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Combination of case-based reasoning and analytical hierarchy process for providing intelligent decision support for product recycling strategies

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ABSTRACT

Waste electric and electronic equipment (WEEE) may cause environmental problems during the waste management phase if it is not designed to be environment friendly. Many governments have made considerable efforts to frame policies to reduce the use of hazardous materials and improve a product's recyclability. In this research, recyclability parameters are introduced to represent a product component's recyclability and to aid a designer in evaluating the component's recyclability. The recyclability index is defined as a measure of the ability of a material to regain its valued properties when subjected to a special recycling process. A method is proposed to determine the recyclability of a material during the design phase. This research method combines case-based reasoning (CBR) and the analytical hierarchy process to simplify the calculation of the recyclability index for a product. Designers can extract experiences from past cases to (1) calculate the recyclability rate of a designed product, (2) determine the possibility of recycling end-of-life (EOL) products, and (3) finalise a recycling plan for EOL products when including a new product in a recycling and treatment system.

1. Introduction

Waste electric and electronic equipment (WEEE) that has not been designed to be environment friendly has the potential to cause environmental problems during the waste management phase. Many governments have taken steps not only to reduce the use of hazardous materials but also to improve a product's recyclability. For example, the EU has specified the recycling rate for waste electric and electronic products for manufacturers (CD, 1975, 2002). Many organizations, especially in Taiwan, are involved with the development of design for recycling methods to help designers perform recycling analysis for materials during the designing of the materials.

Shergold (1994) has indicated that in the automotive industry, the part of a discarded vehicle that can be recycled is only 75% by weight at present. The author has stated that only the parts that are in demand in the market are removed by a dismantler and that these generally include the engine, the gearbox, electronic components, and other mechanical parts. Wittenburg (1992) has proposed the concept of recycling path for components and materials, similar to that envisaged by BMW. Hegde and Karmarkar (1993) have obtained an economic structure for product support. They considered discounting issues and the non-linear cost structure of the product failure cost and established an altogether between design parameters and customer costs (Comparini & Cagan, 2003). Kuo (2006) has presented a graph-based heuristic method for the disassembly analysis of end-of-life products that involves the eco-design concept. In his research, life-cycle analysis (LCA) is used to analyze disassembly trees from which a disassembly sequence can be derived. Zhang, Yu, Jin, Ling, and Barnes (2000) has used an analytical hierarchy process (AHP) to determine the best recycling strategy. The AHP-based evaluation involves the consideration of the environmental impact, cost, and reclaimed materials as the major criteria for strategy determination. Lee, Lye, and Khoo (2001) tried to develop an alternative process that can maximize profits and minimize environmental impacts and examine the process in a coffee maker. Kuo, Chang, and Huang (2006) has also presented an innovative method, namely, green fuzzy design analysis (GFDA) that comprises simple and efficient procedures to evaluate product design alternatives based on environmental consideration; the method involves the use of fuzzy logic. A hierarchical structure for the environmentally conscious design indices was constructed using the AHP; for the construction, five aspects were considered: (1) energy, (2) recycling, (3) toxicity, (4) cost, and (5) material. Although numerous studies have been presented on improving products' recyclabilities, designers prefer to ignore the studies and to focus on developing new methods instead of risking the wastage of resources in attempting to confirm the effectiveness of the proposed methods. It is not easy to develop products that can easily be recycled since designing for recycling is complicated and involves multi-criteria decision making.

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Designers need to consider not only the product's recyclability, but also its cost, function, and quality. Ashby (1992) has shown how engineers study the interaction between function, material, shape, and process in order to identify materials best suited for a certain application. The materials are chosen according to the function the product will have, the processes that can be used to manufacture the product (i.e., casting, melting), the shape requirements (i.e., the degree of bending required), and the material properties the product must have (i.e., the maximum cost and desired strength). The following are the problems faced on the designing for recyclability (Gehin, Zwolinski, & Brissaud, 2008; Wu, Kuo, & Lu, 2007).

