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ARTICLE

Applying the Integration Method of Logistics Management for Post-Sale Waste Recycling of Enterprise Products of Six Special Municipalities in Taiwan

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ABSTRACT

Logistics Management for Post-Sale Waste Recycling of Enterprise Products is very important in Taiwan. When recycling of waste resources of the six special municipalities cannot be managed effectively, ecological environment in supply chain will be harmed and body health of the public will be affected. Nowadays, enterprises attach great importance to ESG (Environment, Society and Governance). Hence, evaluating management situation of the six special municipalities over influence of major wastes resource recycling on ecological environment and the public's health will be helpful for regulators of Taiwan environment protection agencies to work out future strategies for the six special municipalities to manage influence of all waste resource recycling on ecological environment and health of the public. VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) method, and link linear regression analysis method and grey prediction model, as well as dynamic waste recycling quantity management method were adopted to predict predictive value of Taiwan's six special municipalities' waste recycling quantity in advance and generate predicted results of management evaluation. Good effects were achieved in predicting and pre-warning evaluation in the research by applying VIKOR method and link linear regression analysis method and grey prediction model. The predicted ranking of the six special municipalities' waste recycling quantity management is 100% consistent with the actual values of the management ranking situation of the six special municipalities. The reason for accurately predicting and knowing the resource recycling ranking of the six cities is that the state can know the resource recycling capacity of the six cities in advance and allocate recycling

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personnel and equipment to them.

Keywords: Logistics Management; Post-Sale Waste Recycling of Enterprise Products; Environment in Supply Chain; VIKOR Method; Linear Regression Analysis Method; Grey Prediction Model

1. Introduction

Major execution agencies in Taiwan for waste resource recycling mainly manage six special municipalities, including Taipei City, New Taipei City, Taoyuan City, Taichung City, Tainan City and Kaohsiung City. For batteries of cell phones and other wastes generated from retail products, enterprises which sell them shall be responsible for recycling. On the other hand, in the circulation management of the transportation industry, waste cartons and rubber products generated by loading and transportation with trucks need to be recycled. Considering the enormous population in the six special municipalities of Taiwan, the waste resource recycling management situation will have a great influence on the ecological environment and the health of the people. For example, discarded plastic and glass products, which always enter rivers or seas, will have a great influence on the ecological environment of the Earth. If they are not recycled, people's activities in rivers and seas will be affected, so as to affect the health of people's bodies. Discarded metals, batteries and paper products that are buried in soil will influence crop farming, the environment of soil and the production of crops. Therefore, it is necessary to study the influence of the waste recycling management situation of the six special municipalities in Taiwan on the ecological environment and body health. Recycling quantity of 9 categories, which include paper products and paper, metal products, plastic and rubber products, glass products, textile products, home appliances, batteries, information and communication products, pesticide containers, special environment medicine containers and edible oil, are taken as evaluation indicators for waste recycling management. The reason for accurately predicting and knowing the resource recycling ranking of the six cities is that the state can know the resource recycling capacity of the six cities in advance and allocate recycling personnel and equipment to them.

Thus, the VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR, Multi-Criteria Optimization and Compromise Solution) method, the linear regression analysis method and the grey prediction model were adopted to evaluate waste resource recycling management predictive situation of the six special municipalities in Taiwan in advance, followed by the proposal of a pre-warning mechanism, information application and sources [1]. According to research results, the waste recycling management situation of the six special municipalities in Taiwan can be effectively evaluated in advance, which is helpful to pre-warn and improve the waste resource recycling situation. Furthermore, it can provide a reference for regulators of environmental protection agencies to work out future pre-warning mechanisms for waste resource recycling management strategy. The VIKOR method links the linear regression analysis method and the grey prediction model were applied to predict and conduct pre-warning evaluation on the waste resource recycling management situation of the six special municipalities in Taiwan in advance. According to the results of the research, good effects were achieved in evaluating the management situation of waste resource recycling of the six special municipalities in Taiwan by adopting the VIKOR method, the link linear regression analysis method, and the grey prediction model to predict and pre-warn waste resource recycling.

2. Materials and Methods

The application of the VIKOR method and the linear regression analysis method in the research contains three steps. The first step is to collect data into an Excel file from the environment statistical and inquiry website of Taiwan's Ministry of Environment. The second step is to calculate the interest ratio of solutions for 2020 to 2024 and rank the evaluation situation of waste recycling quantity of the six special municipalities in Taiwan through the VIKOR method. Finally, the actual value of waste recycling quantity in 2024 is predicted by linear regression analysis based on the actual values of waste recycling quantity from 2020 to 2023. The results are used to calculate the interest ratio of the 2024 predictive solution and the ranking of the six special municipalities through the VIKOR method. The ranking of the six

special municipalities obtained through the VIKOR method is compared with the ranking of the actual value of 2024. 2020–2024 data about the waste resource recycling quantity of the six special municipalities will be taken as verification examples. The theory of linear regression was first proposed by Kasza and Wolfe, Hossain Parash et al., Darlington and Hayes, Zapf et al., and Montgomery et al.[2–6], and many researchers have used this theory to study issues, such as establishing empirical relationships[7], Medical Research[8], energy performance of residential buildings[9], and Business Behaviour Analysis[10].

The theory of the grey prediction model was first proposed by Deng[11] many researchers have used this theory to study issues, such as Interval Grey Action Quantity[12], Medical Trauma Rehabilitation[13], Probabilistic accumulation[14], incidence trend[15], On the Limitations of Univariate Prediction[16].

The theory of VIKOR was first proposed by Opricovic and Tzeng[17] and Opricovic[18], and many researchers have used this theory to study issues, such as Ranking Technique[19], comprehensive main path analysis[20], Information Security Policies[21], Algorithm in Material Decision Support[22], Manufacturing Process Application[23], group decision-making[24], and pollution control[25].

Step 1: Transfer waste recycling item data from platform[1] to an Excel file.

Step 2: Vise Kriterijumska Optimizacija I Kompromisno Resenje (VIKOR).

Step 3: Input H_{ij} as the original evaluation values of waste recycling items (paper products and paper, metal products, plastic and rubber products, glass products, textile products, home appliances, batteries, information and communication products, pesticide containers, special environment medicine containers, and edible oil) of the six special municipalities of Taiwan.

