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Research on Factors Influencing Municipal Household Solid Waste Separate Collection: Bayesian Belief Networks

Zhujie Chu [1,2,*], Wenna Wang [1,2], Bairong Wang [3,*] and Jun Zhuang [3]

1 School of Economics and Management, Harbin Engineering University, Harbin 150001, China; hegangwwn@163.com
2 Research Institute of Disaster and Crisis Management, School of Economics and Management, Harbin Engineering University, Harbin 150001, China
3 Department of Industrial and Systems Engineering, University at Buffalo, State University of New York, 317 Bell Hall, Buffalo, NY 14260-2050, USA; jzhuang@buffalo.edu
* Correspondence: chuzhujie@hrbeu.edu.cn (Z.C.); bairongw@buffalo.edu (B.W.); Tel.: +86-451-8251-9916 (Z.C.); +1-716-645-4707 (B.W.)

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Abstract: Municipal household solid waste (MHSW) has become a serious problem in China over the course of the last two decades, resulting in significant side effects to the environment. Therefore, effective management of MHSW has attracted wide attention from both researchers and practitioners. Separate collection, the first and crucial step to solve the MHSW problem, however, has not been thoroughly studied to date. An empirical survey has been conducted among 387 households in Harbin, China in this study. We use Bayesian Belief Networks model to determine the influencing factors on separate collection. Four types of factors are identified, including political, economic, social cultural and technological based on the PEST (political, economic, social and technological) analytical method. In addition, we further analyze the influential power of different factors, based on the network structure and probability changes obtained by Netica software. Results indicate that technological dimension has the greatest impact on MHSW separate collection, followed by the political dimension and economic dimension; social cultural dimension impacts MHSW the least.

Keywords: municipal household solid waste; separate collection; influence factors; Bayesian belief networks model

1. Introduction

Municipal Household Solid Waste (MHSW) in China has increased significantly due to the rapid economic development. It not only causes serious pollution problems, which are not conducive to environment and human health [1,2], but also retards sustainable development of society [3]. It will prolong the processing cycles if MHSW is not been separated properly. The MHSW collected and transportation in China was 172 million tons in 2013. In addition, that number reached 179 million tons in 2014. However, there were still 15 million tons of MHSW that had not been harmlessly treated in 2014, which caused a series of environmental problems [4,5]. This is mainly because of unsatisfactory levels of MHSW separate collection, which causes poor effectiveness of the subsequent processing. MHSW separate collection is the prerequisite for the MHSW reduction [6] and causes fewer environmental problems than other solutions [7]. Hence it is of high importance in effectively mitigating the environmental problems caused by MHSW [8,9]. However, many problems make MHSW separate collection hard to be popularized [10]. Examples include the complicated composition of MHSW, its large production, difficulties in treatment, low environmental awareness of the public,

an imperfect management system, *etc.* In order to improve the effectiveness of MHSW separate collection, it is necessary to analyze the influencing factors on separate collection, which will in turn return significant guidance in achieving the optimal resource utilization of MHSW [11].

2. Literature Review

Existing research has shown that economic, political, social conditions and the attitudes of people are necessary for recycling success [12–19]. Guagnano *et al.* [20] concluded that all the external factors including psychology, finance, law and society may bring a positive or negative impact on the residents' behavior. Noehammer and Byer [21] founded that compulsory recycling programs launched by the government had a higher participation rate than voluntary resident recycling. Rada *et al.* [22] proposed that the MHSW legislation at the national and international level was necessary for the planning of good MHSW management. DETR [23] stated that all actions of the UK Government were aimed to promote the implementation of MHSW reduction, and also took steps to reduce the amount of MHSW. The Strategy Unit [24] also stressed the importance of governmental related actions to stem the spread of MHSW.

A number of studies have shed light on the significance of financial incentives in MHSW separate collection. Everett and Peirce [25] suggested that the financial incentives were the direct impetus to MHSW separate collection behaviors. Ragazzi *et al.* [26] pointed out that incentives might give people a strong sense of collaboration, which could motivate more people to get involved in the fight against MHSW. Glenn [27] and Steuteville [28] showed that the success of separate collection depended on market conditions. They also suggested that government should make relevant incentive policies to encourage public participation. Noh *et al.* [29] also found that penalties could stimulate participating initiative of people who did not do separate collection. Meanwhile rewarding people who perform well in separate collection also motivates the public greatly. Yau [30] suggested that economic incentives worked well in promoting MHSW separate collection in Hong Kong.

Environmental attitudes of the public matters greatly in MHSW separate collection. By using empirical analysis, Minton and Rose [31] concluded that the environmental attitudes were the determinant of MHSW separate collection behaviors. A man who cared about nature was more likely to engage in separating collection. Desa *et al.* [32] pointed out that the knowledge level, the attitude and the environmental consciousness of the public impacted MHSW separate collection. Miafodzyeva and Brandt [33], Afroz *et al.* [34] considered that the participation and willingness of the public were the key influential factors in MHSW separate collection. However, Zhang and Wen [35] hold an opposite opinion that attitudes and willingness did not have significant impacts on MHSW separate collection behavior in the case study at Suzhou, China. As for the public propaganda and education, Wellar and Barry [36] and Guerra [37] performed a thorough study. They showed that propaganda could motivate residents to realize the significance of MHSW separate collection and hence perform MHSW separate collection better. De Feo and De Gisi [38] presented the idea that public education and citizen encouragement could reduce MHSW in the design of separate collection processes.