(1) Most companies, especially small- and medium-sized companies (SMEs), hesitate to implement environmentally friendly strategies because they cannot determine the economic risks accurately.
(2) The high-level managers in many SMEs are just beginning to emphasize environmental issues; however, they are short of human resources and budgets to address environmental concerns.
(3) Most of the designing environmentally friendly products' researches have been confined to a single type of products.
(4) The recommendations made by environmental design (e.g., guidelines) are seldom integrated with the design activity since the implementation of the recommendations involves additional processes and therefore increased cost.
(5) The last problem to be mentioned is also the most critical one. The major concerns of designers are linked to the complexity of the decision-making process during the design phase. Designers have to deal with multi-criteria decision making, and the environment is often considered as a new and complex variable.

From the above, we can understand the pressing need for an easy evaluation method that can help designers measure and evaluate a product's recyclability. Therefore, in this study, we introduce recyclability parameters to represent a product's recyclability and to assist a designer in determining the component's recyclability. The recyclability index denotes the ability of a material to regain specific properties upon undergoing a recycling process (Villabla, Segarra, Fernandez, Chimenos, & Espiell, 2002). The recyclability evaluation method proposed by Ashby (1992) is used to identify the appropriate material during the design phase. Further, a combination of case-based reasoning (CBR) and AHP is used for easily calculating the recyclability index for a product. The CBR method is used because it has the following two advantages. The first one is that a new problem can be solved by identifying a similar problem that was overcome in the past and using the same solution for the new problem. The second advantage is that CBR is an approach that is suitable for incremental, sustained learning since a new experience is acquired whenever a problem is solved, making it available for the future (Aamodt & Plaza, 1994). Designers can therefore use past experiences for (1) the calculation of the recyclability rate of a designed product, (2) evaluating the possibility of recycling EOL products, and (3) charting a recycling plan for EOL products whenever new products are added to the recycling and treatment system. In this study, we also present a case study to confirm the results.

2. Overview of CBR

CBR, one of the learning approaches for artificial intelligence (AI), has been drawing the attention of researchers in recent years. CBR was first proposed by Schank and Abelson (1977) during the late 1970s. It is a multi-disciplinary subject that creates and uses a database of old problems (cases, similarities, recycling indexing) to resolve new problems. In CBR, knowledge is represented in the form of experiences (or cases) (Kolodner, 1993). A case is a conceptualized piece of knowledge representing an experience. The essence of CBR is to identify past cases very similar to a new problem and extract experiences from them for solving the new problem. The use of CBR for solving a new problem involves (1) retrieving previous cases, (2) using the cases, (3) revising the solution of the cases based on their use, and (4) storing the new experience by incorporating it in the existing knowledge base. Aamodt and Plaza (1994) have described the hierarchy in a general CBR cycle as follows (Fig. 1).

(1) Retrieve the most similar case or cases.
(2) Use the information and knowledge in the case/cases to solve the new problem.
(3) Revise the proposed solution.

The CBR methodology has been employed in many industrial applications. For example, Schank (1983) developed a theory of learning and reminding on the basis of retaining experiences in a dynamic, evolving memory structure. Kwong, Smith, and Lau (1997) proposed a CBR system to determine injection molding parameters for producing a plastic part. Chiu, Chang, and Chiu (2003) developed a CBR system to predict the due dates of different orders for a wafer fabrication factory. Using a k-nearest-neighbour-based CBR approach with dynamic feature weights and non-linear similarity functions, they found that further performance improvement could be achieved. Veerakamolmal and Gupta (2002) developed a CBR approach for automating disassembly process planning. The approach involves procedures to initialize a case memory for different product platforms and to operate a CBR system; thus, the approach can be used to plan disassembly processes. Chang, Liu, and Lai (2008) developed a sales forecasting model by using fuzzy CBR for selecting past cases that are not similar to the current case, but that are useful to the current case. These authors investigated the use of fuzzy sets and multi-criteria decision making for accurate, efficient, and flexible case retrieval in CBR for solving sales forecasting problems in PCB industries. Yang and Wang (2009) presented a revised case-based reasoning (RCBR) algorithm to solve hierarchical criteria architecture (HCA) problems based on multiple objectives decision. Pandey and Mishra (2009) have developed an integrated model of CBR and combine rule-based reasoning (RBR) for generating cases, and ANN (artificial neural