Step 4: Multiply by the weights after calculating the distances between the ideal solutions and the negative ideal solutions of waste recycling items (paper products and paper, metal products, plastic and rubber products, glass products, textile products, home appliances, batteries, information and communication products, pesticide containers, special environment medicine containers, and edible oil) of the six special municipalities of Taiwan and all evaluation criteria to obtain Equation (1).

$$w_j \left(\frac{H_j^* - H_{ij}}{H_j^* - H_j^-} \right) \tag{1}$$

Step 5: Multiply by the weights after calculating the distances between the ideal solutions and the negative ideal solutions of waste recycling items (paper products and paper, metal products, plastic and rubber products, glass products, textile products, home appliances, batteries, information and communication products, pesticide containers, special environment medicine containers, and edible oil) of the six special municipalities of Taiwan and all evaluation criteria, and then sum up all values to obtain the two comprehensive index values, which are K_i (Equation (2)) and L_i (Equation (3)).

$$d_i^{p=1} = K_i = \sum_{j=1}^{n} w_j \left(\frac{H_j^* - H_{ij}}{H_j^* - H_j^-} \right) \tag{2}$$

$$d_i^{p=\infty} = L_i = \max_i \left\{ \left(\frac{H_j^* - H_{ij}}{H_j^* - H_j^-} \right) \middle| j = 1, 2, \cdots, n \right\} \tag{3}$$

Step 6: Find from K_i that K^- is the maximum value and K^* is the minimum value. Find from L_i that L^- is the maximum value and L^* is the minimum value.

Step 7: Calculate P_i (Equation (4)) to obtain the VIKOR values of the evaluation of waste recycling items of the six special municipalities of Taiwan, and then rank based on the overall ranking values of waste recycling items of the six special municipalities of Taiwan and ideal levels. The value closer to 0 is better.

$$\begin{aligned} P_i = {} & v[(K_i - k^*)/(k^- - k^*)] \\ & + (1 - v)[(L_i - L^*)/(L^- - L^*)], v = 0.5 \end{aligned} \tag{4}$$

Step 8: Predict the predictive values of waste recycling items of the six special municipalities using the linear regression analysis method or grey prediction model and calculate P_i values using equations. Steps 3–7 and rank. Compare them with the ranking of actual P_i values.

3. Results

3.1. VIKOR Analysis Results

As shown in **Table 1**, among the recycled waste resources of the six special municipalities, waste recycling items of the six special municipalities of Taiwan include 9

kinds of waste resources, such as paper products and paper, metal products, plastic and rubber products, glass products, textile products, home appliances, batteries, information and communication products, pesticide containers, special environment medicine containers, and edible oil. Values of pesticide container items cannot be compared due to a lack of information. Meanwhile, values of other items cannot be compared because standards for such items are not consistent. Therefore, only the waste recycling quantity of 9 items are adopted among 11 items.

Table 1. Statistical table of 2020 waste recycling quantity of the six special municipalities of Taiwan.

Waste Recycling Quantity	Paper Products and Paper	Metal Products	Plastic and Rubber Products	Glass Products	Textile Products	Home Appliances	Batteries	Information and Communication Products	Edible Oil
New Taipei City	874,191	456,686	237,379	104,767	34,052	8,319	12,562	1,850	63
Taipei City	495,277	285,096	158,473	15,897	4,747	1,176	1,697	259	1
Taoyuan City	734,366	373,444	122,583	81,508	101,418	5,945	25,157	2,518	75
Taichung City	578,525	315,812	98,383	78,096	41,763	3,505	5,849	2,628	170
Tainan City	549,139	273,094	119,032	61,912	57,899	6,050	5,225	3,120	180
Kaohsiung City	761,442	414,048	127,633	54,590	54,785	33,717	30,837	4,369	159

Source: Environment statistical and inquiry website of Taiwan's Ministry of Environment [1].

Among recycled waste resources of the six special municipalities, for paper products and paper, the waste recycling quantity of New Taipei City is the most, while that of Taipei City is the least. As for metal products, the waste recycling quantity of New Taipei City is the most, while that of Tainan City is the least. With regard to plastic and rubber products, the waste recycling quantity of New Taipei City is the most, while that of Taichung City is the least. For glass products, waste recycling quantity of New Taipei City is the most, while that of Taipei City is the least. As for textile products, the waste recycling quantity of Taoyuan City is the most, while that of Taipei City is the least. With regard to home appliances, the waste recycling quantity of Kaohsiung City is the most, while that of Taipei City is the least. For batteries, the waste recycling quantity of Kaohsiung City is the most, while that of Taipei City is the least. As for information and communication products, the waste recycling quantity of Kaohsiung City is the most, while that of Taipei City is the least. With regard to waste recycling, the quantity of Tainan City is the most, while that in Taipei City is the least.

Step 1: Input $H_{ij,}$ the original evaluation values of waste recycling items, including paper products and paper, metal products, plastic and rubber products, glass products, textile products, home appliances, batteries, information and communication products, pesticide containers, special environment medicine containers, and edible oil, in the six special municipalities of Taiwan, as shown in **Table 2**.

Step 2: Multiply by the weights after calculating the distances between the ideal solutions and the negative ideal solutions of the waste recycling items in the six special municipalities of Taiwan and all evaluation criteria (paper products and paper, metal products, plastic and rubber products, glass products, textile products, home appliances, batteries, information and communication products, pesticide containers, special environment medicine containers, and edible oil), and the results are shown in **Table 3**.

Table 2. All original H_{ij} input values of the annual average evaluation indexes of the waste recycling items in the six special municipalities of Taiwan (2020).

Waste Recycling Quantity	Paper Products and Paper	Metal Products	Plastic and Rubber Products	Glass Products	Textile Products	Home Appliances	Batteries	Information and Communication Products	Edible Oil
New Taipei City	1.0000	1.0000	1.0000	1.0000	0.3358	0.2467	0.4074	0.4234	0.3500
Taipei City	0.5666	0.6243	0.6676	0.1517	0.0468	0.0349	0.0550	0.0593	0.0056
Taoyuan City	0.8401	0.8177	0.5164	0.7780	1.0000	0.1763	0.8158	0.5763	0.4167
Taichung City	0.6618	0.6915	0.4145	0.7454	0.4118	0.1040	0.1897	0.6015	0.9444
Tainan City	0.6282	0.5980	0.5014	0.5909	0.5709	0.1794	0.1694	0.7141	1.0000
Kaohsiung City	0.8710	0.9066	0.5377	0.5211	0.5402	1.0000	1.0000	1.0000	0.8833

Table 3. Results obtained by multiplying the distances between the ideal solutions and the negative ideal solutions of the waste recycling items in the six special municipalities of Taiwan and all evaluation criteria by the weights (2020).