The MHSW collection also serves matter, like the quantity, species and locations of equipment. Enough supply of assorted dustbins could improve MHSW cyclic utilization. Derksen and Gartrell [39] studied the residents' behaviors of MHSW separate collection, and found that people would classify MHSW if the dustbins were convenient to reach in the communities. Even people who were not concerned about the environment would perform recycling too, because of the convenience. Hence, the convenience of MHSW separate collection is also one of the decisive factors to promote separate collection of MHSW, as shown by Timlett and Williams [40], Ando and Gosselin [41] and Sidique *et al.* [42]. Bernstad [43] found that besides the convenience, infrastructure construction was quite necessary to separate collection.

In conclusion, existing research shows that influencing factors on MHSW separate collection can vary from policy, law, finance, culture, *etc.*, which laid the foundation for this study. However, there

are no comprehensive studies regarding MHSW separate collection in China, the biggest developing country, with the largest population in the world. Harbin is in the northeast region of China, its unique features of climate makes the MHSW separate collection more pertinent. The research results on MHSW separate collection in the region are universal, which can be conducive to achieve the minimization, recycling and harmlessness of MHSW. Bayesian Belief Networks (BBNs) model has been used as an effective tool for uncertainty events analysis [44,45] and gains a great advantage in influencing factors investigation research, such as the one in this study. Therefore, together with the PEST analytical method and system theory, we analyze the influential factors of MHSW separate collection from four dimensions: political, economic, social cultural and technological dimension.

3. Data and Methodology

3.1. Study Area

Harbin, the capital city of the Heilongjiang province, is an important political, economic and cultural center in northeastern China with its abundant natural resources such as forests, minerals, *etc.* It also has the largest land area and the second largest population in municipalities of China, which makes our investigation for Harbin more representative and general. Studied districts are illustrated in Figure 1 [46].

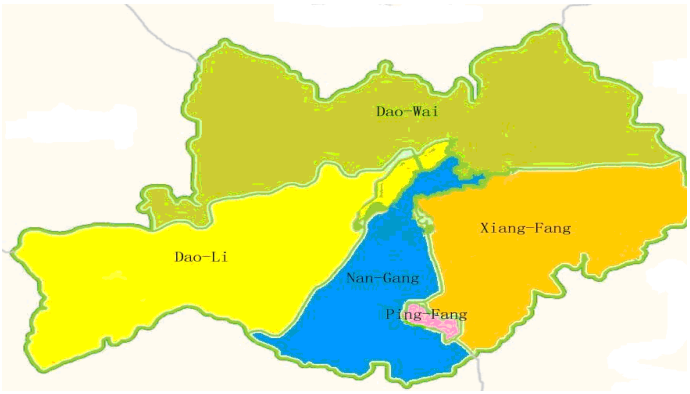

Figure 1. Studied districts of Harbin city.

Harbin has a population of 9,952,100 in 2013, with an urban population of 4,736,300. The city of Harbin collects and transports about 1,314,000 tons of MHSW each year [47]. Generation quantities and the composition of MHSW change with seasons and months. For example, more MHSW is produced by inhabitants in the winter than summer due to the generation of heating waste, such as coal ash. At the same time, MHSW is more in January, February, and October than other months because of holiday activities. MHSW generated by households is temporarily stored in bins, and then sanitation vehicles provide two collection services every day to collect and transport MHSW in the area. However, there is obviously a distinction between the numbers of MHSW bins in different communities. Senior communities have more MHSW bins. Each building has one bin which ensures the public make separate collections in a convenient and efficient way. Nevertheless, for ordinary communities, several buildings share one collection. MHSW are collected by sanitation workers door-to-door.

3.2. Data Collection

Both simple random sampling and stratified sampling were used during the selection of investigated household families.

Families are selected from the districts of Nan-gang, Dao-li, Dao-wai, Xiang-fang and Ping-fang. There were five communities selected in each district and then sixteen household families were

surveyed with questionnaires in each community. In this survey, family members who were familiar with MHSW separate collection finished the questionnaires.

Five groups of students from Harbin Engineering University participated in the research survey during 12–26 March 2015. Data was obtained mainly by door-to-door visits. Families with retired members were visited in the morning and those with working members were surveyed in the afternoon or lunchtime. Phone survey techniques were adopted for families who missed the first survey visits. 387 out of the 400 sampled households were surveyed in this study, yielding a 96.75% completion rate (the questionnaire is available in Appendix A).

3.3. Influential Factors of MHSW Separate Collection

3.3.1. Political Dimension

China is a government-leading country which means all levels of governments are responsible for issuing legislation on MHSW separate collection. Dimensions for politics is denoted by P, and its parent nodes are: (1) The enforcement of laws; (2) waste classification indicators; and (3) supervision intensity of governments, denoted by P_1, P_2 and P_3, respectively.

3.3.2. Economic Dimension

Financial support motivates MHSW separate collection, and hence two factors, infrastructure investment and support for involved companies, are identified for economic dimension, expressed as E_1 and E_2, respectively. Investment in infrastructure includes MHSW collection buckets and transport vehicles. Support for relevant companies refers to governmental subsidization to companies dealing with MHSW, such support includes tax reduction, direct financially support, *etc.*

3.3.3. Sociocultural Dimension

Social culture has evolved in the long-term historical development of human society and exerts influence on people's behaviors. In this study, three specific factors comprising sociocultural dimensions are identified: (1) public environmental awareness, denoted by S_1; (2) intensity of publicity, denoted by S_2; (3) importance community has attached into MHSW separate collection, denoted by S_3.