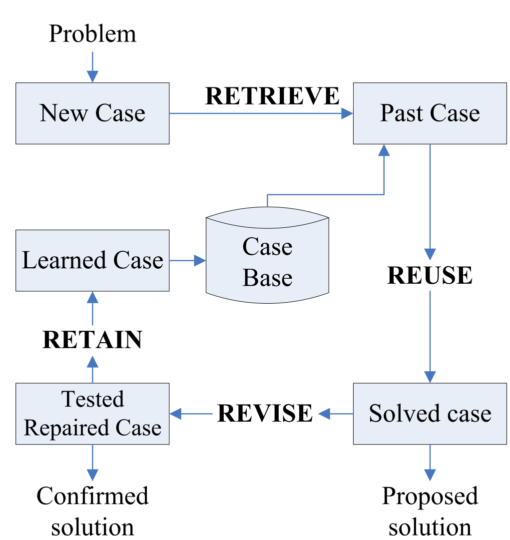

Fig. 1. CBR cycle Lee et al. (2001).

nets) for matching cases for the interpretation and diagnosis of neuromuscular diseases.

3. Framework of proposed CBR approach

The EU WEEE directive (CD, 2002) places the responsibility for end-of-life treatment of products on manufacturers. According to this directive, manufacturers must recycle 70% (in terms of the weight) of the product, operate collection programs, and use eco-design in their new products. The approach proposed in the present study facilitates recycling strategy selection during the design stages, as shown in Fig. 2. A designer can determine a product's recyclability in the early design stages by combining the methods of CBR and AHP.

3.1. Material recycling index

According to the EU WEEE directive passed on 27 January 2003, manufacturers have to ensure that their products are reusable, recyclable, or recoverable.

- Reuse is defined as 'any operation by which WEEE or components thereof are used for the same purpose for which they are conceived, including the continued use of the equipment or components thereof which are returned to collection points, distributors, recyclers or manufacturers'.
- Recycle is defined as 'the reprocessing in a production process of the waste materials for the original purpose or for other purposes, but excluding energy recovery which means the use of combustible waste as a means of generating energy through direct incineration with or without other waste but with recovery of the heat'.
- Recovery is defined as 'any of the applicable operations provided for in Annex IIB to Directive 75/442/EEC (CD, 1975)'.

A convenient method to calculate the recyclability of a product is to compare materials on the same scale. Normally, components or materials that are reused have a higher recycling index than those that are recycled (Villabla et al., 2002). Generally, a recycling index is calculated for and assigned to each material. The material recycling index is calculated by the expression

$$R_{m_j}^{cyc} = \frac{V_p}{V_m}, \tag{1}$$

where $R_{m_j}^{cyc}$ is the recycling index for material m_j; V_p, the cost after m_j is recycled, but before being treated or shaped for a specific use ($/kg); and V_m, the minimum cost of m_j ($/kg).

V_m is the minimum cost of the material before it is treated or shaped for a specific use (e.g., metals in ingots, polymers in the form of granules). Generally, the greater the difference between V_m and V_p, the more the material is devalued during use. The material recyclability indices of some materials are listed in Table 1. The recovery indices of the materials, denoted by R_m^{cov}, are also presented.

- If $V_p \cong V_m$, then the material has a recycling index of 1.
- If $V_p \ll V_m$, then the material has a recycling index lower than 1, and in most cases, the material is reused, used for energy recovery, or landfilled.
- If $V_p \gg V_m$, then the recycling process is not profitable at plant scale and tipping fees, further research, etc. are required.

3.2. Recyclability and recovery index calculation

After the material recycling index is determined, the next step is to determine the product's recyclability. Assume that a product P comprises n components. Thus, it can be represented as $P = \{C_1, C_2, \ldots, C_i\}$, $i = 1, 2, \ldots, n$. Among these components, some can be disassembled to be homogeneous material, while others are still in an assembly type. A material is defined as whose characteristics or properties are not a function of the position within the material. The recycling index for components that can be disassembled to be homogeneous material can be directly calculated. In contrast, the recycling indices of the assembly types can be calculated by using the CBR and AHP method. The bill of material (BOM) structure of a product is shown in Fig. 3. For any component i in a product, C_i, the structure also includes both the recycling rate $R_{C_i}^{cyc}$ and recovery rate $R_{C_i}^{cov}$. Therefore, for a product, P, both of its recycling rate, R_C^{cyc}, and recovery rate, R_C^{cov}, are the sum of its