Waste Recycling Quantity	Paper Products and Paper	Metal Products	Plastic and Rubber Products	Glass Products	Textile Products	Home Appliances	Batteries	Information and Communication Products	Edible Oil
New Taipei City	1.0000	1.0000	1.0000	1.0000	0.3358	0.2467	0.4074	0.4234	0.3500
Taipei City	0.0000	0.0000	0.0000	0.0000	0.0738	0.0837	0.0658	0.0641	0.0722
Taoyuan City	0.0482	0.0417	0.0369	0.0943	0.1059	0.1072	0.1050	0.1045	0.1105
Taichung City	0.0178	0.0203	0.0537	0.0247	0.0000	0.0915	0.0205	0.0471	0.0648
Tainan City	0.0376	0.0343	0.0651	0.0283	0.0654	0.0996	0.0900	0.0443	0.0062
Kaohsiung City	0.0413	0.0447	0.0554	0.0455	0.0477	0.0912	0.0923	0.0318	0.0000

Step 3: Obtain the two comprehensive indexes, which are K_i (Equation (2)) and L_i (Equation (3)), and the results are shown in **Table 4**.

Step 4: Find from K_i that K^* is 0.1933 and K^- is 0.7542. Find from L_i that L^* is 0.0532, L^- is 0.1105. The results are shown in **Table 4**.

Table 4. Results of the evaluation of the waste recycling items in the six special municipalities of Taiwan by applying the VIKOR method (2020).

Waste Recycling Quantity	New Taipei City	Taipei City	Taoyuan City	Taichung City	Tainan City	Kaohsiung City
K_i	0.3596	0.7542	0.3403	0.4706	0.4497	0.1933
L_i	0.0837	0.1105	0.0915	0.0996	0.0923	0.0532
P (v = 0.5)	0.4144	1.0000	0.4654	0.6517	0.5697	0.0000
Ranking	2	6	3	5	4	1

Step 5: Calculate P_i (Equation (4)), and the results are shown in **Table 4**.

As shown in **Table 5**, among the recycled waste resources of the six special municipalities, for paper products and paper, the waste recycling quantity of New Taipei City is the most, while that of Taipei City is the least. As for metal products, the waste recycling quantity of New Taipei City is the most,while that of Taoyuan City is the least. With regard to plastic and rubber products, the waste recycling quantity of New Taipei City is the most, while that of Taipei City is the least. For glass products, the waste recycling quantity of Taoyuan City is the most, while that of Taipei City is the least. As for textile products, the waste recycling quantity of Kaohsiung City is the most, while that of Taipei City is the least. With regard to home appliances, the waste recycling quantity of Kaohsiung City is the most, while that of Taipei City is the least. For batteries, the waste recycling quantity of Kaohsiung City is the most, while that of Taipei City is the least. As for information and communication products, the waste recycling quantity of Taoyuan City is the most, while that of Taipei City is the least. With regard to edible oil, the waste recycling quantity of Taichung City is the most, while that of New Taipei City is the least.

Tables 6–**8** summarize the 2021 VIKOR analysis for the six special municipalities. **Table 6** shows the raw annual average evaluation data (H_{ij}) for each waste recycling item. **Table 7** illustrates the weighted distances from the ideal and negative ideal solutions across all criteria, and **Table 8** presents the municipalities' final performance scores and rankings derived from the VIKOR method.

Table 5. Statistical table of 2021 waste recycling quantity of the six special municipalities of Taiwan.

Waste Recycling Quantity	Paper Products and Paper	Metal Products	Plastic and Rubber Products	Glass Products	Textile Products	Home Appliances	Batteries	Information and Communication Products	Edible Oil
New Taipei City	457,253	290,468	116,045	34,392	5,918	13,410	2,140	2,571	60
Taipei City	281,688	157,186	12,497	4,070	929	1,680	1,319	832	70
Taoyuan City	358,884	127,181	77,931	90,573	5,077	26,728	2,715	9,306	126
Taichung City	399,030	130,657	93,391	56,733	4,196	10,161	3,031	3,831	5,835
Tainan City	296,961	130,146	67,259	63,153	6,696	5,768	2,392	2,573	205
Kaohsiung City	452,140	147,112	59,461	53,804	34,981	36,492	4,441	7,044	86

Source: Environment statistical and inquiry website of Taiwan's Ministry of Environment [1].

Table 6. All original H_{ij} input values of the annual average evaluation indexes of the waste recycling items in the six special municipalities of Taiwan (2021).

Waste Recycling Quantity	Paper Products and Paper	Metal Products	Plastic and Rubber Products	Glass Products	Textile Products	Home Appliances	Batteries	Information and Communication Products	Edible Oil
New Taipei City	1.0000	1.0000	1.0000	0.3797	0.1692	0.3675	0.4819	0.2763	0.0103
Taipei City	0.6160	0.5411	0.1077	0.0449	0.0266	0.0460	0.2970	0.0894	0.0120
Taoyuan City	0.7849	0.4378	0.6716	1.0000	0.1451	0.7324	0.6113	1.0000	0.0216
Taichung City	0.8727	0.4498	0.8048	0.6264	0.1200	0.2784	0.6825	0.4117	1.0000
Tainan City	0.6494	0.4481	0.5796	0.6973	0.1914	0.1581	0.5386	0.2765	0.0351
Kaohsiung City	0.9888	0.5065	0.5124	0.5940	1.0000	1.0000	1.0000	0.7569	0.0147

Table 7. Results obtained by multiplying the distances between the ideal solutions and the negative ideal solutions of the waste recycling items in the six special municipalities of Taiwan and all evaluation criteria by the weights (2021).

Waste Recycling Quantity	Paper Products and Paper	Metal Products	Plastic and Rubber Products	Glass Products	Textile Products	Home Appliances	Batteries	Information and Communication Products	Edible Oil
New Taipei City	0.0000	0.0000	0.0000	0.0689	0.0923	0.0703	0.0576	0.0804	0.1100
Taipei City	0.0427	0.0510	0.0991	0.1061	0.1082	0.1060	0.0781	0.1012	0.1098
Taoyuan City	0.0239	0.0625	0.0365	0.0000	0.0950	0.0297	0.0432	0.0000	0.1087
Taichung City	0.0141	0.0611	0.0217	0.0415	0.0978	0.0802	0.0353	0.0654	0.0000
Tainan City	0.0390	0.0613	0.0467	0.0336	0.0898	0.0935	0.0513	0.0804	0.1072
Kaohsiung City	0.0012	0.0548	0.0542	0.0451	0.0000	0.0000	0.0000	0.0270	0.1095

Table 8. Results of the evaluation of the waste recycling items in the six special municipalities of Taiwan by applying the VIKOR method (2021).

