18 “Evaluation on reverse logistics system of city waste based on Circular Economy”

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18.1 Abstract

With the rapid development of the city, it generates large amounts of waste. More and more city waste seriously damage city environment. Therefore, how to effectively deal with city waste is urgent issues. Taking reverse logistics system of city waste as studying object, this paper constructs a set of reverse logistics system of city waste and comprehensive evaluation index system based on circular economy. And then give the fuzzy comprehensive evaluation method to evaluate reverse logistics system of city waste. This paper can provide a theoretical reference for the construction of city waste reverse system and evaluation.

Keywords : City waste; reverse logistics; circular economy; fuzzy comprehensive evaluation method

18.2 Introduction

Management of city waste is a priority for urban communities. Actually, the city waste management system can be considered as reverse logistics problem in supply chain management. In supply chain management, the main concerns of reverse logistics are waste management, material recovery (recycling), parts recovery or product recovery (through remanufacturing). Therefore, we can use circular economy theory to deal with city waste. It can solve the problem of environmental pollution very well.

Previous studies of city waste mainly focus on an optimization model of industry waste (i.e. electronic and material waste) and hazardous waste (i.e. nuclear waste). In the area of hazardous waste, an optimization model was formulated to manage problems of transportation routing among transfer stations, disposal facilities, and long-term storage impoundments (Peirce and Davidson, 1982). A regionally hazardous waste management system was developed involving selection of treatment and disposal facilities, allocation of hazardous waste or residues from generator to disposal plants, and selection of the transportation routes(Nema and Gupta, 1999).
A coordinated reverse logistics management system was presented in a high-technology manufacturing zone for the treatment of multi-source hazardous waste (Sheu, 2007). A Risk Assessment Model and multi-objective reverse logistics model was proposed to design a hazardous waste management system for selecting an

optimum configuration of management facilities and allocation of hazardous waste to these facilities (Fengjiao Wan. 2013). In the area of industry waste, a reverse logistics system was advanced for recovery of discarded products (Krikke et al., 1999). An inexact reverse logistics model for municipal solid waste management systems was proposed. The application of the model was illustrated through a classical municipal solid waste management case. With different cost parameters for landfill and the WTE, two scenarios were analyzed (Yi, Guo and Li, 2011). A functional model of waste management was proposed that represented supply chains in terms of processes, their interconnections, material flows, waste streams and cumulative costs (Hicks et al., 2004).

Generally, seldom research focused on evaluation of city waste logistics system under circular economy. Therefore, the objective of this study is to develop a reverse logistics evaluation system for city waste management. Waste collection system, transportation system and processing system will be considered in evaluation system.
According to construction and evaluation of city waste reverse logistics system, this paper can provide the theoretical basis for the management of city waste and find out the bottleneck which have influenced city waste disposal system efficiency, then give suggestion for the optimization of management process improvement.

18.3 Reverse logistics system of city waste based on Circular Economy

A reverse logistics management system of city waste involves a number of processes with socio-economic and environmental implications, such as waste generation, transportation, treatment, and disposal and so on. In general, the traditional processing method of waste is incineration, landfill and composting. However, these methods can cause serious adverse effects. For example, incineration needs large investment and will produce a lot of waste gas to pollute the environment.
Nowadays, resource depletion and environmental degradation has restrained economic sustainable development. So, all the countries have adopted the strategy of sustainable development, the idea of circular economy is rising. The nature of the circular economy is a kind of ecological economy. It needs to transfer the traditional model “resources --products -- waste" into a new economic development model "resources -- products -- renewable resources".
This involves the reverse logistics. Reverse logistics is defined by the council of Logistics Management as: the process of planning, implementing, and controlling the efficient, cost-effective flow of raw materials, in-process inventory, finished goods and related information from the point of origin to the point of consumption for the purpose of conforming to customer requirements. Based on that, the reverse logistics management system of city waste under circular economy that we proposed can comprise of three levels of organization (see fig.1):

(1) Waste collection stations which receive all generated waste from each distinct, and separate and transport some recyclable/reusable waste to remanufacturers.

There are two kinds of collection method: mixed collection and sorting collection. Advantages and disadvantages of the two methods listed in Table 1.

Table 1 Advantages and Disadvantages of the two methods

Collection method	Advantage	Disadvantage
Mixed collection	Simple , low cost of operation	Reduce the purity of useful substances and recycling value, increase the difficulty to deal with waste
Sorting collection	Resource, reduction, reduce the cost of treatment	Complex, difficult (need economic strength, legislation and so on)

(2) Waste distribution centers which store and transfer the waste from city collection station to disposal facilities.

With the rapid expanding of city, waste disposal facilities is often far from the city, so many cities built waste distribution center to store waste. Then use large trailer to transfer waste.