3.3.4. Technological Dimension

Advanced technology lays the foundation for the effectiveness of MHSW separate collection and facilitates the smooth going of its operation. We divided the technological dimension into two parts. The first one refers to technology and equipment in MHSW disposal centers and is denoted by T_1. The second factor is the construction of a MHSW disposing center and is denoted by T_2.

3.4. Bayesian Belief Networks for Influence Factors

3.4.1. Bayesian Belief Network Model

Bayesian Belief Networks (BBNs), based on probability analysis and graph theory, serve as both a great inference pattern and a description of uncertain knowledge. It is represented by directed acyclic graphs illustrating dependence between variables. Specifically, nodes in the graph represent all random variables studied, and the directed arcs show conditional dependencies between these variables.

A Bayesian Belief Network consists mainly of the topological structure (G) and the parameter (θ). Therefore the learning of BBNs contains structure learning and parameter learning which refers to constructing the directed acyclic structure and obtaining the related conditional probabilistic tables (CPTs), respectively.

The mathematical basis of BBNs is the Bayesian equation, as shown below in Equation (1):

$$P(A|B) = \frac{P(B|A)\,P(A)}{P(B)} \tag{1}$$

Two variables of a BBN, G and θ, confirm the only distribution among the nodes $X_1, \cdots, X_m$. Each joint distribution can be represented by the conditional probability. To each variable X_i, we can calculate its conditional probability under all direct or indirect control of variables $X_1, \cdots, X_{i-1}$. The joint probability distribution for $X = \{X_1, \cdots, X_n\}$ is given by the chain rule:

$$P(X_1, \cdots, X_n) = \prod_{i=1}^{n} P(X_i | X_1, \cdots, X_{i-1}) \quad (2)$$

On the basis of Markov hypothesis for structures, every variable X_i depends only on the node P_{α_i} to which its arrow is towards. The joint distribution in Equation (2) could be simplified further as following in Equation (3):

$$P(X_1, \cdots, X_n) = \prod_{i=1}^{n} P\left(X_i | P_{\alpha_i}\right) \quad (3)$$

3.4.2. Structure Learning in BBNs

In this study, we obtain a BBN with 15 nodes and 14 lines as shown in Figure 2. Arrows connecting the nodes show dependencies between variables and probabilities on lines represent the extent of dependencies. Three types of nodes are identified in this network, namely root nodes, parent nodes and child nodes. The single one root node refers to the final effectiveness of MHSW separate collection. Parent nodes represent sub-factors from each influencing factor dimension. Children nodes mainly refer to factors from the four dimensions. For instance, the parent nodes of Economic dimension (E) are infrastructure investment (E_1) and financial support (E_2), the child node depends on its parent nodes and it directly affects effectiveness of MHSW.

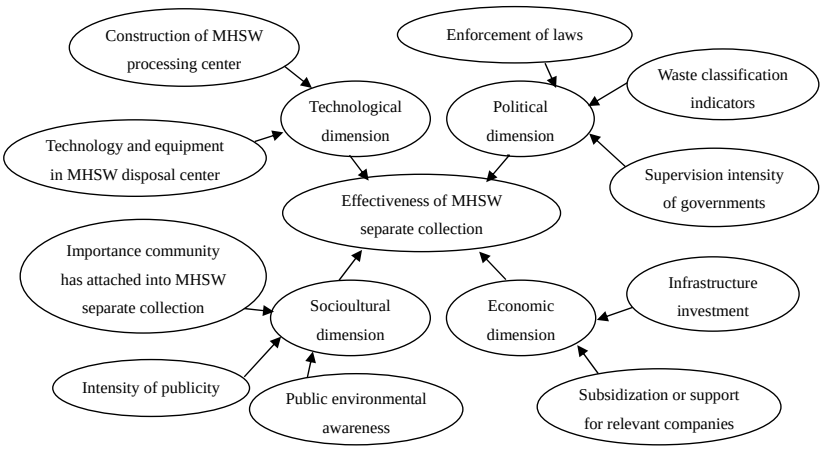

Figure 2. Bayesian Belief Network (BBN) structure for factors influencing municipal household solid waste (MHSW) separate collection.

3.4.3. Parameter learning in BBNs

Specifically, nodes' contributions are divided into five levels: "excellent" = 5, "good" = 4, "medium" = 3, "bad" = 2 and "extremely bad" = 1. According to standards in each level, participants will score MHSW service, separate collection knowledge, *etc.* For example, the question that (NO. 2 in questionnaire) "How much do you know MHSW classification standards?" is used to measure the completeness and standardization on the MHSW separate collection evaluation index system. "Excellent" means a satisfying formal and comprehensive classification standard exists in this area.

Children nodes are scored and divided into five levels with the aforementioned method and a score for each child node, namely P, E, S and T, is computed as the average score of its parent nodes. Therefore, the score of each child node also ranges from 1 to 5. We assume that the score is uniformly

distributed, and divided it into (4.2, 5], (3.4, 4.2], (2.6, 3.4], (1.8, 2.6] and [1, 1.8] five intervals in total, which correspond to "excellent", "good", "medium", "bad", and "extremely bad" respectively.

The satisfaction level of "excellent" is defined by "A", "good" is defined by "B", "medium" is defined by "C", "bad" is defined by "D", and "extremely bad" is defined by "E".

We can obtain a Bayesian network by using Netica software with the probability distribution of each node. The results are shown in Figure 3.