Waste Recycling Quantity	New Taipei City	Taipei City	Taoyuan City	Taichung City	Tainan City	Kaohsiung City
K_i	0.4795	0.8021	0.3995	0.4171	0.6029	0.2919
L_i	0.1100	0.1098	0.1087	0.0978	0.1072	0.1095
$P(v = 0.5)$	0.6824	1.0000	0.5526	0.1218	0.6905	0.4786
Ranking	4	6	3	1	5	2

As shown in **Table 9**, waste recycling items of the six special municipalities of Taiwan include 9 kinds of waste resources, such as paper products and paper, metal products, plastic and rubber products, glass products, textile products, home appliances, batteries, information and communication products, pesticide containers, special environment medicine containers and edible oil.

Among recycled waste resources of the six special municipalities, for paper products and paper, the waste recycling quantity of Taichung City is the most, while that of Taipei City is the least. As for metal products, the waste recycling quantity of New Taipei City is the most, while that of Tainan City is the least. With regard to plastic and rubber products, the waste recycling quantity of New Taipei City is the most, while that of Taipei City is the least. For glass products, the waste recycling quantity of Taoyuan City is the most, while that of Taipei City is the least. As for textile products, the waste recycling quantity of Kaohsiung City is the most, while that of Taipei City is the least. With regard to home appliances, the waste recycling quantity of Kaohsiung City is the most, while that of Taipei City is the least. For batteries, the waste recycling quantity of Kaohsiung City is the most, while that of Taoyuan City is the least. As for information and communication products, the waste recycling quantity of Taoyuan City is the most, while that of Taipei City is the least. With regard to edible oil, the waste recycling quantity of Taichung City is the most, while that of New Taipei City is the least.

Tables 10–12 summarize the 2022 VIKOR analysis for the six special municipalities. **Table 10** provides the raw annual average evaluation data ((H_{ij}) for each waste recycling item, **Table 11** illustrates the weighted distances from the ideal and negative ideal solutions across all criteria, and **Table 12** presents the resulting performance scores and rankings derived from the VIKOR method.

Table 9. Statistical table of 2022 waste recycling quantity of the six special municipalities of Taiwan.

Waste Recycling Quantity	Paper Products and Paper	Metal Products	Plastic and Rubber Products	Glass Products	Textile Products	Home Appliances	Batteries	Information and Communication Products	Edible Oil
New Taipei City	502,992	327,874	131,578	37,481	8,304	14,523	2,247	3,801	61
Taipei City	286,426	162,833	11,942	3,962	1,245	1,873	1,789	1,039	69
Taoyuan City	354,766	137,475	84,672	102,857	5,361	30,004	1,389	8,625	125
Taichung City	504,533	192,475	120,387	67,879	3,984	11,325	4,105	3,998	4,775
Tainan City	295,503	128,841	65,701	61,402	6,637	5,707	2,622	2,527	187
Kaohsiung City	485,993	162,425	60,576	53,844	34,747	39,359	4,173	6,852	147

Source: Environment statistical and inquiry website of Taiwan's Ministry of Environment [1].

Table 10. All original H_{ij} input values of the annual average evaluation indexes of the waste recycling items in the six special municipalities of Taiwan (2022).

Waste Recycling Quantity	Paper Products and Paper	Metal Products	Plastic and Rubber Products	Glass Products	Textile Products	Home Appliances	Batteries	Information and Communication Products	Edible Oil
New Taipei City	0.9969	1.0000	1.0000	0.3644	0.2390	0.3690	0.5385	0.4407	0.0128
Taipei City	0.5677	0.4966	0.0908	0.0385	0.0358	0.0476	0.4287	0.1205	0.0145
Taoyuan City	0.7032	0.4193	0.6435	1.0000	0.1543	0.7623	0.3329	1.0000	0.0262
Taichung City	1.0000	0.5870	0.9149	0.6599	0.1147	0.2877	0.9837	0.4635	1.0000
Tainan City	0.5857	0.3930	0.4993	0.5970	0.1910	0.1450	0.6283	0.2930	0.0392
Kaohsiung City	0.9633	0.4954	0.4604	0.5235	1.0000	1.0000	1.0000	0.7944	0.0308

Table 11. Results obtained by multiplying the distances between the ideal solutions and the negative ideal solutions of the waste recycling items in the six special municipalities of Taiwan and all evaluation criteria by the weights (2022).

Waste Recycling Quantity	Paper Products and Paper	Metal Products	Plastic and Rubber Products	Glass Products	Textile Products	Home Appliances	Batteries	Information and Communication Products	Edible Oil
New Taipei City	0.0003	0.0000	0.0000	0.0706	0.0846	0.0701	0.0513	0.0621	0.1097
Taipei City	0.0480	0.0559	0.1010	0.1068	0.1071	0.1058	0.0635	0.0977	0.1095
Taoyuan City	0.0330	0.0645	0.0396	0.0000	0.0940	0.0264	0.0741	0.0000	0.1082
Taichung City	0.0000	0.0459	0.0095	0.0378	0.0984	0.0791	0.0018	0.0596	0.0000
Tainan City	0.0460	0.0674	0.0556	0.0448	0.0899	0.0950	0.0413	0.0786	0.1068
Kaohsiung City	0.0041	0.0561	0.0600	0.0529	0.0000	0.0000	0.0000	0.0228	0.1077

Table 12. Results of the evaluation of the waste recycling items in the six special municipalities of Taiwan by applying the VIKOR method (2022).

Waste Recycling Quantity	New Taipei City	Taipei City	Taoyuan City	Taichung City	Tainan City	Kaohsiung City
K_i	0.4487	0.7955	0.4398	0.3321	0.6254	0.3036
L_i	0.1097	0.1095	0.1082	0.0984	0.1068	0.1077
$P(v = 0.5)$	0.6470	1.0000	0.5721	0.0275	0.6968	0.4110
Ranking	4	6	3	1	5	2

As shown in **Table 13**, among the recycled waste resources of the six special municipalities, the waste recycling items of the six special municipalities of Taiwan include 9 kinds of waste resources, such as paper products and paper, metal products, plastic and rubber products, glass products, textile products, home appliances, batteries, information and communication products, pesticide containers, special environment medicine containers and edible oil.

Table 13. Statistical table of 2023 waste recycling quantity of the six special municipalities of Taiwan.

