The Analytic Hierarchy of Resource Recycling via ISM

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Abstract-With the human being's advances in technology and business economic growth, the consumption of material grows rapidly, and cause many environmental problems. If we can understand the importance of resource recycling, then, it can leave a clean space for future generations. Hence, the main purpose of the paper provides the Interpretive Structure Modeling (ISM) to analyze the hierarchy of influence factor in resource recycling. Based on the characteristic of ISM, it is one of the elementary mathematics models in kansei engineering, and the main function of ISM is to deal with complex issues. Firstly, the mathematics concept of ISM is presented. Secondly, a real example of environment field, which is the hierarchy analysis of major influence factor in resource recycling, is used as an example. Also in the paper, we develop a Matlab toolbox to verify the results. Through the actual analysis, the results not only can do hierarchical analysis to complex systems, but also clusters the system structure, which provides a method to solve our problem.

Keywords- Environmental problems, ISM, Hierarchy, Resource recycling, Kansei, Matlab

I. INTRODUCTION

The paper uses a large-scale environmental field in central Taiwan as research subject. By using ISM method in *Kansei* engineering to analyze the resource recycling factors. The class weightings of factors are analyzed to identify the focus of the resource recycling business impact. ISM method was proposed by John Nelson Warfield in 1986 [1], and it is used to classify complicated system in a constructive way. There are many papers proposed in the past; for example, in students self-Learning [2], University-industry alliance partner selection[3], analyzing the influence factors of greenness of products[4], decision making[5] and impact on retail chain [6], it doesn't involve resource recycling. However, for resource recycling studies, they include the application of recycling in the construction industry [7], the recycling planning system proposed [8], the use of grey relational analysis and data envelopment analysis to evaluate the effectiveness of local recycling efforts together with factorial analysis [9], conditional analysis of the correlation between external conditions such as demographics and disposable income on recycling [10], the relationship between scavengers and the logistics industry proposed [11], the plan for a waste logistics system [12], the hierarchical model of corporate social responsibility[13], the grey entropy to analyze the weighting of influence factor in resource recycling[14], the rough set method to analyze the weighting of influence factor in resource recycling[15], the analysis of influence factor in resource recycling by using Grey AHP[16].

Due to in the current resource recycling system, we rely on resource collection points. However, current studies on resource collection points in Taiwan are quite few. It is mainly because that there is no entrepreneurial management in the resource collection points. It is not only difficult to reach the information and data, but there is also no class divided on the discussion of the impact influence of each other. Hence, we propose the ISM method to be the class analysis model, and a large-scale environmental field in central Taiwan is used as example to analyze the hierarchical relationship of resources recycling factors and then provide strategy for resource recycling business.

In II, the basic concept of ISM is presented. III is real example in the analytic hierarchy of resource recycling. The final section of this study consists of a conclusion and recommendations for future research.

II. MATHEMATICS MODEL

A. Basic Concept

Generally speaking, $S=\{s_i \mid 1\le i\le n\}$ is used to represent a set in mathematics. In the equation, the relationship among *R*, s_i and s_j can be defined as s_iRs_j, which is also called binomial relationship and uses $R(s_i,s_j)$ to express the magnitude of s_iRs_j. There are three basic rules of the binomial relationship [17].

- Reflexivity: $s_iRs_i, \forall s_i \in S$
- Symmetry: $s_iRs_j \to s_jRs_i, \forall s_i, s_i \in S$
- Transitivity: $s_iRs_k, s_kRs_j \to s_iR^2s_j, \forall s_i, s_i, s_k \in S$

In practice, there are *n* numbers of elements which form a set S.

$$S=(s_1,s_2,\cdots,s_n) \tag{1}$$

then, define the cross product of *S* as follows.

$$S \times S = \{(s_i, s_j) \mid s_i, s_j \in S\} \tag{2}$$

B. ISM

If there is a cause-effect relationship between s_i and s_j, Forms an ordered pair $(s_i, s_j) \in R$, which R is a part set of set $S \times S$. Using graph theory at this time to convert an ordered pair into a matrix form, as shown in (3).