(3) Waste disposal/treatment facilities such as landfill, incinerator and composting plant.

In China, we often use the following three kinds of city waste treatment method: landfill, incineration, composting. Their advantage and disadvantage are shown in table 2.

According to the advantages and disadvantages of collection and treatment method, and then combined with the characteristics of city waste reverse logistics system and circular economy; we construct process of city waste reverse logistics based on circular economy. (See fig.1)

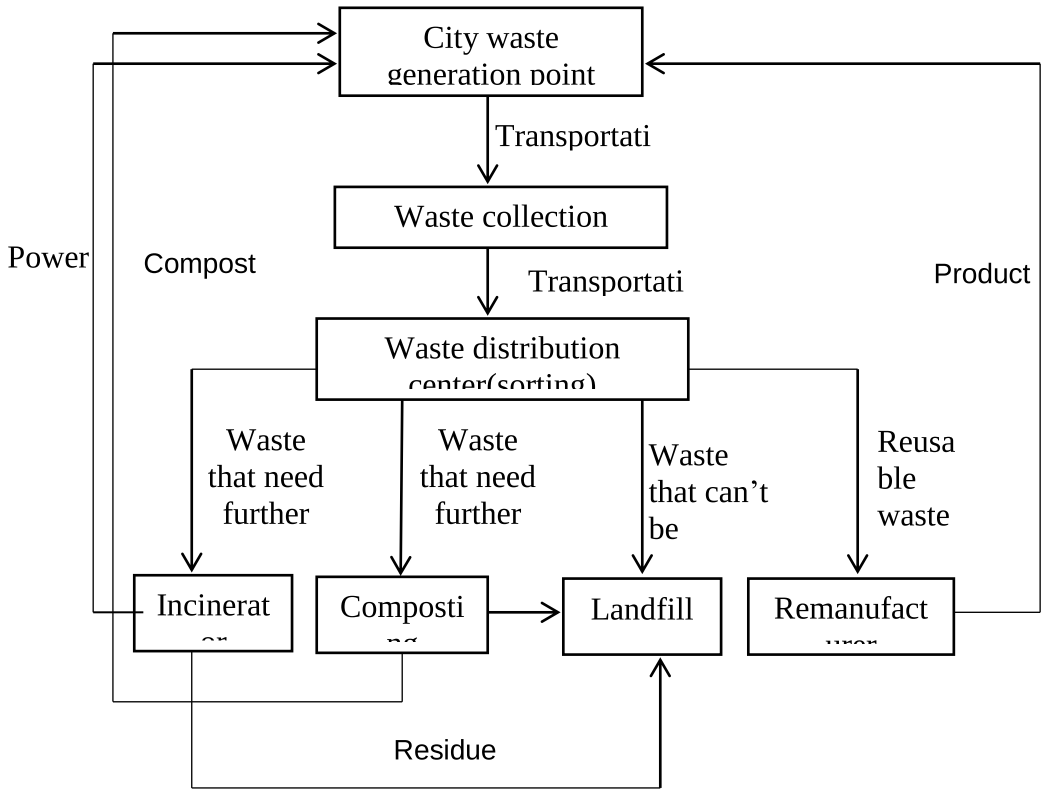

Fig.1 City waste management system

Table 2 Advantage and Disadvantage of city waste treatment method

Treatment method	Advantage	Disadvantage
Landfill	Simple and easy operation, large treatment capacity, low cost	occupy large land, difficult site, hazardous substances in the waste can cause ground water pollution, buried in the field of odor will cause secondary pollution.
Incineration	Incineration treatment thoroughly, make full use of waste heat value	The investment and operation cost is high, the gas generated will cause secondary pollution
Composting	organic components separated from waste can be used as fertilizer	It is difficult to completely decompose organic matter, composting time is long, it may cover an large area

18.4 Evaluation on reverse logistics system of city waste based on Circular Economy

18.4.1 The construction of index system

Based on the process of city waste reverse logistics system (see fig.1), and then combined with the relevant regulations of environmental pollution, we construct the comprehensive evaluation index system of city waste reverse logistics system. The index system is shown in table 3.