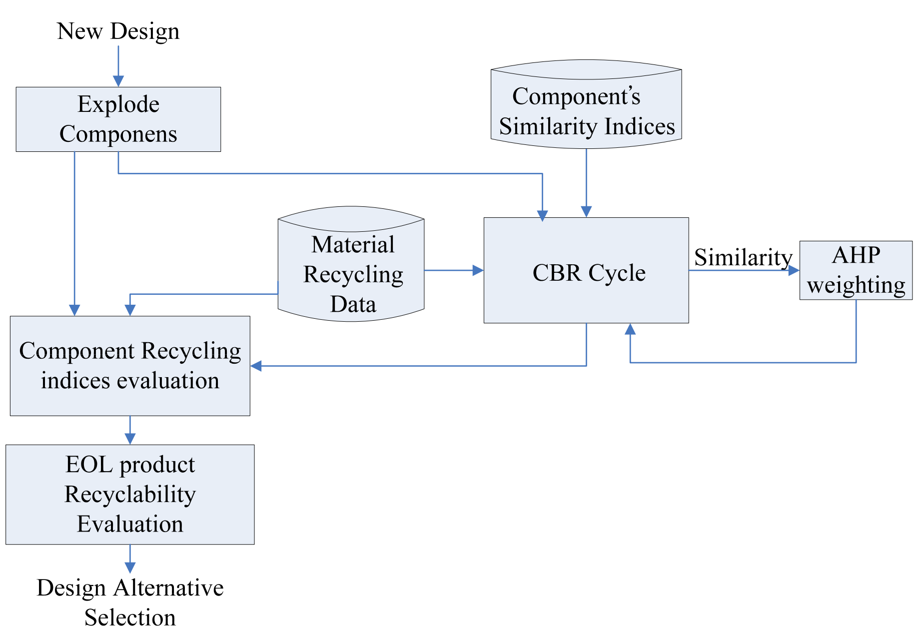

Fig. 2. Combination of CBR and AHP for a product recycling model.

Table 1
V_m and V_p for some metals and materials in units of \$/kg for December 1999 (Geological Survey 1997, 1998, 1999, 2000, US Geological Survey 1997, 2000, Analysis of National Solid Waste Recycling Programs 1999, American Metal Market 1999, Financial Times 2000).

Metal	Average V_m	V_p	R^{cyc}
Al	1.59	1.45	0.91
Cu	1.77	1.67	0.94
Zn	1.20	1.20	1.00
Au	9653.23	9653.23	1.00
Ag	166.55	166.55	1.00
Ni	7.84	7.84	1.00
Steel	0.29	0.29	1.00
PET[a]	1.68	1.15	0.68
Paper	0.90	0.14	0.16
Glass	0.38	0.304	0.80
HDPE[b]	1.10	0.93	0.85
Stainless steel	1.94	1.94	1.00

[a] Polyethylene terepthalate.
[b] High-density polyethylene.

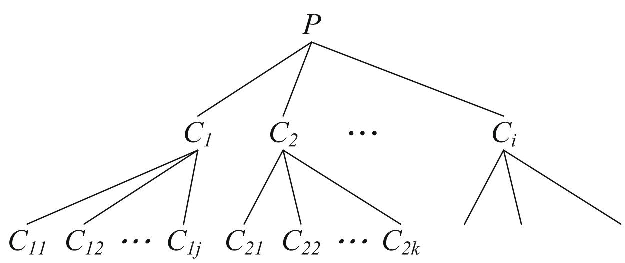

Fig. 3. Product BOM structure.

components' recycling rate and recovery rate based on its BOM structure. The relationships can be represented as follows.

$$R_C^{cyc} = \sum_{i=1}^{n} R_{C_i}^{cyc} = \sum_{i=1}^{n} R_{m_j}^{cyc} \times \frac{w_{C_i}}{D_{C_i}}, \tag{2}$$

$$R_C^{cov} = \sum_{i=1}^{n} R_{C_i}^{cov} = \sum_{i=1}^{n} R_{m_j}^{cov} \times \frac{w_{C_i}}{D_{C_i}}. \tag{3}$$

Here, w_{c_i} is the weight for component i and D_{c_i} is the disassembly time for component i.

3.3. Component similarity indices

In order to simplify the calculation of the recycling rate of a component, a CBR method is used. By using CBR, a designer can adopt data related to a case library from its historical data. Generally, there will be a lot of historical data in an enterprise. In order to perform the CBR, the similarity of different components should be analyzed to identify similar components first. The CBR cycle can be described as follows.