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & a_{ij} & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix} \quad \text{where} \begin{cases} a_{ij} = 1 & if, (s_i, s_j) \in R \\ a_{ij} = 0 & if, (s_i, s_j) \notin R \end{cases} \tag{3}$$

1) Build up the relational matrix

$$A = \begin{array}{c} \\ s_1 \\ s_2 \\ \vdots \\ s_{n-1} \\ s_n \end{array} \begin{array}{c} \begin{array}{ccccc} s_1 & s_2 & \cdots & s_{n-1} & s_n \end{array} \\ \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1(n-1)} & a_{1n} \\ a_{21} & a_{22} & \vdots & a_{2(n-1)} & a_{2n} \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ \vdots & \cdots & \cdots & \cdots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{n(n-1)} & a_{nn} \end{bmatrix} \end{array} \tag{4}$$

2) Build up the reachable matrix

Build up the: Based on (4), to build the new matrix, which is $A + I$ as shown in (5).

$$A + I = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1(n-1)} & a_{1n} \\ a_{21} & a_{22} & \vdots & a_{2(n-1)} & a_{2n} \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ \vdots & \cdots & \cdots & \cdots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{n(n-1)} & a_{nn} \end{bmatrix} + \begin{bmatrix} 1 & 0 & \cdots & 0 & 0 \\ 0 & 1 & \cdots & 0 & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ \vdots & \cdots & \cdots & \cdots & \vdots \\ 0 & 0 & \cdots & 0 & 1 \end{bmatrix} \tag{5}$$

where I is an unit matrix

3) Repeating the calculation

Repeating the calculation, until the results of the matrix stops changing, the matrix is called reachable matrix, and $n-1$ is called the layer.

$$(A + I)^n = (A + I)^{n-1} \equiv T \tag{6}$$

4) Structuring hierarchy

In (6), in terms of the T matrix, a set called a "row" is a reachable set and is indicated with $R(s)$. A set called an "intersection" is an advance set, which is indicated with $Q(s)$, and the intersection of the two is defined as

$$R(s) \cap Q(s) \tag{7}$$

III. REAL EXAMPLE

Generally speaking, most influence item in resource recycling has the main relationship, which is the prices, and each item had their important essential (please see TABLE I to TABLE III). Now, we select eight items as our example, as shown from Fig. 1 to Fig. 10, and use ISM method to get the structuring hierarchy [17].

Fig. 1 Paper

Fig. 2 Poly bottles

Fig. 3 Plastic

Fig. 4 Iron (steel bar)

Fig. 5 Iron (stainless)

Fig. 6 Aluminum (window)

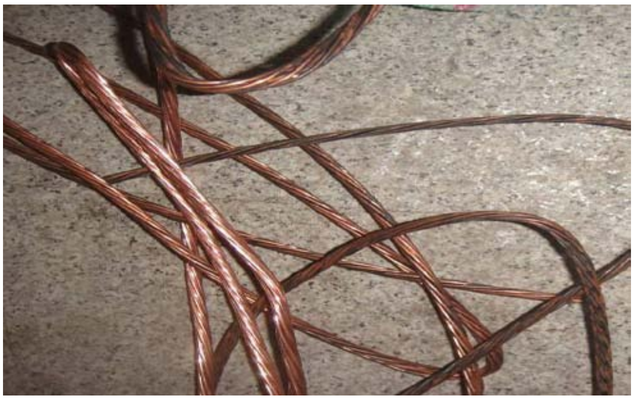

Fig. 7 Copper

Fig. 8 Electrical wiring

Fig. 9 Battery (general type)

Fig. 10 Battery (Lead-acid type)

A. *Mathematics Analysis Steps*

1) *Build up the similarity relationship:*

Two items through the average pries, and valued them by company, then, takes the mean from the CEO, we can get similarity matrix R, as shown in TABLE IV.