Table 3 The comprehensive evaluation index system of city waste reverse logistics system

Target layer(u)	One class indicator (criterion layer)	Two class indicator (sub criteria layer)	Three class indicator (index layer)
The	Waste collection system(u_1)	Collection method(u_{11})	
		Collection way(u_{12})	
		Collection facilities(u_{13})	
	Transportation system(u_2)	Equipment compatibility(u_{21})	
		The total cost of transportation(u_{22})	
		Environment(u_{23})	
	Treatment system(u_3)	Economy(u_{31})	The project total investment(u_{311})
			The unit operation cost(u_{312})

comprehensive evaluation index system of city waste reverse logistics system(u)			Investment utilization rate(u_{313})
			The payback period of investment(u_{314})
			Land occupancy(u_{315})
		Suitability(u_{32})	
		Systematic(u_{33})	Reliability(u_{331})
			Safety(u_{332})
			Advanced technology(u_{333})
		treatment effect($_{34}$)	Resource(u_{341})
			Reduction(u_{342})
			Harmless(u_{343})
		social effect(u_{35})	public satisfaction(u_{351})

18.4.2 Fuzzy comprehensive evaluation method

The comprehensive evaluation index of city waste reverse logistics is non-quantitative, and unable to use the general method to compare directly. The fuzzy comprehensive evaluation method is in fuzzy environment, it can consider the influence of various factors. It also can make comprehensive judgment or decision under some purpose, and can deal with fuzzy information which cannot be treated by other methods. Therefore, this paper adopts the fuzzy comprehensive evaluation method to make comprehensive evaluation on city waste reverse logistics comprehensive benefit.

20.4.2.1 Determine the evaluation factor set

According to the analysis of 20.4.1, evaluation set is divided into 3 layers, first layers of the total target factor set is $u = \{u_1, u_2, u_3\}$; second level target factor set is $u_1 = \{u_{11}, u_{12}, u_{13}\}; u_2 = \{u_{21}, u_{22}, u_{23}\}; u_3 = \{u_{31}, u_{32}, u_{33}, u_{34}, u_{35}\}$; third level target factor set is $u_{31} = \{u_{311}, u_{312}, u_{313}, u_{314}, u_{315}\}; u_{33} = \{u_{331}, u_{332}, u_{333}\}; u_{34} = \{u_{341}, u_{342}, u_{343}\}$;

20.4.2.2 Determine the evaluation set

The evaluation set is a kind of language to descript evaluation indexes of each level; it is the evaluation set that reviewers give. For different evaluation goal, the evaluation level has different meanings. According to the characteristics of city waste reverse logistics, given evaluation set $v = \{v_i\}$, a total of 5 evaluation class $v = \{v_1, v_2, v_3, v_4, v_5\}$,

Wherein $v_1 = \{very\ good\}, v_2 = \{good\}, v_3 = \{general\}, v_4 = \{poor\}, v_5 = \{very\ poor\}$, The evaluation set is $v = \{very\, good, good, general, poor, verypoor\}$,

20.4.2.3 Determine the weight of each index in the evaluation system

In the fuzzy comprehensive evaluation, the weight can impact the final evaluation results; Different weights will produce different results, thus affecting the decision-making. Therefore, it is crucial to determine the weights. There are many ways to determine the weights, such as analytic hierarchy process (AHP), experts' estimation method, entropy method. According to the index system and city characteristics of reverse logistics, AHP may be applied to determine the weight of each index. In order to obtain scientific index weight, we set up a total of 20 people university expert jury which is composed by the management personnel, technical personnel, expert of university. They evaluate the weight of the index, $u_i(i=1,2,3), u_{ij}(i=1,2,3;\ j=1,...,5), u_{3jk}(j=1,...,5;\ k=1,...,5)$ and then we determine the comparison judgment matrix, the weight of each index by AHP method is shown in table 4.

Table 4 The weight of each index

Target layer(u)	One class indicator	weight	Two class indicator	weight	Three class indicator	weight
The evaluation index system of city waste reverse logistics system(u)	Waste collection system(u_1)	0.6483	Collection method(u_{11})	0.63		
			Collection way(u_{12})	0.1515		
			Collection facilities(u_{13})	0.2184		
	Transportation system(u_2)	0.2297	Equipment compatibility(u_{21})	0.1047		
			The total cost of transportation(u_{22})	0.2583		
			Environment(u_{23})	0.637		
	Treatment system(u_3)	0.122	Economy(u_{31})	0.0503	The project total investment(u_{311})	0.0815
					The unit operation cost(u_{312})	0.0815
					Investment utilization rate(u_{313})	0.1485
					The payback period of investment(u_{314})	0.2499
					Land occupancy(u_{315})	0.4386
			Suitability(u_{32})	0.0979		
			Systematic(u_{33})	0.1062	Reliability(u_{331})	0.1576
					Safety(u_{332})	0.7608
					Advanced technology(u_{333})	0.0816
			treatment effect($_{34}$)	0.273	Resource(u_{341})	0.1047
					Reduction(u_{342})	0.2583
					Harmless(u_{343})	0.637

			social effect(u_{35})	0.4727	public satisfaction(u_{351})	1

20.4.2.4 Determine the fuzzy evaluation matrix

We invited 20 experts and apply the questionnaire survey method to collect data. All experts have evaluated three class indicators and two class indicators in table 3 according to the evaluation set respectively. The factors of their upper level indicators can calculated through their evaluation results and the corresponding weights. Then we analyze the results of the investigation and obtain the degree of membership of each factor which is shown in table 5 and table 6.

