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Feedback-Based Eco-Design for Integrating the Recency, Frequency, and Monetary Value of Eco-Efficiency into Sustainability Management

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Abstract: Customer feedback is used to understand customer requirements. Early design phases require the consideration of items including manufacturing, the environment, and sustainability management. Therefore, it is crucial that eco-efficiency is taken into account in the early design phases. Traditionally, eco-efficiency is considered only in terms of eco-design issues, not customer requirements based on business values such as Recency, Frequency, and Monetary (RFM) value. In the meantime, integrating innovation from eco-design is one important aspect. Here, I propose that customer feedback-based eco-efficiency and TRIZ-based innovation can be considered in early eco-design based on the RFM value for sustainability management. The analytic hierarchy process (AHP) and fuzzy-based AHP were integrated to explore the relative weights of RFM variables for business value evaluation. The innovative method of the paper is using a TRIZ contradiction matrix associated with engineering parameters for eco-design. The experimental study has been carried out, and it meets the forecasting business value for green product usage. The business value was used as the decision-making factor in order to evaluate both environmental and marketing performance.

Keywords: sustainability; eco-efficiency; TRIZ; QFD; eco-design

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1. Introduction

In recent years, with the rapid development of technology, new electronic products have been promoted to lead to a high level of consumer convenience and entertainment. However, the serious damage to the environment and resource waste during the process of production should never be neglected. The waste caused by profligate energy and resource consumption seriously damages the environment and results in problems such as the greenhouse effect [1,2], etc. Since past studies tended to focus on product design and manufacturing's effects in relation to environmental laws, instead of the influence of green products on the 3Rs (Reduce, Reuse, and Recycle) [3,4] and customer feedback, it is difficult to know the reasons for products' negative effects and improve them. Customer feedback is used to understand customer requirements. Early design phases require the consideration of items including manufacturing, the environment, and sustainability management [5]. The environmental aspects of a product have to be considered in order to explore eco-products with other business values. Therefore, it is crucial that eco-efficiency is taken into account along with business value in the early design phases.

Some studies apply a number of assessment methods in order to evaluate environmental impact. Although many aspects of environmental impact used in production [6] have already been investigated, the indicator of environmental impact is still rare. Bovea and Belies [7] discussed eco-design tools to evaluate environmental impact in the product design process. A systematic method was used to explore a quantitative analysis of life cycle assessment (LCA) [8]. In accordance with eco-efficiency principles, engineering solutions have implemented both waste management and green product development through LCA [9]. The previous studies proposed a business process reengineering method that could enhance the use of the LCA approach in early design phases [10]. Using an LCA and cost analysis, they aimed to determine the lowest environmental impact [11]. Previous research has shown that multi-criteria decision analysis is an effective method of waste management decision-making [12].

In our analysis of the literature on green product development, we distinguish three issues: (i) customer feedback problems; (ii) product innovations; and (iii) eco-efficiency.

According to customer feedback, environmental impact is a major problem that must be taken into account by R&D [13]. Roome [14] built environmental consideration into an R&D strategy. Customer feedback is used to understand customer requirements. The research on reverse logistics and a closed-loop supply chain taking into account customer feedback is growing rapidly.

Product innovators are people who bring something new to product design. Typical new product development generally involves stages such as planning, concept design, detail development, prototype, production, market launch, and product review. The innovation and environmental impact of a new product are emphasized. This accelerates eco-innovation by integrating case-based reasoning and the TRIZ method [15]. In general, eco-innovations focus on reducing the environmental impact due to production and consumption process. The definition of eco-innovation is identified by European Commission [16]. A design engineer trying to solve a customer complaint usually faces conflict and systematic incompatibility. Traditionally, the design engineer compromises to address customer complaints. Park and Kim [17], Trappey et al. [18] and Kim et al. [19] have proposed analyzing both customer requirements and product design. The eco-design engineers avoid recurring problems and research new strategies for eco-efficiency in related fields.

Some of the literature reviews discussing environmental strategy selection are by Krikke et al. [20], Linton [21], and Wu [22]. Sousa and Wallace [23] developed an automated classification system to guide a systematic identification of life cycle assessment, based upon environmental categories for different groups of products. Few literature reviews mention that green products must meet 3R value. The 3R value of green product innovation is very crucial because of the eco-design. Past studies develop mathematical models to maximize profit, and the market segmentation strategy is very important [24]. Waste management decision-making is explored with a weighted sum model to evaluate the trade-offs [25]. This previous study attempted to explore a quantitative evaluating model of construction waste management using a system dynamics method [26]. The objective of this paper is to recover as much business value as possible, and to reduce the overall quantities of waste produced using eco-efficiency measures such as the 3Rs. This proposed approach was used to evaluate the Recency, Frequency, and Monetary (RFM) value of sustainability management in early eco-design.