2) *Take λ cut*

For λ =0.6, the relational A is shown in TABLE V [18].

3) *Build up the relational matrix*

$$
\begin{array}{c@{}c}
 & \begin{array}{ccccc} s_1 & s_2 & \cdots\cdots & s_7 & s_8 \end{array} \\
A = \begin{array}{c} s_1 \\ s_2 \\ \vdots \\ s_7 \\ s_8 \end{array} &
\begin{bmatrix} 1 & & & & \\ 0 & 1 & & & \\ \vdots & \vdots & \ddots & & \\ 0 & 0 & \cdots & 1 & \\ 0 & 0 & \cdots & 1 & 1 \end{bmatrix}
\end{array}
$$

4) *Build up the reachable matrix:*

Based on (4), and repeating the calculation until the results of the matrix stops changing, in our example, $(A+I)^3 \equiv T$, means

$$
T = \begin{bmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 1 & 1 & 0 & 0 & 0 \\
1 & 1 & 1 & 1 & 1 & 1 & 0 & 0 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1
\end{bmatrix}
$$

5) Structuring hierarchy:

Build up the reachable set via $R(s) \cap Q(s)$, as shown in TABLE VI.

6) Repeating the calculation:

The final reduction is shown in TABLE VII.

TABLE VII THE FINAL RESULTS

Layer		
1st	8	
2nd	7	
3rd	6	
4th	3	5
5th	4	
6th	1	2

7) Complete final structure analysis:

Based on the reduction results, the final hierarchy structure diagram can be found, as shown in Fig. 11

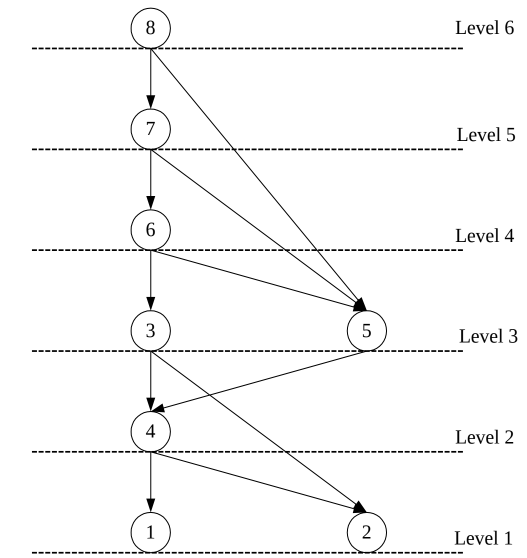

Fig. 11 The layer from ISM method

B. *The Auxiliary of Toolbox*

In the toolbox, the input/output interface is based on *Matlab* structure, and according to the characteristics of *Matlab*, the input data can expand into infinite to make this toolbox more powerful. In the ISM matrix, no matter how huge, the operation processing will not be influenced. Hence, for the user, it can make the results on the analysis system more convincing and practical [19~21]. The main functions in our toolbox are shown from Fig. 12 to Fig. 15.