Step 1: Determine the similarity of components
Assume that the total similarity of a component C_i is represented as D_{C_i}, where $i = 1,2,\ldots,n$. According to Shih, Chang, and Lin (2006), D_{C_i} should be rescaled by normalization before being substituted

$$D_{C_i} = \text{Total similarity} = \frac{\sum_{j=1}^{n} w_j \times sim\left(f_j^I, f_j^R\right)}{\sum_{j=1}^{n} w_j}, \tag{4}$$

where $sim\left(f_j^I, f_j^R\right) = 1 - \left|\frac{f_j^I - f_j^R}{Range_j}\right|$. Here, j denotes the jth index; w_j, the weight of the jth index ($0 < w_j < 1$ and $\sum_{j=1}^{n} w_j = 1$); and n, the number of indices. *sim* is a function indicating the similarity between the indices of the new and old cases and corresponds to the interval $(0,1)$. Further, f_j^I is the value of the jth index of the new case; f_j^R, the value of the jth index of the retrieved case; and $Range_j$, the range of $\{f_j\}$.
Step 2: Determine the weighting factor
From the above discussion, it is clear that every component has more than one similarity index. The similarity results vary with the weight. Therefore, to determine the similarity of a component in *CBR*, the analytical hierarchy process (AHP) method is used. The AHP method developed by Satty (1980a) has been proved to be efficient. It considers various facets of the decision problem using a single optimization function known as the objective function. In the AHP method, a decision process is modelled as a hierarchy. This is illustrated in Fig. 4. At each level in the hierarchy, the decision maker is required to carry out a pair-wise comparison between decision alternatives and between criteria by using a ratio scale. The AHP method allows the decision maker to focus on the comparison of just two alternatives, which helps reduce extraneous influences on the observation. The crux of AHP is the determination of relative weights for similarity indices.
The AHP is a fundamental method that has been described in many research studies (Satty, 1980b). Therefore, here, we provide only a summary of the steps in the AHP. The steps are as follows:

- Establish the hierarchy structure.
- Construct a pair-wise comparison matrix.
- Calculate the priority vector.
- Calculate the maximum eigenvalue.
- Examine the consistency.
- Arrange the evaluation criteria and their weights in an appropriate order.

4. Case study and analysis

We performed a case study by considering a router; the BOM structure of the router is shown in Fig. 5. The router contains three components: an upper cover (C_1), a bottom cover (C_2), and printed circuit board assembly (PCBA) (C_3). C_2 is obtained by assembling three components—C_{21} (a front cover), C_{22} (a main body), and C_{23} (a decoration board).

The next step is to calculate the recycling rate for a candidate product. The component names, constituent materials, and weights are listed in Table 2. Since most of the components, C_1, C_{21}, C_{22}, C_{23}, are homogenous material,, except for the C_3, we can directly calculate their recycling rates based on Table 1. The similarity data for the subassembly PCBA in the router is listed in Table 3. The reference value for each similarity are assumed based on value of the historical data. The references for different components should be different. The recommended range values listed in Table 3 are only for this case study.

4.1. Determining the similarity for PCBA

The next step is to determine the PCBA's recyclability index by using the CBR method. In this case, more than seven hundred cases

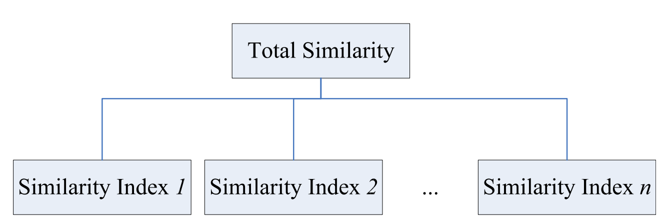

Fig. 4. Hierarchy for the determination of the weighting factor for the similarity indices.

