020,0.049,0.145)	(0.000,0.017,0.088)	(0.033,0.070,0.175)	(0.010,0.039,0.125)	(0.003,0.022,0.095)	(0.001,0.018,0.091)	(0.001,0.019,0.095)	(0.017,0.043,0.122)	(0.001,0.018,0.091)	(0.003,0.025,0.107)	(0.002,0.012,0.075)	(0.005,0.027,0.100)	(0.009,0.034,0.120)	(0.005,0.026,0.101)	(0.001,0.018,0.093)
F13	(0.005,0.030,0.115)	(0.011,0.038,0.128)	(0.000,0.016,0.083)	(0.035,0.069,0.169)	(0.003,0.025,0.106)	(0.000,0.016,0.085)	(0.000,0.016,0.086)	(0.000,0.017,0.089)	(0.003,0.022,0.097)	(0.000,0.016,0.085)	(0.003,0.023,0.100)	(0.001,0.019,0.096)	(0.001,0.007,0.058)	(0.014,0.039,0.120)	(0.001,0.017,0.088)	(0.000,0.017,0.087)
F14	(0.007,0.032,0.116)	(0.005,0.030,0.119)	(0.000,0.015,0.081)	(0.023,0.057,0.155)	(0.003,0.024,0.104)	(0.000,0.016,0.084)	(0.006,0.024,0.091)	(0.000,0.017,0.087)	(0.000,0.018,0.091)	(0.000,0.016,0.084)	(0.012,0.034,0.109)	(0.001,0.018,0.094)	(0.001,0.017,0.085)	(0.001,0.010,0.071)	(0.002,0.020,0.090)	(0.000,0.016,0.086)
F15	(0.001,0.022,0.107)	(0.005,0.031,0.120)	(0.000,0.015,0.082)	(0.016,0.050,0.149)	(0.001,0.020,0.101)	(0.000,0.016,0.084)	(0.000,0.016,0.085)	(0.004,0.025,0.096)	(0.000,0.018,0.092)	(0.014,0.035,0.102)	(0.001,0.019,0.096)	(0.001,0.019,0.095)	(0.000,0.016,0.085)	(0.007,0.028,0.108)	(0.001,0.007,0.059)	(0.018,0.040,0.109)
F16	(0.025,0.060,0.157)	(0.044,0.080,0.182)	(0.001,0.019,0.097)	(0.059,0.099,0.210)	(0.014,0.044,0.137)	(0.002,0.021,0.100)	(0.003,0.025,0.104)	(0.013,0.041,0.123)	(0.004,0.028,0.114)	(0.001,0.021,0.100)	(0.017,0.047,0.136)	(0.002,0.025,0.113)	(0.002,0.022,0.102)	(0.014,0.042,0.134)	(0.004,0.026,0.107)	(0.001,0.011,0.073)

Table A4. Weighted supermatrix achieved by normalizing crisp total-relation matrix.

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16
F1	0.049	0.108	0.097	0.100	0.117	0.086	0.095	0.072	0.113	0.106	0.090	0.102	0.102	0.083	0.083	0.077
F2	0.106	0.045	0.086	0.092	0.108	0.110	0.089	0.103	0.099	0.095	0.073	0.079	0.094	0.092	0.095	0.080
F3	0.099	0.090	0.040	0.070	0.089	0.068	0.067	0.093	0.091	0.080	0.063	0.083	0.073	0.053	0.065	0.063
F4	0.049	0.050	0.051	0.025	0.056	0.059	0.054	0.046	0.049	0.062	0.047	0.057	0.077	0.053	0.063	0.059
F5	0.091	0.089	0.067	0.067	0.040	0.061	0.094	0.078	0.080	0.067	0.078	0.098	0.066	0.072	0.074	0.067
F6	0.069	0.066	0.107	0.055	0.066	0.038	0.092	0.078	0.064	0.065	0.099	0.069	0.063	0.097	0.068	0.083
F7	0.054	0.064	0.069	0.062	0.062	0.094	0.033	0.061	0.059	0.053	0.057	0.052	0.060	0.089	0.052	0.063
F8	0.042	0.044	0.056	0.040	0.052	0.077	0.049	0.027	0.063	0.062	0.065	0.048	0.053	0.057	0.074	0.053
F9	0.096	0.075	0.058	0.075	0.083	0.058	0.064	0.054	0.039	0.058	0.080	0.097	0.076	0.057	0.055	0.059
F10	0.054	0.059	0.074	0.063	0.051	0.054	0.059	0.073	0.049	0.033	0.064	0.083	0.060	0.066	0.091	0.106
F11	0.041	0.042	0.046	0.048	0.035	0.044	0.043	0.052	0.039	0.045	0.021	0.038	0.044	0.036	0.043	0.042
F12	0.051	0.058	0.051	0.062	0.058	0.056	0.049	0.046	0.073	0.050	0.048	0.029	0.061	0.054	0.058	0.048
F13	0.043	0.047	0.048	0.061	0.042	0.046	0.046	0.043	0.045	0.047	0.044	0.040	0.026	0.058	0.045	0.045
F14	0.045	0.040	0.046	0.052	0.041	0.046	0.058	0.042	0.040	0.045	0.057	0.039	0.045	0.022	0.049	0.044
F15	0.036	0.040	0.048	0.047	0.036	0.046	0.046	0.054	0.040	0.077	0.040	0.039	0.045	0.046	0.025	0.078
F16	0.073	0.085	0.056	0.082	0.064	0.056	0.061	0.079	0.056	0.057	0.074	0.049	0.056	0.063	0.060	0.033

Table A5. Limiting supermatrix derived from weighted supermatrix.

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	Rank
F1	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	1
F2	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090	2
F3	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	3
F4	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	12
F5	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	4
F6	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	5
F7	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.061	0.062	0.062	0.062	0.062	9
F8	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	11
F9	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	6
F10	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	7
F11	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	16
F12	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	10
F13	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	14
F14	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	15
F15	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	16
F16	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	8

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