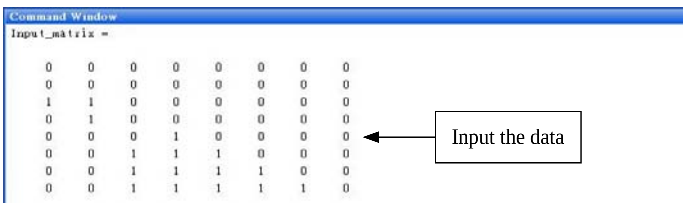

Fig. 12 The input matrix

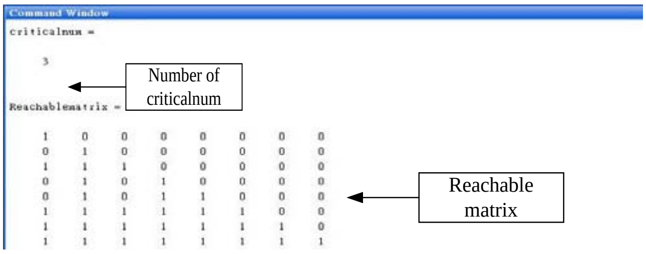

Fig. 13 The number of layer and reachable matrix

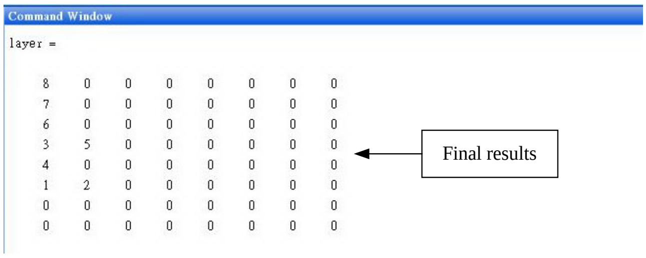

Fig. 14 The final results from ISM method

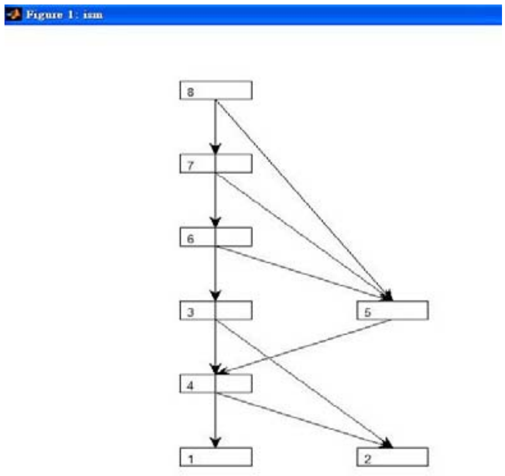

Fig. 15 The layer from ISM toolbox

IV. CONCLUSIONS

In the previous studies, there aren't many studies on resource recycling, and most of them are limited to in the theoretical analysis. There are also few integrated practical studies. The ISM method proposed in this paper not only integrates the resource recycling fields in the environmental engineering, but also presents the advantages of them. It can understand the weighting size of each factor to the system in resource recycling, and do the class analysis at the same time.

Especially, the results show that the top two are batteries and wires while the final two are paper and plastic bottles, which are also the same class. Besides, the results are in good agreement with previous study which used the method of grey entropy, which shows the similarity matrix created by the experts is correct, and the ISM method is rational.

There are two limitations of this paper. One is that we only use λ cut 0.6 and the other is that there is only one example of resource recycling analysis. In order to improve this shortcoming, we can increase the numbers of resource recycling plants and impact factors. Also, we can interview more experts. As a result, we can make the similarity matrix values more accurate. Next, we can adjust the numbers of λ cut to compare the results, and it is believed to reach better results.

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TABLE I THE RECYCLED NUMBERS IN KILOGRAMS OF THE NINE BUSINESS ITEMS FROM MARCH, 2010 TO JANUARY, 2011(KG)

	Paper	Poly bottles	Plastic	Iron	Aluminium	Copper	Electrical wiring	Battery
March	37756.3	3938.3	3954.1	87169.5	1657.7	1504.2	587.3	101
April	32363.8	2536.1	2839.8	467150.6	1364.4	897.8	90.2	796.1
May	20080.9	4316.4	2988.7	39349	984.2	472.8	148.6	172.8
June	35521.9	4183.5	2579.8	421099.2	669.2	181.3	74	101.2
July	44522.6	6001.3	3323.1	66146.1	910.5	566.3	129.3	100.6
August	48723.5	6609.9	3690.4	45129.9	793	194.4	175.3	67.4
September	54787.8	7649.4	3614.4	73189.2	1556.9	952.5	570	204.4
October	58745.6	6520.3	4756.4	76507.6	1323.2	1024.6	1299.0	410.9
November	57502.4	5401.5	6288.2	62643.0	923.0	475.4	1176.2	120.2
December	54743.1	6508	6046.1	104431.1	1243.7	261.1	325.6	455.2
January(2011)	63814.2	5941.6	4405.3	153219.1	2605.9	837.4	1126.1	1591.7