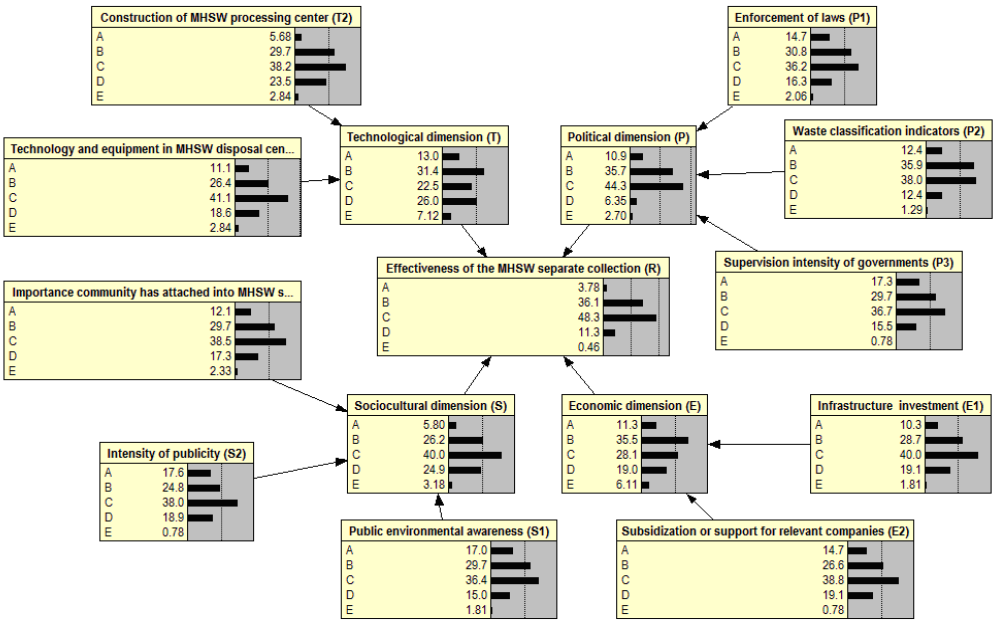

Figure 3. BBN for factors influencing MHSW separate collection.

Each node possesses a conditional probabilistic table (CPT) showing relations between each node and its parents. Part of the CPT for node *R* (effectiveness of MHSW separate collection) is illustrated in Figure 4. The left side of the table shows different combinations of its parent nodes *P*, *E*, *S* and *T*. The right side shows the conditional probability distribution of node *R* given different combinations of its parent nodes.

Node: R Apply Okay

Chance % Probability Reset Close

Technological dimension	Political dimension	Sociocultural dimension	Economic dimension	A	B	C	D	E
A	A	A	A	100	0	0	0	0
A	A	A	B	90	2.5	2.5	2.5	2.5
A	A	A	C	60	10	10	10	10
A	A	A	D	100	0	0	0	0
A	A	A	E	0	100	0	0	0
A	A	B	A	100	0	0	0	0
A	A	B	B	100	0	0	0	0
A	A	B	C	100	0	0	0	0
A	A	B	D	0	100	0	0	0
A	A	B	E	0	100	0	0	0
A	A	C	A	100	0	0	0	0
A	A	C	B	100	0	0	0	0
A	A	C	C	0	100	0	0	0
A	A	C	D	0	100	0	0	0
A	A	C	E	0	100	0	0	0
A	A	D	A	100	0	0	0	0
A	A	D	B	0	100	0	0	0
A	A	D	C	0	100	0	0	0
A	A	D	D	0	100	0	0	0
A	A	D	E	0	0	100	0	0
A	A	E	A	0	100	0	0	0
A	A	E	B	0	100	0	0	0
A	A	E	C	0	100	0	0	0
A	A	E	D	0	0	100	0	0
A	A	E	E	0	0	100	0	0
A	B	A	A	100	0	0	0	0
A	B	A	B	100	0	0	0	0

Figure 4. Part of CPT for node *R*.

4. Results and Discussion

In order to learn better information about the relations between the effectiveness of MHSW separate collection and its influencing factors, we discuss results by reverse inference, namely comparing changes in satisfying level distributions of each dimension given two different satisfying levels of final effectiveness of separate collection. Two cases where effectiveness of MHSW separate collection (R) shows "excellent", scored at 5 and "medium", scored at 3, are studied. The network reasoning results are shown in Figures 5 and 6 respectively.