Waste Recycling Quantity	Paper Products and Paper	Metal Products	Plastic and Rubber Products	Glass Products	Textile Products	Home Appliances	Batteries	Information and Communication Products	Edible Oil
New Taipei City	586,003	287,859	114,780	35,483	9,132	21,579	2,295	3,854	286

Table 13. *Cont.*

Waste Recycling Quantity	Paper Products and Paper	Metal Products	Plastic and Rubber Products	Glass Products	Textile Products	Home Appliances	Batteries	Information and Communication Products	Edible Oil
Taipei City	373,321	213,156	14,298	3,654	1,169	2,199	1,964	1,290	92
Taoyuan City	330,333	128,580	87,694	105,378	4,601	26,283	954	8,445	131
Taichung City	514,637	203,274	118,147	57,492	4,127	14,410	4,942	3,846	5,821
Tainan City	301,157	131,212	66,956	62,551	6,775	5,777	2,607	2,582	153
Kaohsiung City	508,201	170,129	65,747	55,923	33,046	42,801	4,128	6,783	130

Source: Environment statistical and inquiry website of Taiwan's Ministry of Environment [1].

Among the recycled waste resources of the six special municipalities, for paper products and paper, the waste recycling quantity of New Taipei City is the most, while that of Tainan City is the least. As for metal products, the waste recycling quantity of New Taipei City is the most, while that of Taoyuan City is the least. With regard to plastic and rubber products, the waste recycling quantity of Taichung City is the most, while that of Taipei City is the least. For glass products, the waste recycling quantity of Taoyuan City is the most, while that of Taipei City is the least. As for textile products, the waste recycling quantity of Kaohsiung City is the most, while that of Taipei City is the least. With regard to home appliances, the waste recycling quantity of Kaohsiung City is the most, while that of Taipei City is the least. For batteries, the waste recycling quantity of Taichung City is the most, while that of Taoyuan City is the least. As for information and communication products, the waste recycling quantity of Taoyuan City is the most, while that of Taipei City is the least. For edible oil, the waste recycling quantity of Taichung City is the most, while that of New Taipei City is the least.

Tables 14–16 summarize the 2023 VIKOR analysis for the six special municipalities. **Table 14** provides the raw annual average evaluation data (H_{ij}) for each waste recycling item, **Table 15** illustrates the weighted distances from the ideal and negative ideal solutions across all criteria, and **Table 16** presents the resulting performance scores and rankings derived from the VIKOR method.

Table 14. All original H_{ij} input values of the annual average evaluation indexes of the waste recycling items in the six special municipalities of Taiwan (2023).

Waste Recycling Quantity	Paper Products and Paper	Metal Products	Plastic and Rubber Products	Glass Products	Textile Products	Home Appliances	Batteries	Information and Communication Products	Edible Oil
New Taipei City	1.0000	1.0000	0.9715	0.3367	0.2763	0.5042	0.4644	0.4564	0.0491
Taipei City	0.6371	0.7405	0.1210	0.0347	0.0354	0.0514	0.3974	0.1528	0.0158
Taoyuan City	0.5637	0.4467	0.7422	1.0000	0.1392	0.6141	0.1930	1.0000	0.0225
Taichung City	0.8782	0.7062	1.0000	0.5456	0.1249	0.3367	1.0000	0.4554	1.0000
Tainan City	0.5139	0.4558	0.5667	0.5936	0.2050	0.1350	0.5275	0.3057	0.0263
Kaohsiung City	0.8672	0.5910	0.5565	0.5307	1.0000	1.0000	0.8353	0.8032	0.0223

Table 15. Results obtained by multiplying the distances between the ideal solutions and the negative ideal solutions of the waste recycling items in the six special municipalities of Taiwan and all evaluation criteria by the weights (2023).

Waste Recycling Quantity	Paper Products and Paper	Metal Products	Plastic and Rubber Products	Glass Products	Textile Products	Home Appliances	Batteries	Information and Communication Products	Edible Oil
New Taipei City	0.0000	0.0000	0.0032	0.0737	0.0804	0.0551	0.0595	0.0604	0.1057
Taipei City	0.0403	0.0288	0.0977	0.1073	0.1072	0.1054	0.0670	0.0941	0.1094
Taoyuan City	0.0485	0.0615	0.0286	0.0000	0.0956	0.0429	0.0897	0.0000	0.1086
Taichung City	0.0135	0.0326	0.0000	0.0505	0.0972	0.0737	0.0000	0.0605	0.0000
Tainan City	0.0540	0.0605	0.0481	0.0452	0.0883	0.0961	0.0525	0.0771	0.1082
Kaohsiung City	0.0148	0.0454	0.0493	0.0521	0.0000	0.0000	0.0183	0.0219	0.1086

Table 16. Results of the evaluation of the waste recycling items in the six special municipalities of Taiwan by applying the VIKOR method (2023).

Waste Recycling Quantity	New Taipei City	Taipei City	Taoyuan City	Taichung City	Tainan City	Kaohsiung City
K_i	0.4379	0.7571	0.4754	0.3281	0.6301	0.3104
L_i	0.1057	0.1094	0.1086	0.0972	0.1082	0.1086
P (v = 0.5)	0.4893	1.0000	0.6524	0.0212	0.8082	0.4686
Ranking	3	6	4	1	5	2

As shown in **Table 17**, among the recycled waste resources of the six special municipalities, waste recycling items of the six special municipalities of Taiwan include 9 kinds of waste resources, such as paper products and paper, metal products, plastic and rubber products, glass products, textile products, home appliances, batteries, information and communication products, pesticide containers, special environment medicine containers and edible oil.

Table 17. Statistical table of 2024 waste recycling quantity of the six special municipalities of Taiwan.

Waste Recycling Quantity	Paper Products and Paper	Metal Products	Plastic and Rubber Products	Glass Products	Textile Products	Home Appliances	Batteries	Information and Communication Products	Edible Oil
New Taipei City	593,847	345,813	126,192	40,950	9,558	20,134	2,707	4,110	280
Taipei City	408,815	232,461	17,048	2,570	1,082	2,423	2,507	1,436	93
Taoyuan City	294,484	116,590	81,019	92,335	4,490	28,053	908	7,328	130
Taichung City	506,193	202,426	119,011	65,511	4,373	13,644	5,457	3,932	8,311
Tainan City	302,464	131,724	67,244	62,819	6,855	5,814	2,609	2,589	130
Kaohsiung City	536,831	178,473	69,013	55,319	32,390	41,514	4,477	7,099	68

Source: Environment statistical and inquiry website of Taiwan's Ministry of Environment [1].

Among recycled waste resources of the six special municipalities, for paper products and paper, the waste recycling quantity of New Taipei City is the most, while that of Taoyuan City is the least. As for metal products, the waste recycling quantity of New Taipei City is the most, while that of Taoyuan City is the least. With regard to plastic and rubber products, the waste recycling quantity of New Taipei City is the most, while that of Taipei City is the least. For glass products, the waste recycling quantity of Taoyuan City is the most, while that of Taipei City is the least. As for textile products, the waste recycling quantity of Kaohsiung City is the most, while that of Taipei City is the least.