TABLE II THE AVERAGE PRICES FROM MARCH, 2011(KG/NT DOLLOR)

	Paper	Poly bottles	Plastic	Iron	Aluminium	Copper	Electrical wiring	Battery
March	5	10	3	10	25	160	35	12
April	5	10	3	11	28	180	35	8
May	3.5	10	3	8	25	160	30	10
June	3	10	3	8	24	165	20	8
July	3.5	10	3	9	24	190	25	10
August	4.3	10.5	3	10	24	200	25	10
September	3.7	12	4.7	11.7	31	160	34	14
October	4.8	10	4	10.13	31	200	46	20
November	4.8	10	5	11	31	154	42	13
December	5	11	3.2	12	31	166	27	18
January(2011)	4.6	11.4	4.2	12.5	38.4	191.5	33	22

TABLE III THE TOTAL PRICE OF THE ALL ITEMS(NT DOLLAR)

	Paper	Poly bottles	Plastic	Iron	Aluminium	Copper	Electrical wiring	Battery
March	188781.5	39383	11862.3	871695	41442.5	240672	20555.5	1212
April	161819	25361	8519.4	5138657	38203.2	161604	3157	6368.8
May	70283.15	43164	8966.1	314792	24605	75648	4458	1728
June	106565.7	41835	7739.4	3368794	16060.8	29914.5	1480	809.6
July	155829.1	60013	9969.3	595314.9	21852	107597	3232.5	1006
August	209511.1	69403.95	11071.2	451299	19032	38880	4382.5	674
September	202714.9	91792.8	16987.68	856313.6	48263.9	152400	19380	2861.6
October	281978.9	65203	19025.6	775022	41019.2	204920	59754	8218
November	276011.5	54015	31441	689073	28613	73211.6	49400.4	1562.6
December	273715.5	71588	19347.52	1253173	38554.7	43342.6	8791.2	8193.6
January(2011)	293545.3	67734.24	18502.26	1915239	100066.6	160362.1	37161.3	35017.4

TABLE IV SIMILARITY MATRIX R (R IS LOWER TRIANGLE MATRIX)

	Paper	Poly bottles	Plastic	Iron	Aluminium	Copper	Electrical wiring	Battery
Paper	1							
Poly bottles	0.5	1						
Plastic	0.7	0.7	1					
Iron	0.3	0.6	0.5	1				
Aluminium	0.5	0	0.5	0.9	1			
Copper	0.5	0	0.9	0.8	0.8	1		
Electrical wiring	0	0	0.9	0.7	0.8	1	1	
Battery	0	0	0.7	0.9	0.7	1	1	1

TABLE VI THE VALUES OF RELATIONAL MATRIX (λ =0.6)

	Paper	Poly bottles	Plastic	Iron	Aluminium	Copper	Electrical wiring	Battery
Paper	1							
Poly bottles	0	1						
Plastic	1	1	1					
Iron	0	1	0	1				
Aluminium	0	0	0	1	1			
Copper	0	0	1	1	1	1		
Electrical wiring	0	0	1	1	1	1	1	
Battery	0	0	1	1	1	1	1	1

TABLE VI THE RELATION OF REACHABLE SET

Element S_i	Reachable set $R(s)$	Antecedent set $Q(s)$	Intersection set $R(s)\cap Q(s)$
1	1	1,3,5,6,8	1
2	2	2,3,4,5,6,7,8	2
3	1,2,3	3,6,7,8	3
4	2,4	4,5,6,7,8	4
5	2, 4,5	5,6,7,8	5
6	1,2,3,4,5,6	6,7,8	6
7	1,2,3,4,5,6,7	7,8	7
8	1,2,3,4,5,6,7,8	8	8

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