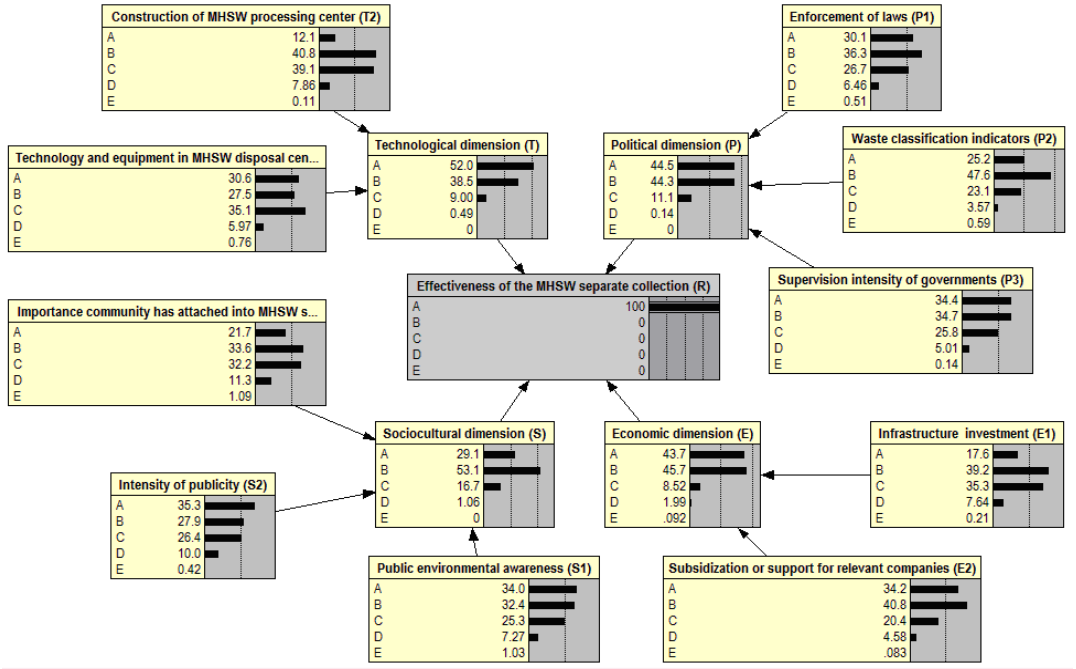

Figure 5. Bayesian network parameter graph for R = 5.

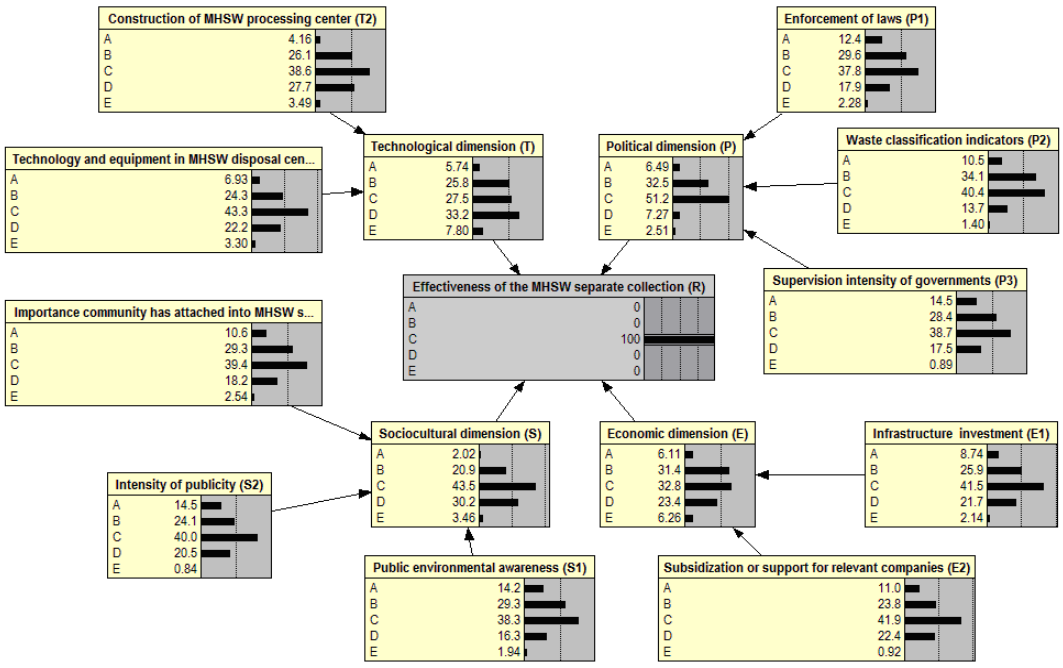

Figure 6. Bayesian network parameter graph for R = 3.

The satisfaction level distribution of each node given final separate collection effectiveness is excellent (R = 5) and is significantly different from that when final effectiveness is medium (R = 3). Distributions for politics dimension (P), economy dimension (E), social cultural dimension (S) and technology dimension (T) all change significantly, which are shown in Figures 7–10 respectively. The "ABCDE" represent five satisfaction levels ranging from excellent to extremely bad ("excellent" = A, "good" = B, "medium" = C, "bad" = D, and "extremely bad" = E). Four graphs refer to the satisfaction level distribution of node P, P_1, P_2 and P_3 respectively (shown Figure 7a–d). Three graphs express the satisfaction level distribution of node E, E_1 and E_2 respectively (shown Figure 8a–c). Four graphs refer to the satisfaction level distribution of node S, S_1, S_2 and S_3 respectively (shown Figure 9a–d). Three graphs represent the satisfaction level distribution of node T, T_1 and T_2 respectively (shown Figure 10a–c).

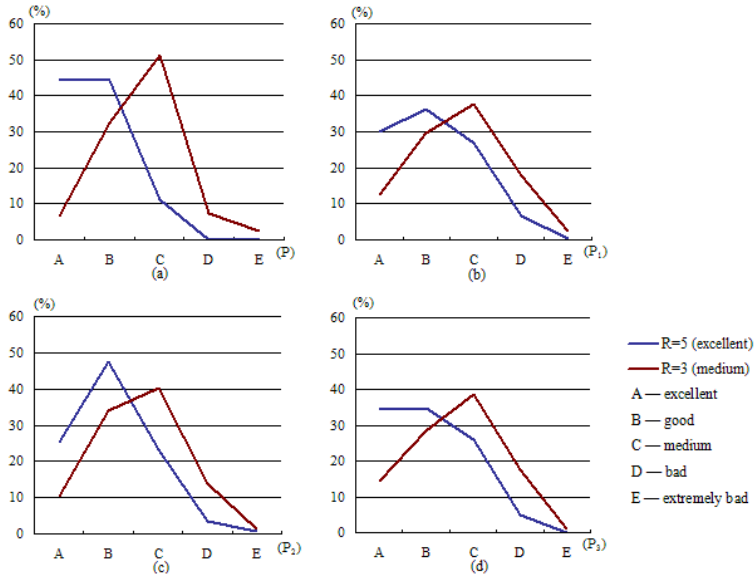

Figure 7. Changes in Political Dimension between R = 5 and R = 3.