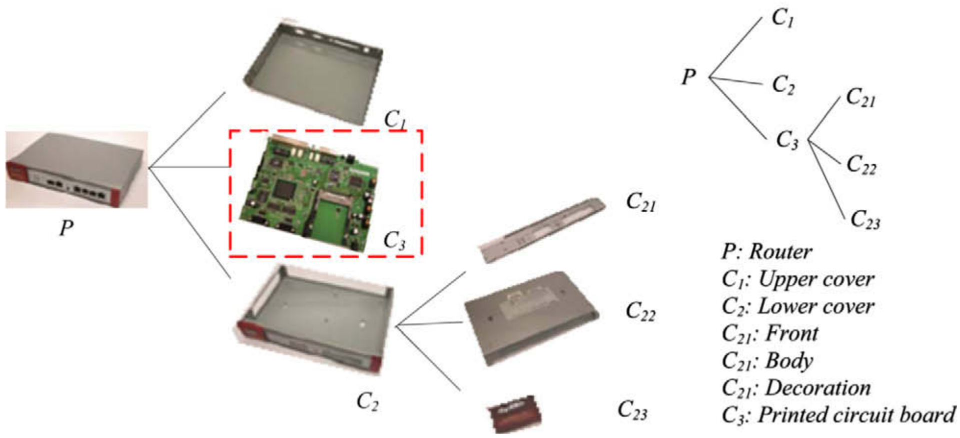

Fig. 5. BOM structure of a router.

Table 2
Component data for the router.

No	Component name	Material	Disassembly time (s)	Weight (g)
Router				
C_1	Upper cover	Steel	30	446.2
C_2	Lower cover	–	–	–
C_{21}	Front	Steel	15	48.2
C_{22}	Body	Steel	10	406.4
C_{23}	Decoration board	Aluminium	5	27.2
C_3	PCBA	Assembled	20	193

Table 3
PCBA data and range values.

	$S_{C_3^1}$ (cm^2)	$S_{C_3^2}$	$S_{C_3^3}$	$S_{C_3^4}$
Unknown PCBA	23688	193	4	11.00156
Reference value	150000	1500	10	100

relating to PCBAs, obtained from historical data, are analyzed and categorized into ten case libraries, which form a case database. The constituent materials of each type of PCBA are listed in Table 4.

From the analysis of the archived data, four similarity indices are selected: area ($S_{C_3^1}$), weight ($S_{C_3^2}$), number of layers ($S_{C_3^3}$), and weight percentage of the electronic capacitor ($S_{C_3^4}$). The recycling rates of the ten PCBAs are calculated using the material recyclability indices. Table 5 presents the PCBA case library.

4.2. Determining the weighting factor between similarities for the PCBA

By using the pair-wise comparison matrix as specified in the AHP theory, we calculate the weights for the similarity indices. Table 6 lists the weights. The AHP method provides weights for each similarity index. Therefore, the relative weights are determined on the basis of the information in Table 6 by using the AHP method. The relative weighting factors for each similarity index are as follows: $S_{C_3^1} = 0.398,\ S_{C_3^2} = 0.085,\ S_{C_3^3} = 0.218$, and $S_{C_3^4} = 0.299$.

4.3. Similarity calculation

In CBR, it is necessary to calculate the similarity between the new case and old cases. Subsequently, the recyclability can be calculated. We can obtain the component's rank from the similarity. From Table 7, it can be observed that for the PCBA in the router, there are three cases—*case 6, case 1, and case 3*—that involve PCBAs very similar to it. By considering these three cases, a designer can evaluate the detailed material composition and finalise its appropriate recycling rate.

Since the recyclability of the PCBA has been calculated, the recycling rate for the router can be calculated. After the calculation, it can be observed that the recycling rate and recovery rate for the designed product are around 95% and around 5%, respectively

$$R_C^{cyc} = \sum_{i=1}^{n} R_{C_i}^{cyc} = \sum_{i=1}^{n} R_{m_j}^{cyc} \times \frac{w_{C_i}}{D_{C_i}} \cong 95\%, \tag{5}$$

$$R_C^{cov} = \sum_{i=1}^{n} R_{C_i}^{cov} = \sum_{i=1}^{n} R_{m_j}^{cov} \times \frac{w_{C_i}}{D_{C_i}} \cong 5\%. \tag{6}$$

Table 4
Composition of the 10 PCBAs.