In the abovementioned situation, there is a need to develop innovative green product procedures based on 3R value. TRIZ was identified in the former Soviet Union by Alltshuller [27]. The problem-solving process is based on the TRIZ contradiction matrix. Silverira [28] used the design trade-offs in the conflicting performance conditions for manufacturing fields. Fresner et al. [29] used TRIZ in cleaner production to minimize industrial waste. However, customers may experience observation uncertainty and fuzzy uncertainty. Fuzzy sets were introduced by Zadeh [30]. Fuzzy uncertainty is the main focus of this paper.

Electronic waste (e-waste) is an emerging pollution problem [31–33]. A previous paper proposed several tools in e-waste management [34]. These tools represent a systematic approach to improving the environmental performance of products [35,36]. In this article, a case study was used to discuss the proposed method. It concerns an electronic product such as a notebook computer.

2. Material and Methods

2.1. RFM

Hughes [37] used an RFM scoring method to cluster five customer groups. Stone [38] presented the relative weights method using RFM variables. The RFM was defined by Bult and Wansbeek in marketing research [39]. Based on the RFM value, marketing performance can be clustered into different groups. Chang and Tsai [40] proposed a new framework called GRFM (group RFM) to evaluate the calculation of the RFM value's significance. Variants of RFM-based predictive models are constructed in the context of customer segmentation for customer response models [41]. Cheng and Sun [42] proposed a strategy framework to provide different usage analysis using the RFM model. Some previous studies have extended the original RFM model by considering response techniques [43]. Some previous studies used the sequential pattern mining procedure including the RFM analysis [44].

2.2. Fuzzy Membership Function

In fuzzy set theory, a fuzzy subset of the universe of discourse U is described by a membership function $U_A(u)$: U: [0, 1], which represents the degree to which $A \in U$ belongs to the set A in Figure 1. A fuzzy term such as U is a linguistic value.

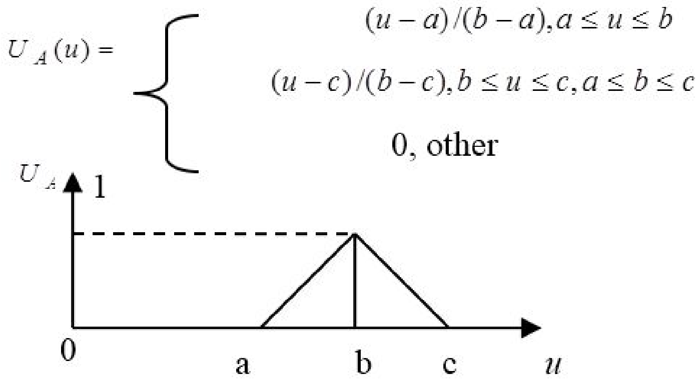

Figure 1. Fuzzy membership functions.

2.3. Eco-Efficiency

Eco-efficiency has been proposed as an approach to attaining sustainable development [45]. It is more like a management method than an indicator of environmental impact efficiency. One of the definitions is given by Equation (1):

$$\text{Eco} - \text{efficiency} = \text{product or service value}/\text{environmental impact}. \tag{1}$$

Eco-efficiency can be used as an evaluated indicator in eco-design [46]. Eco-design includes green design, design for X (where X might be low environmental impact), and green product design. The WBCSD (World Business Council for Sustainable Development) has classified seven major eco-efficiency elements: A–G. Liu and Chen [47] proposed the relationship between 39 engineering parameters and eco-efficiency.

A Material reduction (Reduce the material intensity of goods and service, units of material per unit of economic value).
B Energy reduction (Reduce the energy intensity of goods and services, units of energy per unit of economic value).
C Toxicity reduction (Reduce toxic dispersion, units of toxicity per unit of goods).
D Material recyclables (Enhance material recyclability, units of re-usage per unit of material).
E Resource sustainable (Maximize sustainable use of renewable resources, units of re-usage per unit of renewable material).
F Product durability (Extend product durability, usage lifetime per unit of product and services).
G Product service (Increase the service intensity of goods and services, units of service function per unit of product and services).

2.4. TRIZ

The Orloff [48] and Moehrle [49] proposed TRIZ method into the process industry with the contradictions matrix and 40 inventive principles [50,51]. The contradictions matrix is partly shown in Figure 2 [52].

Improving Engineering Parameter \ Worsening Engineering Parameter		Speed	Face	Tension Pressure	Shape
		9	10	11	12
....					
9	Speed		13,28,15,19	06,18,38,40	35,15,18,34
10	Force	13,28,15,12		18,21,11	10,35,40,34
11	Tension Pressure	06,35,36	06,35,21		35,04,15,10
12	Shape	35,10,37,40	35,10,37,40	34,15,10,14	
…					

Figure 2. TRIZ matrixes [52].