Table 5 The fuzzy evaluation matrix of two class indicator

One class indicator	Two class indicator	Very good	Good	General	poor	Very poor
Waste collection system(u_1)	Collection method(u_{11})	0	0.4	0.4	0.2	0
	Collection way(u_{12})	0	0.3	0.4	0.2	0.1
	Collection facilities(u_{13})	0.05	0.4	0.3	0.2	0.05
Transportation system(u_2)	Equipment compatibility(u_{21})	0.1	0.3	0.5	0.1	0
	The total cost of transportation(u_{22})	0.2	0.4	0.3	0.1	0
	Environment(u_{23})	0	0.05	0.4	0.4	0.15
Treatment system(u_3)	Economy(u_{31})	0.1	0.5	0.4	0.1	0
	Suitability(u_{32})	0.2	0.4	0.3	0.1	0
	Systematic(u_{33})	0.05	0.2	0.4	0.25	0.1
	treatment effect($_{34}$)	0.1	0.3	0.3	0.2	0.1
	social effect(u_{35})	0	0.2	0.2	0.4	0.2

Table 6 The fuzzy evaluation matrix of three class indicator

One class indicator	Two class indicator	Three class indicator	Very good	Good	General	poor	Very poor
Treatment system(u_3)	Economy(u_{31})	The project total investment(u_{311})	0.2	0.4	0.3	0.1	0
		The unit operation cost(u_{312})	0.1	0.5	0.4	0	0
		Investment utilization rate(u_{313})	0.3	0.4	0.3	0	0
		The payback period of investment(u_{314})	0.2	0.6	0.2	0	0
		Land occupancy(u_{315})	0	0.4	0.5	0.1	0
	Suitability(u_{32})						
	Systematic(u_{33})	Reliability(u_{331})	0	0.2	0.6	0.1	0.1
		Safety(u_{332})	0.05	0.15	0.4	0.3	0.1

		Advanced technology(u_{333})	0.1	0.2	0.4	0.2	0.1
	treatment effect(u_{34})	Resource(u_{341})	0.1	0.4	0.4	0.1	0
		Reduction(u_{342})	0.2	0.6	0.1	0.1	0
		Harmless(u_{343})	0.1	0.2	0.4	0.2	0.1
	social effect(u_{35})	public satisfaction(u_{351})	0	0.2	0.2	0.4	0.2

20.4.2.5 Comprehensive evaluation

We evaluate from the bottom, the evaluation algorithm is based on comprehensive evaluation model $B = A \circ R$, B represent a fuzzy comprehensive evaluation result, A represent the weight of each index and R represent the membership degree of fuzzy subset in each level.

According to the weight of the two indicators: $A_1 = (0.63, 0.1515, 0.2184)$;

$A_2 = (0.1047, 0.2583, 0.637)$; $A_3 = (0.0503, 0.0979, 0.1062, 0.273, 0.4727)$;

Obtain fuzzy comprehensive evaluation result of a class index: $B_1 = A_1 \circ R_1 = (0.011, 0.385, 0.378, 0.2, 0.026)$;

From the results, it can be seen that the evaluation of waste collection system is 'good', the membership degree is 38.5%. $B_2 = A_2 \circ R_2 = (0.062, 0.167, 0.385, 0.291, 0.096)$;

From the results, it can be seen that the evaluation of waste transportation system is 'general', the membership degree is 38.5%. $B_3 = A_3 \circ R_3 = (0.057, 0.26, 0.268, 0.285, 0.13)$;

From the results, it can be seen that the evaluation of waste transportation system is 'poor', the membership degree is 26.8%.

According to the weight of the first level index $A = (0.6483, 0.2297, 0.122)$; the fuzzy comprehensive evaluation index result of city waste reverse logistics system is $B = A \circ R = A \circ \begin{bmatrix} B_1 \\ B_2 \\ B_3 \end{bmatrix} = (0.028, 0.32, 0.366, 0.231, 0.055)$ .The result has shown that the china city waste reverse logistics system is general, its membership degree is 36.6%.

18.5 Conclusions

At present, China city waste reverse logistics is still in the initial stage, the social haven't fully realized its influences. At the same time, although China has established some related policies and regulations to implement waste reverse logistics, because management facilities is backward, it is very difficult to develop reverse logistics and cannot solve the environmental pollution of the city waste. This paper evaluates the city waste reverse logistics system; it can help government timely to find out the bottleneck that has impact the development of waste reverse logistics. It also make social to understand the waste reverse logistics comprehensively and give some suggestions to improve the optimization of management process, and then ultimately improve the overall effect.

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