Class	Constituent material	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10
		Constituent material (wt%)									
Plastics	Plastic mixture	24.357	10.666	13.162	13.974	6.605	13.067	8.165	5.391	9.616	5.069
Metals	Cu	1.21	0	0	0.466	14.9	6.56	2.493	1.617	4.323	1.586
	Aluminium	0	0	0	0	0	0	9.455	9.738	16.836	0
	Iron	4.69	16.944	13.971	15.423	38.512	1.867	16.584	8.156	17.372	10.861
Others	IC	2.575	5.295	6.25	4.022	0	7.147	3.432	4.487	4.163	6.514
	Glass	0.303	0	0	0	0	0	0.978	0.115	0.125	0.17
	Electronic capacitor	10.136	1.891	4.044	1.865	3.752	10.347	1.652	3.992	2.247	5.862
	Epoxy + components	52.496	63.389	61.691	63.015	35.374	53.067	51.491	61.952	43.447	68.536
	Rubber	0	0	0	0	0	0	3.188	3.544	0	0
	Waste	4.236	1.815	0.882	1.282	0.856	7.947	2.562	0.998	1.871	1.402

Table 5
Case-based library for the PCBA.

Case library	$S_{C_3^1}$ (cm^2)	$S_{C_3^2}$	$S_{C_3^3}$	$S_{C_3^4}$	Recycling rate (%)
1	9020	66.3	4	10.14%	75.23
2	18,650	132.5	6	1.89%	85.50
3	18,650	136.1	6	4.04%	84.30
4	44,200	257.9	4	1.87%	85.81
5	45,120	455.7	4	3	92.46
6	25,810	188	4	10.35%	72.28
7	84,270	1023	8	1.65%	85.33
8	84,270	872.1	8	3.99%	83.15
9	82,240	876.8	8	1.93%	88.30
10	103,400	706.3	8	5.86%	82.78

Table 6
Pair-wise comparison of similarity indices.

	$S_{C_3^1}$ (cm^2)	$S_{C_3^2}$	$S_{C_3^3}$ (layers)	$S_{C_3^4}$ (%)
$S_{C_3^1}$ (cm^2)	1	3	2	2
$S_{C_3^2}$	1/3	1	1/4	1/4
$S_{C_3^3}$ (layers)	1/2	1	1	1/2
$S_{C_3^4}$ (%)	1/2	4	2	1

Table 7
Rank for similar components.

Case library	$S_{C_3^1}$ (cm^2)	$S_{C_3^2}$	$S_{C_3^3}$	$S_{C_3^4}$	Similarity	Rank
1	0.9022133	0.915533	1	0.9913444	0.9513	***2***
2	0.9664133	0.959667	0.8	0.9088944	0.9124	
3	0.9664133	0.962067	0.8	0.9304244	0.9190	***3***
4	0.8632533	0.956733	1	0.9086344	0.9146	
5	0.85712	0.824867	0.6	0.8899844	0.8082	
6	0.9858533	0.996667	1	0.9934544	0.9921	***1***
7	0.59612	0.446667	0.6	0.9065044	0.6771	
8	0.59612	0.547267	0.6	0.9299044	0.6926	
9	0.6096533	0.544133	0.6	0.9092644	0.6916	
10	0.4685867	0.6578	0.6	0.9486044	0.6568	

5. Summary and conclusions

Design for recycling has been a critical issue for enterprises and it is difficult to implement. The reason is that most of the designers are not willing to evaluate the product's recycling rate since the design time is very short. Also, it is not easy to collect and calculate the recycling rate if the data is not well defined. The method proposed in this paper has been adopted, revised, and implemented in some companies in Taiwan. This method has many advantages since it combines CBR and AHP methods. First, by using the CBR method, a designer can predict the recycling rate for the design product for the period close to the end of its life. The method helps save resources. Second, the critical components that cannot be easily recycled can easily be identified in the early design stages. Since the components's recyclabilities are known, the designer can adjust or change his design early in the design process. Third, the designer can identify materials that should be replaced for realising environmentally friendly products. Although the use of the proposed method has been demonstrated only for a router, it could be applied to other similar electric and electronic equipment. However, the weighting factors could be more moderate in the future research.