2.5. AHP

The analytic hierarchy process (AHP) method is a hierarchy decision-making method to solve complex problems with alternative evaluation by Saaty [53]. The AHP explore the pair-wise comparison matrix [54]. However, the weights for performance indices are not judged the same by different experts. Thus, the fuzzy number is suggested for AHP analysis, and is called fuzzy AHP [55,56]. Based on Saaty's experience, AHP can be used in the problem types as follows: Setting Priorities, , the Best Policy Alternatives, Determining Requirements, Predicting Results—Risk Assessment, and Conflict Resolution.

2.6. MIR

The Maturity Index on Reliability (MIR) is explored to discover the response of a business process to take action if the right information on process output is available [57]. The Maturity Index on Reliability consists of five levels and is shown in Figure 3.

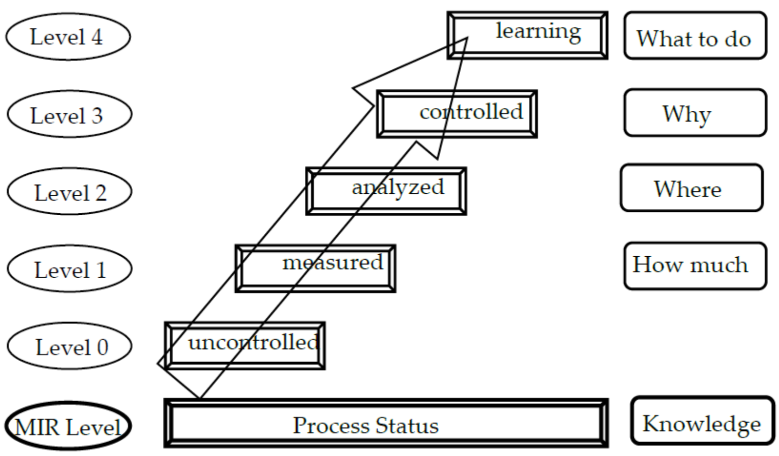

Figure 3. The MIR process.

3. Eco-Innovation Design Procedure

The proposed eco-innovation design approach is shown in Figure 4, which consists of three phases: customer feedback with product problem & purchasing, TRIZ-based QFD (quality function development), and RFM-based eco-efficiency phases.

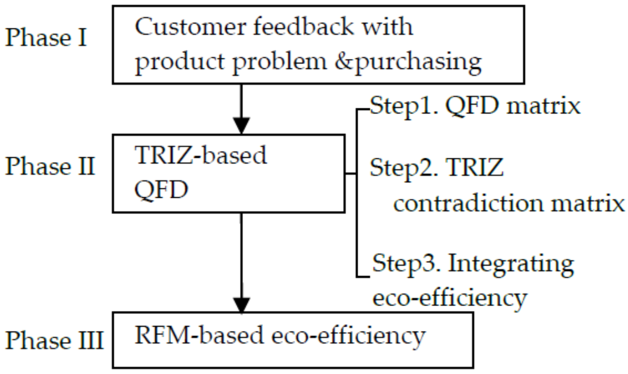

Figure 4. The proposed eco-innovation design procedure.

3.1. Phase I

The customer feedback product problem & purchasing phase is to understand green product problems for user. The so-called maturity index on reliability (MIR) feedback model was explored in order to see whether the right information meets the right activity at the right moment in time. The MIR scale uses four levels to assess the quality of information in identified loops. We use the MIR model in this eco-efficiency and business value for environmental impact. On this four-level scale the MIR level is described as follows:

MIR level 1: How well has eco-efficiency been integrated into the business plan?
MIR level 2: The relevant eco-efficiency, with the ability to infer the business value, can be identified.
MIR level 3: The inference root effect of the business values can be determined by the eco-efficiency.
MIR level 4: Adequate measures to analyze the business value can be identified.

The feedback-based model on MIR is given in Figure 5. Eco-efficiency can be used to quantify the business value.

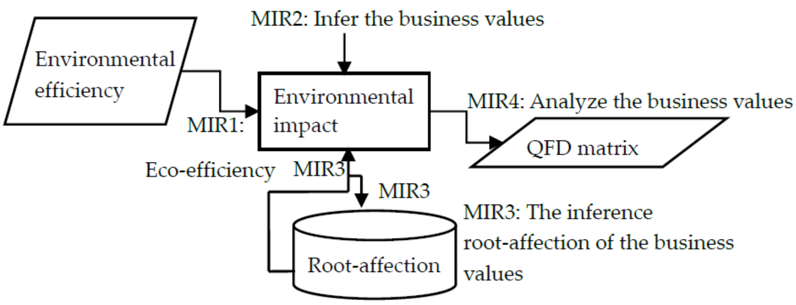

Figure 5. The feedback-based model of MIR.