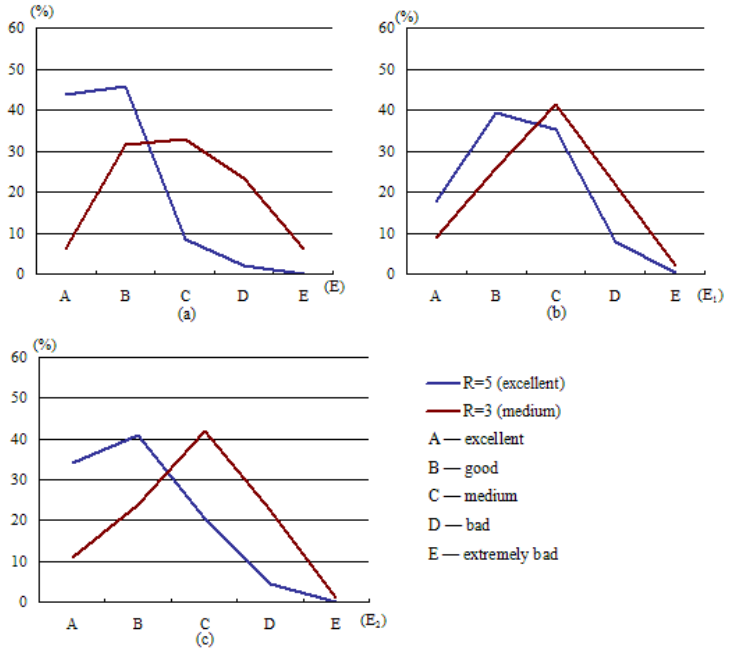

Figure 8. Changes in Economic Dimension between R = 5 and R = 3.

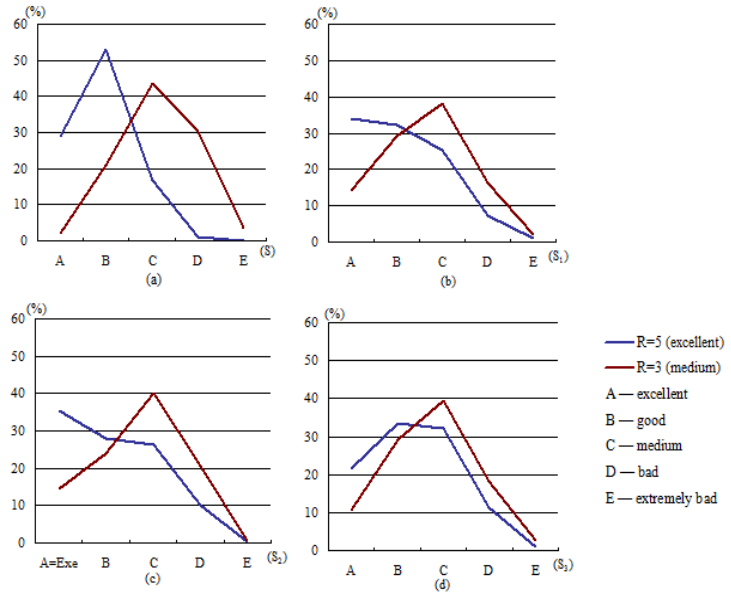

Figure 9. Changes in Sociocultural Dimension between R = 5 and R = 3.

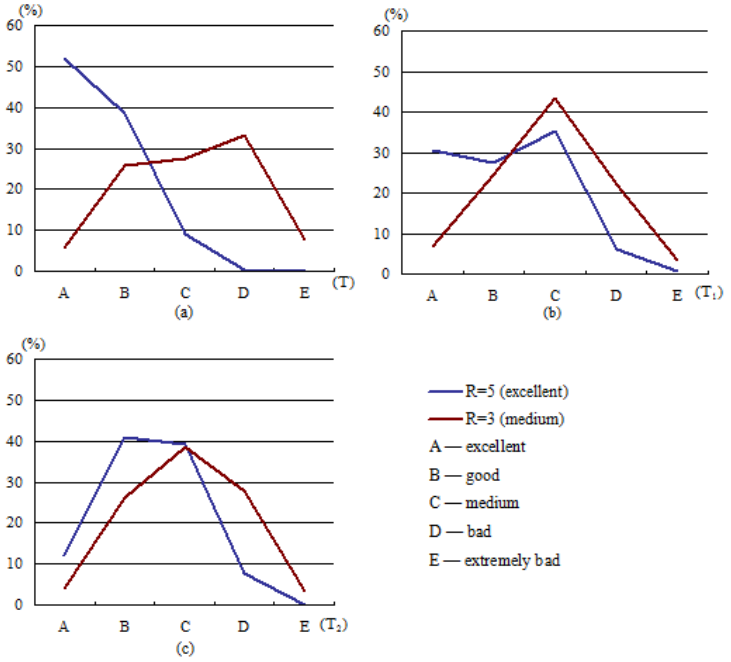

Figure 10. Changes in Technological Dimension between R = 5 and R = 3.