With regard to home appliances, the waste recycling quantity of Kaohsiung City is the most, while that of Taipei City is the least. For batteries, the waste recycling quantity of Taichung City is the most, while that of Taoyuan City is the least. As for information and communication products, the waste recycling quantity of Taoyuan City is the most, while that of Taipei City is the least. With regard to edible oil, the waste recycling quantity of Taichung City is the most, while that of Kaohsiung City is the least.

Tables 18–20 summarize the 2024 VIKOR analysis for the six special municipalities. **Table 18** provides the raw annual average evaluation data (H_{ij}) for each waste recycling item, **Table 19** illustrates the weighted distances from the ideal and negative ideal solutions across all criteria, and **Table 20** presents the resulting performance scores and rankings derived from the VIKOR method.

Table 18. All original H_{ij} input values of the annual average evaluation indexes of the waste recycling items in the six special municipalities of Taiwan (2024).

Waste Recycling Quantity	Paper Products and Paper	Metal Products	Plastic and Rubber Products	Glass Products	Textile Products	Home Appliances	Batteries	Information and Communication Products	Edible Oil
New Taipei City	1.0000	1.0000	1.0000	0.4435	0.2951	0.4850	0.4961	0.5609	0.0337
Taipei City	0.6884	0.6722	0.1351	0.0278	0.0334	0.0584	0.4594	0.1960	0.0112
Taoyuan City	0.4959	0.3371	0.6420	1.0000	0.1386	0.6757	0.1664	1.0000	0.0156
Taichung City	0.8524	0.5854	0.9431	0.7095	0.1350	0.3287	1.0000	0.5366	1.0000
Tainan City	0.5093	0.3809	0.5329	0.6803	0.2116	0.1400	0.4781	0.3533	0.0156
Kaohsiung City	0.9040	0.5161	0.5469	0.5991	1.0000	1.0000	0.8204	0.9688	0.0082

Table 19. Results obtained by multiplying the distances between the ideal solutions and the negative ideal solutions of the waste recycling items in the six special municipalities of Taiwan and all evaluation criteria by the weights (2024).

Waste Recycling Quantity	Paper Products and Paper	Metal Products	Plastic and Rubber Products	Glass Products	Textile Products	Home Appliances	Batteries	Information and Communication Products	Edible Oil
New Taipei City	0.0000	0.0000	0.0000	0.0618	0.0783	0.0572	0.0560	0.0488	0.1074
Taipei City	0.0346	0.0364	0.0961	0.1080	0.1074	0.1046	0.0601	0.0893	0.1099
Taoyuan City	0.0560	0.0737	0.0398	0.0000	0.0957	0.0360	0.0926	0.0000	0.1094
Taichung City	0.0164	0.0461	0.0063	0.0323	0.0961	0.0746	0.0000	0.0515	0.0000
Tainan City	0.0545	0.0688	0.0519	0.0355	0.0876	0.0956	0.0580	0.0719	0.1094
Kaohsiung City	0.0107	0.0538	0.0503	0.0445	0.0000	0.0000	0.0200	0.0035	0.1102

Table 20. Results of the evaluation of the waste recycling items in the six special municipalities of Taiwan by applying the VIKOR method (2024).

Waste Recycling Quantity	New Taipei City	Taipei City	Taoyuan City	Taichung City	Tainan City	Kaohsiung City
K_i	0.4095	0.7465	0.5032	0.3233	0.6331	0.2929
L_i	0.1074	0.1099	0.1094	0.0961	0.1094	0.1102
P (v = 0.5)	0.5281	1.0000	0.7026	0.0339	0.8459	0.5000
Ranking	3	6	4	1	5	2

3.2. Linear Regression Analysis Results

Good effects were achieved on predicting and prewarning evaluation in the research by applying the VIKOR method and the linear regression analysis method. The situation can be grasped in advance and the predicted values of waste recycling quantity for 2024 are shown in **Table 21**.

The theory of linear regression was first proposed by Kasza and Wolfe, Hossain Parash et al., Darlington and Hayes, Zapf et al., and Montgomery et al.[2–6].

Step 1: Transfer waste recycling items data from platform[1] to an Excel file.

Step 2: Linear regression analysis: $y_i = ax_i + b$.

Step 3: The perdiction values y_i (**Table 21**).

Table 21. 2024 waste recycling quantity prediction table of the six special municipalities in Taiwan via linear regression analysis.

Waste Recycling Quantity	Paper Products and Paper	Metal Products	Plastic and Rubber Products	Glass Products	Textile Products	Home Appliances	Batteries	Information and Communication Products	Edible Oil
New Taipei City	609156	333109	109957	37198	9124	22559	2493	4691	295
Taipei City	373985	215388	12321	3261	1203	2287	2729	1366	91
Taoyuan City	320995	136026	89276	106098	4309	28707	389	7989	107
Taichung City	608999	250320	139293	70550	4366	17148	5680	4658	5397
Tainan City	312361	122022	68851	64302	7068	6018	2358	2636	154
Kaohsiung City	544165	187525	68740	55453	33561	47062	4030	7031	153

Source: Environment statistical and inquiry website of Taiwan's Ministry of Environment[1] and predicted results obtained through linear regression analysis in the research.

Normalized results of the perdiction values of waste recycling quantity are shown in **Table 22**, and results of ideal solutions and the negative ideal solutions are listed in **Table 23**.

Table 22. All original H_{ij} input values of the annual average evaluation indexes of the waste recycling items in the six special municipalities of Taiwan (via linear regression analysis and the VIKOR method) (2024).

Waste Recycling Quantity	Paper Products and Paper	Metal Products	Plastic and Rubber Products	Glass Products	Textile Products	Home Appliances	Batteries	Information and Communication Products	Edible Oil
New Taipei City	1.0000	1.0000	0.7894	0.3506	0.2719	0.4793	0.4389	0.5872	0.0547
Taipei City	0.6139	0.6466	0.0885	0.0307	0.0358	0.0486	0.4805	0.1710	0.0169
Taoyuan City	0.5270	0.4084	0.6409	1.0000	0.1284	0.6100	0.0685	1.0000	0.0198
Taichung City	0.9997	0.7515	1.0000	0.6650	0.1301	0.3644	1.0000	0.5831	1.0000

Table 22. *Cont.*

Waste Recycling Quantity	Paper Products and Paper	Metal Products	Plastic and Rubber Products	Glass Products	Textile Products	Home Appliances	Batteries	Information and Communication Products	Edible Oil
Tainan City	0.5128	0.3663	0.4943	0.6061	0.2106	0.1279	0.4151	0.3300	0.0285
Kaohsiung City	0.8933	0.5630	0.4935	0.5227	1.0000	1.0000	0.7095	0.8801	0.0283

Table 23. Results obtained by multiplying the distances between the ideal solutions and the negative ideal solutions of the waste recycling items in the six special municipalities of Taiwan and all evaluation criteria by the weights (2024), via linear regression analysis and the VIKOR method.