Acknowledgement

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References

Aamodt, A., & Plaza, E. (1994). Case-based reasoning: Foundational issues, methodological variations, and system approaches. *AI Communications, 7*(1), 39–59.
Ashby, M. F. (1992). *Materials selection in mechanical design*. Oxford: Pergamon Press.
CD, Council Directive 75/442/EEC of 15 July 1975 on waste, M3 Commission Decision 96/350/EC of 24 May 1996 L135 32.
CD, Council Directive 2002/96/EC of 27 January 2003 on waste electrical and electronic equipment, Official Journal, L037, 27–39.
Chang, P. C., Liu, C. H., & Lai, R. K. (2008). A fuzzy case-based reasoning model for sales forecasting in print circuit board industries. *Expert Systems with Applications, 34*(3), 2049–2058.
Chiu, C., Chang, P. C., & Chiu, N. H. (2003). A case-base expert support system for due-date assignment in a wafer fabrication factor. *Journal of Intelligent Manufacturing, 14*(3), 287–296.
Comparini, E., & Cagan, J. (2003). *Environment across the curriculum and educational modules: Reverse engineering for green design of products; Green Design Initiative*. Pittsburgh, PA: Carnegie Mellon University.
Gehin, A., Zwolinski, P., & Brissaud, D. (2008). A tool to implement sustainable end-of-life strategies in the product design phase. *Journal of Cleaner Production, 16*, 566–576.
Hegde, G. G., & Karmarkar, U. S. (1993). Engineering costs and customer costs in designing product support. *Naval Research Logistics, 40*, 415–423.
Kolodner, F. L. (1993). *Case-based reasoning*. San Francisco: Morgan Kaufmann Publisher.
Kuo, T. C. (2006). Enhancing disassembly and recycling planning using life-cycle analysis. *Robotics and Computer-Integrated Manufacturing, 22*, 420–428.
Kuo, T. C., Chang, S. H., & Huang, S. H. (2006). Environmentally conscious design using fuzzy multi-attribute decision-making. *International Journal of Advanced Manufacturing Technology, 29*, 209–215.
Kwong, C. K., Smith, G. F., & Lau, W. S. (1997). Application of case based reasoning in injection moulding. *Journal of Materials Processing Technology, 63*(1), 463–467.
Lee, S. G., Lye, S. W., & Khoo, M. K. (2001). A multi-objective methodology for evaluating product end-of-life options and disassembly. *The International Journal of Advanced Manufacturing Technology, 18*, 148–156.
Pandey, B., & Mishra, R. B. (2009). An integrated intelligent computing model for the interpretation of EMG based neuromuscular diseases. *Expert Systems with Applications, 36*, 9201–9213.
Satty, T. L. (1980a). *The analytical hierarchy process*. New York: McGraw-Hill.
Satty, T. L. (1980b). *The analytical hierarchy process: Planning, priority setting, resource allocation*. TX: McGraw-Hill.
Schank, R. C. (1983). *Dynamic memory: A theory of reminding and learning in computers and people*. Cambridge University Press.
Schank, R. C., & Abelson, R. P. (1977). *Scripts, plans, goals and understanding*. Hillsdale, NJ: Lawrence Erlbaum.
Shergold, M. (1994). Automotive material recycling for the future. *Proceedings of Institution of Mechanical Engineering, 208*(2), 75–82.
Shih, L.-H., Chang, Y.-S., & Lin, Y.-T. (2006). Intelligent evaluation approach for electronic product recycling via case-based reasoning. *Advanced Engineering Informatics, 20*, 137–145.
Veerakamolmal, P., & Gupta, S. M. (2002). A case-based reasoning approach for automating disassembly process planning. *Journal of Intelligent Manufacturing, 13*(1), 47–60.
Villabla, G., Segarra, M., Fernandez, A. I., Chimenos, J. M., & Espiell, F. (2002). A proposal for quantifying the recyclability of materials. *Resources, Conservation and Recycling, 37*, 39–53.
Wittenburg, G. (1992). Life after death for consumer product: Design for disassembly. *Assembly Automation, 12*(12), 21–25.
Wu, C. H., Kuo, T.-C., & Lu, Louis Y. Y. (2007). Environmental principles applicable to green supplier evaluation by using multi-objective decision analysis. *International Journal of Production Research, 45*(18–19), 4317–4331.
Yang, H.-L., & Wang, C.-S. (2009). Recommender system for software project planning one application of revised CBR algorithm. *Expert Systems with Applications, 36*, 8938–8945.
Zhang, H. C., Yu, Y., Jin, K., Ling, F. F., & Barnes, D. (2000). A decision-making model for materials management of end-of-life electronic products. *Journal of Manufacturing System, 19*(2), 94–107.