Compared with the state when R equals to 3, when R equals to 5, the probability when political dimension (P) is "medium" decreased from 51.2% to 11.1%; the probability when P is "good" performance increased from 32.5% to 44.3% and the probability when P is "excellent" performance increased from 6.49% to 44.5%. According to the maximum subordination principle, the condition ranges from "medium" to "good" and "excellent" almost nearly. It means that the political dimension has an important impact on the effectiveness of MHSW separate collection.

Specifically, when satisfaction levels of P_1 (Enforcement of laws), restrictions to relevant policies and regulations are "bad" and "medium" respectively. The probabilities respectively decrease from 17.9% and 37.8% to 6.46% and 26.7%. While the probabilities when P_1 are "good" and "excellent" increase from 29.6% and 12.4% to 36.3% and 30.1% respectively. When satisfaction levels of P_2 (Waste

classification indicators), the normative degree of evaluation index system are "bad" and "medium" respectively. The probabilities decrease from 13.7% and 40.4% to 3.57% and 23.1% respectively. The probability when P_2 are "good" and "excellent" respectively increase from 34.1% and 10.5% to 47.6% and 25.2%. When satisfaction levels of P_3 (Supervision intensity of governments), government regulations and input are "good" and "excellent" respectively, the probabilities increase from 28.4% and 14.5% to 34.7% and 34.4% respectively.

These changes indicate that a political dimension has a stronger influence on the effectiveness of MHSW separate collection. This improvement benefits from great efforts made by the local Harbin government, such as more complete policies and regulations. It also clears the rights and obligations among players involved, such as governments, enterprises and the public. At the same time, in order to standardize the incorrect behaviors of MHSW separate collection by law, the government has to strengthen the policy guidance, which is helpful in developing correct MHSW disposal habits of the general public. The goal of resource utilization was achieved successfully by all these measures, and the effectiveness of MHSW separate collection has improved obviously.

When comparing with the state when R = 3, in the state when R = 5, the probabilities when E (economic dimension) are "bad" and "medium" decrease from 23.4% and 32.8% to 1.99% and 8.52% respectively. The probabilities when E are "good" and "excellent" respectively increase from 31.4% and 6.11% to 45.7% and 43.7%, respectively. According to the maximum subordination principle, the condition ranges from "medium" to "good" and "excellent" almost nearly. It also respects that the economic dimension has an important impact on the effect of MHSW separate collection.

When E_1 (infrastructure construction investment) are "good" and "excellent", the probabilities when E_1 are "good" and "excellent" respective increase from 25.9% and 8.74% to 39.2% and 17.6% respectively. When E_2 (fund support) is "bad", the probability when E_2 is "bad" decreases from 22.4% to 4.58%, those of "good" and "excellent" decreases from 23.8% and 11.0% to 40.8% and 34.2%, respectively.

These changes indicate that economic factors have important influence on the effectiveness of MHSW separate collection. The Harbin government has increased the investment in infrastructure construction for MHSW separate collection, such as purchasing more MHSW collection cans and trucks. It is reported that the number of MHSW trucks has increased from 380 to 427, and more than 3000 MHSW collection cans with the volume 240 L are bought. Meanwhile, the government provides adequate support to facilitate the shaping of separate collection by making separate collection points to make separating MHSW more convenient. Besides, the government also increased its financial support. For example, it encourages the charitable donations to support development of the MHSW separate collection industry. All these measures promote the effectiveness of MHSW separate collection obviously.

Compared with the state when R = 3, in the state when R = 5, the probabilities when S (sociocultural dimension) are "bad" and "medium" decrease from 30.2% and 43.5% to 1.06% and 16.7% respectively. The probabilities of "good" and "excellent" increase from 20.9% and 2.02% to 53.1% and 29.1% respectively. According to the maximum subordination principle, the state ranges from "medium" to "good". It shows that the sociocultural dimension has a slight effect on the effect of MHSW separate collection.

When S_1 (public environmental awareness) is "excellent", the probability when S_1 is "excellent" increases from 14.2% to 34.0%. When S_2 (strength of publicity) is "medium", the probability when S_2 is "medium" decreases from 40.0% to 26.4%. The probability "excellent" increases from 14.5% to 35.3%. When S_3 (attention to community management) is "excellent", the probability when S_3 is "excellent" increases from 10.6% to 21.7%.

These changes indicate that sociocultural dimension has a slight influence on the effectiveness of MHSW separate collection. In order to improve the effectiveness of MHSW separate collection, some communities in Harbin have made great efforts in increasing propaganda and education. For instance, they make full use of the television, radio, newspapers, as well as the Internet and other media for public education. They also motivate the public members to make every possible effort to reduce

MHSW generation. Members of the public are encouraged to use less disposable goods to avoid waste. They not only have strong environmental awareness, but also know well about the basic knowledge and the importance of the MHSW classification. Furthermore, some communities have adopted some incentives measures. For example, residents will be praised or rewarded for their active participation and outstanding performance in MHSW separate collection.

Compared with the state when R = 3, in the state when R = 5, the probabilities when T (technological dimension) are "bad" and "medium" decrease from 33.2% and 27.5% to 0.49% and 9.00% respectively. The probabilities of "good" and "excellent" increase from 25.8% and 5.74% to 38.5% and 52.0% respectively. According to the maximum subordination principle, the state ranges sharply from "bad" to "excellent". It shows that technological dimension impacts significantly on the effect of MHSW separate collection.

Specifically, when T_1 (technology and equipment in MHSW disposal center) is "excellent", the probability when T_1 is "excellent" increases from 6.93% to 30.6%. The probability when T_1 is "bad" decreases from 22.2% to 5.97%. When T_2 (construction of MHSW processing center) are "good" and "excellent" respectively, the probabilities increase from 26.1% and 4.16% to 40.8% and 12.1% respectively.