Waste Recycling Quantity	Paper Products and Paper	Metal Products	Plastic and Rubber Products	Glass Products	Textile Products	Home Appliances	Batteries	Information and Communication Products	Edible Oil
New Taipei City	0.0000	0.0000	0.0234	0.0722	0.0809	0.0579	0.0623	0.0459	0.1050
Taipei City	0.0429	0.0393	0.1013	0.1077	0.1071	0.1057	0.0577	0.0921	0.1092
Taoyuan City	0.0526	0.0657	0.0399	0.0000	0.0968	0.0433	0.1035	0.0000	0.1089
Taichung City	0.0000	0.0276	0.0000	0.0372	0.0967	0.0706	0.0000	0.0463	0.0000
Tainan City	0.0541	0.0704	0.0562	0.0438	0.0877	0.0969	0.0650	0.0744	0.1079
Kaohsiung City	0.0119	0.0486	0.0563	0.0530	0.0000	0.0000	0.0323	0.0133	0.1080

3.3. VIKOR and Linear Regression Analysis Results

Ranking results of predictive values are shown in **Table 24**.

3.4. Ranking Result of Linear Regression Analysis: Predictive Values and Actual Values

As shown in **Table 25**, upon comparison between the ranking results of predictive values and those of actual values, they are 100% consistent.

3.5. Grey Prediction Model Results

Good effects were achieved in predicting and pre-warning evaluation in the research by applying the VIKOR method and grey prediction model results. The situation can be grasped in advance, and the predicted values of waste recycling quantity for 2024 are shown in **Table 26**.

Table 24. Results of the evaluation of the waste recycling items in the six special municipalities of Taiwan by applying the linear regression analysis and VIKOR method (2024).

Waste Recycling Quantity	New Taipei City	Taipei City	Taoyuan City	Taichung City	Tainan City	Kaohsiung City
K_i	0.4476	0.7631	0.5108	0.2785	0.6565	0.3233
L_i	0.1050	0.1092	0.1089	0.0967	0.1079	0.1080
P (v = 0.5)	0.5078	1.0000	0.7281	0.0000	0.8398	0.4969
Ranking	3	6	4	1	5	2

Table 25. Upon comparison between the ranking results of linear regression analysis predictive values and those of actual values, they are 100% consistent: The predicted ranking of the six special municipalities' waste recycling quantity management is 100% consistent with the actual values of the management ranking situation of the six special municipalities.

Waste Recycling Quantity	New Taipei City	Taipei City	Taoyuan City	Taichung City	Tainan City	Kaohsiung City
Predicted results of 2024 (linear regression analysis) + (VIKOR method) Q (v = 0.5)	0.5078	1.0000	0.7281	0.0000	0.8398	0.4969
Ranking	3	6	4	1	5	2
2024 Q (v = 0.5) (VIKOR method)	0.5281	1.0000	0.7026	0.0339	0.8459	0.5000
Ranking	3	6	4	1	5	2

Table 26. 2024 waste recycling quantity prediction table of the six special municipalities in Taiwan via the grey prediction model.

Waste Recycling Quantity	Paper Products and Paper	Metal Products	Plastic and Rubber Products	Glass Products	Textile Products	Home Appliances	Batteries	Information and Communication Products	Edible Oil
New Taipei City	658,821	299,574	119,595	36,863	11,405	26,909	2,385	4,801	98
Taipei City	420,940	243,577	14,888	3,500	1,359	2,499	2,412	1,595	102
Taoyuan City	320,626	132,449	93,573	115,025	4,569	27,247	492	7,956	132
Taichung City	595,391	256,073	136,426	61,420	4,032	16,955	6,278	3,906	5,462
Tainan City	302,109	131,140	66,334	61,764	6,782	5,759	2,758	2,569	136
Kaohsiung City	540,528	184,030	68,541	56,688	32,379	46,278	3,940	6,635	166

Source: Environment statistical and inquiry website of Taiwan's Ministry of Environment [1] and predicted results obtained through the grey prediction model in the research.

The theory of the grey prediction model was first proposed by Deng [11].

Step 1: Transfer waste recycling item data from platform [1] to an Excel file.

Step 2: $x_0(k)$, $k = 1, 2, 3, \ldots n$, Original matrix $B(x_0(k))$.

Step 3: AGO generation $B(x_0(k))$, $k = 1, 2, 3, \ldots, n$.

Step 4: Mean generation $B(x_0(k))$, $k = 1, 2, 3, \ldots, n$.

Step 5: $B(x_0(k))tB(x_0(k))$, $k = 1, 2, 3, \ldots, n$.

Step 6: Inverse of $B(x_0(k))tB(x_0(k))$, $k = 1, 2, 3, \ldots, n$.

Step 7: The prediction model results $x_0(k + 1)$, $k = 1, 2, 3, \ldots, n$.

Normalized results of the prediction values of waste recycling quantity are shown in **Table 27**, and results of ideal solutions and the negative ideal solutions are listed in **Table 28**.

3.6. VIKOR and Grey Prediction Model Results

Ranking results of predictive values are shown in **Table 29**.

3.7. Ranking Result of Grey Prediction Model Predictive Values and that of Actual Values

As shown in **Table 30**, upon comparison between the ranking results of predictive values and those of actual values, they are 100% consistent.

Table 27. All original H_{ij} input values of the annual average evaluation indexes of the waste recycling items in the six special municipalities of Taiwan (via the grey prediction model and the VIKOR method) (2024).

Waste Recycling Quantity	Paper Products and Paper	Metal Products	Plastic and Rubber Products	Glass Products	Textile Products	Home Appliances	Batteries	Information and Communication Products	Edible Oil
New Taipei City	1.0000	1.0000	0.8766	0.3205	0.3522	0.5815	0.3799	0.6034	0.0179
Taipei City	0.6389	0.8131	0.1091	0.0304	0.0420	0.0540	0.3842	0.2005	0.0187
Taoyuan City	0.4867	0.4421	0.6859	1.0000	0.1411	0.5888	0.0784	1.0000	0.0242
Taichung City	0.9037	0.8548	1.0000	0.5340	0.1245	0.3664	1.0000	0.4910	1.0000
Tainan City	0.4586	0.4378	0.4862	0.5370	0.2095	0.1244	0.4393	0.3229	0.0249
Kaohsiung City	0.8204	0.6143	0.5024	0.4928	1.0000	1.0000	0.6276	0.8340	0.0304

Table 28. Results obtained by multiplying the distances between the ideal solutions and the negative ideal solutions of the waste recycling items in the six special municipalities of Taiwan and all evaluation criteria by the weights (2024), via the grey prediction model and the VIKOR method.

Waste Recycling Quantity	Paper Products and Paper	Metal Products	Plastic and Rubber Products	Glass Products	Textile Products	Home Appliances	Batteries	Information and Communication Products	Edible Oil
New Taipei City	0.0000	0.0000	0.0137	0.0755	0.0720	0.0465	0.0689	0.0441	0.1091
Taipei City	0.0401	0.0208	0.0990	0.1077	0.1064	0.1051	0.0684	0.0888	0.1090
Taoyuan City	0.0570	0.0620	0.0349	0.0000	0.0954	0.0457	0.1024	0.0000	0.1084
Taichung City	0.0107	0.0161	0.0000	0.0518	0.0973	0.0704	0.0000	0.0566	0.0000
Tainan City	0.0602	0.0625	0.0553	0.0514	0.0878	0.0973	0.0623	0.0752	0.1083
Kaohsiung City	0.0200	0.0429	0.0563	0.0564	0.0000	0.0000	0.0414	0.0184	0.1077

Table 29. Results of the evaluation of the waste recycling items in the six special municipalities of Taiwan by applying the via grey prediction model and VIKOR method (2024).

Waste Recycling Quantity	New Taipei City	Taipei City	Taoyuan City	Taichung City	Tainan City	Kaohsiung City
K_i	0.4298	0.7455	0.5059	0.3028	0.6622	0.3420
L_i	0.1091	0.1090	0.1084	0.0973	0.1083	0.1077
P (v = 0.5)	0.6444	1.0000	0.7006	0.0000	0.8739	0.4864
Ranking	3	6	4	1	5	2

Table 30. Upon comparison between the ranking results of the grey prediction model's predictive values and those of the actual values, they are 100% consistent: The predicted ranking of the six special municipalities' waste recycling quantity management is 100% consistent with the actual values of the management ranking situation of the six special municipalities.

Waste Recycling Quantity	New Taipei City	Taipei City	Taoyuan City	Taichung City	Tainan City	Kaohsiung City
Predicted results of 2024 (grey prediction model) + (VIKOR method) Q (v = 0.5)	0.6444	1.0000	0.7006	0.0000	0.8739	0.4864
Ranking	3	6	4	1	5	2
2024 Q (v = 0.5) (VIKOR method)	0.5281	1.0000	0.7026	0.0339	0.8459	0.5000
Ranking	3	6	4	1	5	2

4. Discussion

The evaluation value of Taichung City's waste recycling quantity is used linear regression analysis predicted to be the best, with the result value being 0.0000 and ranking No. 1. The evaluation value of Kaohsiung City is 0.4969 and the situation ranking is No. 2; the evaluation value of New Taipei City is 0.5078 and the situation ranking is No. 3. Evaluation value of Taoyuan City 0.7281 and situation ranking No. 4, evaluation value of Tainan City 0.8398 and situation ranking No. 5 and evaluation value of Taipei City: 1.0000 and situation ranking No. 6, which is unsatisfactory. Linear regression analysis predicted the ranking of the six special municipalities in waste recycling quantity management is 100% consistent with the actual values of the management ranking situation of the six special municipalities in Taiwan.

The evaluation value of Taichung City's waste recycling quantity is used grey prediction model predicted to be the best, with the result value being 0.0000 and ranking No. 1. The evaluation value of Kaohsiung City is 0.4864, and the situation ranking is No. 2; the evaluation value of New Taipei City is 0.6444, and the situation ranking is No. 3. Evaluation value of Taoyuan City 0.7006 and situation ranking No. 4; evaluation value of Tainan City 0.8739 and situation ranking No. 5 and evaluation value of Taipei City: 1.0000 and situation ranking No. 6, which is unsatisfactory. Grey prediction model predicted the ranking of the six special municipalities in waste recycling quantity management, which is 100% consistent with the actual values of the management ranking situation of the six special municipalities in Taiwan.

The actual value of Taichung City's 2024 waste recycling quantity is the best, with the result value being 0.0339 and ranking No. 1. The actual value of Kaohsiung City is 0.5000, and the situation ranking is No. 2, actual value of New Taipei City is 0.5281, and situation ranking No. 3. Actual value of Taoyuan City: 0.7026 and situation ranking No. 4, actual value of Tainan City: 0.8459 and situation ranking No. 5; actual value of Taipei City: 1.0000 and situation ranking No. 6, which is unsatisfactory.

Ranking results of linear regression analysis predictive values are shown in **Table 24**. As shown in **Table 25**, upon comparison between the ranking results of predictive values and those of actual values, they are 100% consistent. The predicted ranking of the six special municipalities' waste recycling quantity management is 100% consistent with the actual values of the management ranking situation of the six special municipalities.

Ranking results of the grey prediction model predictive values are shown in **Table 29**. As shown in **Table 30**, upon comparison between the ranking results of predictive values and those of actual values, they are 100% consistent. The predicted ranking of the six special municipalities' waste recycling quantity management is 100% consistent with the actual values of the management ranking situation of the six special municipalities.

5. Conclusions

The VIKOR method link linear regression analysis method and grey prediction model proposed by the research can not only predict effectively and evaluate the influence of waste recycling management situations of the six special municipalities in Taiwan on the ecological environment and body health in advance, but also be used as a reference for regulators of environmental protection agencies to work out a future strategy pre-warning mechanism for the waste resource recycling management for the six special municipalities of Taiwan.

The reason for accurately predicting and knowing the resource recycling ranking of the six cities is that the state can know the resource recycling capacity of the six cities in advance and allocate recycling personnel and equipment to them.

Enterprises attach great importance to ESG and hope to manage waste recycling well, but analysis is always conducted after results come out. The research tried applying a prediction analysis method to predict future waste recycling quantity first and evaluate it with the VIKOR method. In the future, neural networks may provide better effects for subsequent researchers to use as reference by applying time series methods as prediction methods, and grey relational analysis or data envelopment analysis as evaluation methods.

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Informed Consent Statement

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Data Availability Statement

2025 environment statistical and inquiry website of Taiwan's Ministry of Environment cited 2025 Jan. 8 Available from: https://statis.moenv.gov.tw/epanet/. The collect data is to 2020 to 2024 from environment statistical and inquiry website of Taiwan's Ministry of Environment.

Conflicts of Interest

The author declares no conflict of interest.

AI Use Statement

The author declares that no artificial intelligence (AI) tools were used in the preparation of this manuscript.

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