These changes indicate that technological dimension has a significant influence on the effectiveness of MHSW separate collection. Every factor has a positive influence on the technological dimension, and therefore impacts the effectiveness of MHSW separate collection accordingly. Up to now landfills are most widely used in MHSW treatment in Harbin due to their low cost, but they also cause pollution. Thus, the Xiang-yang MHSW treatment plant and Xi'nanbu MHSW treatment plant have innovated the existing technology and equipment, especially in strengthening the anti-seepage measure. Moreover, in order to manage the toxic or harmful substances which are produced by the incomplete MHSW incineration, the Heilongjiang No. 3 Electric Power Construction Corporation incinerator has carried out the technology innovation. On the one hand, it has purchased advanced equipment. On the other hand, it takes efforts to develop new technologies. MHSW has maximized waste recycle by applying advanced harmless treatment technology, and as a result pollution from MHSW treatment is also reduced. The fact that MHSW freezes easily during Harbin's winter time increases the difficulties in MHSW cleaning, and the slippery conditions causes travel inconvenience to the residents. Therefore timely MHSW collected is quite necessary. The Harbin government has increased the MHSW disposal site settings to ensure the timely clean-up and collection of MHSW. All these efforts facilitate greater progress in MHSW separate collection.

These changes can be explained by the fact that MHSW in Harbin is mostly disposed in landfills. Source separation by residents is rarely necessary. Therefore technological dimension factors, like treatment method, equipment in MHSW disposal, have the greatest impact on MHSW separate collection. Economic dimension plays a role in MHSW separate collection in an indirect way, such as increasing the fund support, promoting technology progress, *etc*. Furthermore, effectiveness of government regulations and compulsory measures are also limited in MHSW separate collection. It could motivate residents' participation. However, improving the separation awareness of the public is challenging. Moreover, there are lots people in Harbin earning extra income by selling recyclable MHSW. These behaviors decreased the recycling and separation collection of MHSW. Thus, the sociocultural dimension has a smaller impact on MHSW separate collection.

5. Conclusions

Many previous studies have pointed the factors that impact MHSW separate collection effectiveness. However, they have not provided research on developing countries, especially China. Motivated by this research gap, this paper employs the BBN model to better analyze the influencing factors of MHSW separate collection. The four dimensions include: political, economic, sociocultural and technological. In our study, we find that all dimensions have great influence on effectiveness of MHSW separate collection by experimental survey in Harbin. The technological dimension has

the greatest effect, followed by the political dimension and economic dimension; the sociocultural dimension has the least effect.

The model we proposed can explicitly integrate both prior knowledge and information obtained from the data. BBN is well suited to our study due to its advantage to handle uncertainties. It can present causal relationships with estimated possibilities and consequences of nested determinants. Nevertheless, for the complexity of the model, the choices to evaluate criteria can also impact its accuracy. Furthermore, there is no control to people who answered the questionnaire.

However, this study is limited by unsolved questions. For example, are there any dynamic influencing factors on MHSW separate collection, such as climate, geology, *etc.*? And how do they influence the MHSW separate collection? Further research can be directed toward Bayesian Belief Networks based on the availability of research on the MHSW separate collection. The BBN can still be developed further into a dynamic model that takes into account temporal variables.

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Appendix

Questionnaire

We sincerely hope that it will be convenient for you to fill out this questionnaire. Thank you!

Please mark "√" on the dimension which you think correct.						
Political Dimension	1. Are you satisfied with the implementation of policies and regulations at present?	5-strongly satisfied	4-satisfied	3-middle	2-unsatisfied	1-strongly unsatisfied
	2. How much do you know MHSW classification standards?	5-most	4-very much	3-only some	2-a little	1-nothing
	3. Are you satisfied with the government regulation during MHSW separate collection?	5-strongly satisfied	4-satisfied	3-middle	2-unsatisfied	1-strongly unsatisfied
Economic Dimension	4. Are you satisfied with the investment of the infrastructure construction including MHSW collection cans and trucks?	5-strongly satisfied	4-satisfied	3-middle	2-unsatisfied	1-strongly unsatisfied
	5. Do you think government is necessary to give fund support to the related enterprises?	5-strongly necessary	4-necessary	3-middle	2-unnecessary	1-strongly unnecessary
Sociocultual Dimension	6. Do you think it is important to make MHSW separate collection?	5-strongly important	4-important	3-middle	2-unimportant	1-strongly unimportant
	7. Are you satisfied with the publicity of MHSW separate collection through television, newspapers and Internet?	5-strongly satisfied	4-satisfied	3-middle	2-unsatisfied	1-strongly unsatisfied
	8. Are you satisfied with the attention to MHSW separate collection in your community?	5-strongly satisfied	4-satisfied	3-middle	2-unsatisfied	1-strongly unsatisfied
Technological Dimension	9. Are you satisfied with the existing technology and equipment in MHSW disposal?	5-strongly satisfied	4-satisfied	3-middle	2-unsatisfied	1-strongly unsatisfied
	10. Are you satisfied with the settings of MHSW disposal sites nearby?	5-strongly satisfied	4-satisfied	3-middle	2-unsatisfied	1-strongly unsatisfied
11. Are you satisfied with the effectiveness of MHSW separate collection?		5-strongly satisfied	4-satisfied	3-middle	2-unsatisfied	1-strongly unsatisfied

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