The problem elements from customer feedback are described as follows. A problem is described as a collection of symptoms as to the cause of the problem. The value of symptoms shows in the high (H), medium (M), or low (L).

Further, this phase intends to explore the influences of customer purchasing on the 3Rs (Reduce, Reuse, and Recycle). Through customer feedback, a MIR (Maturity Index on Reliability) model is constructed to generalize the factors influencing customers' purchases. The research analyzes the influences of customer purchasing on the 3Rs (Reduce, Reuse, Recycle) through an AHP questionnaire.

3.2. Phase II

The TRIZ-based QFD (quality function development) phase is to establish an eco-innovation design, which is utilized for converting customers' eco-efficiency into an eco-innovative product function. Here, a conflict with the VOE (Voice of Engineering) item requires appropriate problem-solving to find an innovative solution. The innovative solution comes from the TRIZ matrix using conflict cross-parameters. The relationship of cross-parameters is to be expressed using fuzzy representation. This phase consists of the following sub-steps.

Step 1: An eco-design engineer constructs a QFD matrix from customer feedback with environmental perspectives and the eco-design specifications of a green product. In this step, the VOE items are utilized to describe the environmental aspects. In this way, QFD is an effective tool for product specification to customer requirements in the early product design phase. The QFD consists of customer characteristics items such as VOC (Voice of Customer) items and quality characteristics items such as VOE items, and the top matrix with the relationships between VOE items. The VOC items are divided into three categories according to the 3Rs in Figure 6. At this time, the degrees of importance of the relationships between VOC and VOE are determined on the green product needs and environmental impact.

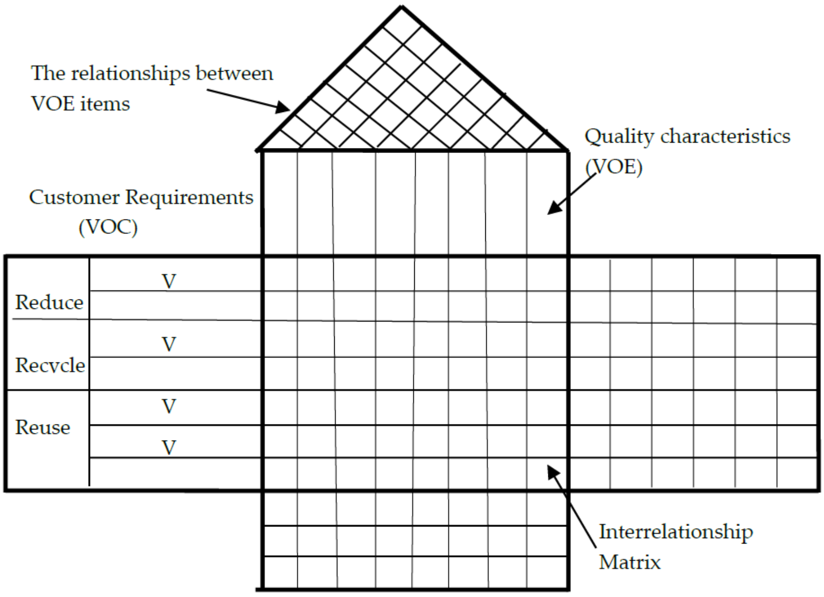

Figure 6. QFD matrix.

Step 2: Analyze the VOE items for conflicting features among them using a TRIZ contradiction matrix. It determines what features are necessary to reduce the environmental impact. Consequently, it determines what features enhance eco-efficiency. The TRIZ matrix is named the prioritized fuzzy relative matrix, expressed as a fuzzy set value.

The matrix is used to determine the "improving engineering parameters", the "worsening engineering parameters", and the "inventive principles" in Figure 2. When a new product is developed, the designers may face conflicts related to the function of the product. At that moment, the designers can verify which function conflict they are faced with and identify the critical point of the problem. Following the 39 items of TRIZ engineering parameters, the designers can determine the parameters they want to improve and the relative parameters that will worsen. After looking up the TRIZ contradictory matrix, designers can obtain possible inventive principles. With further analysis, the designers can then quickly identify the root cause of the problem and the best solution.

Step 3: Integrating eco-efficiency elements into QFD with a TRIZ matrix. From the environmental impact, this performance can be divided into three improvements such as recycling, reuse, and reduction. Recycling includes eco-efficiency element D. Reuse includes eco-efficiency elements E, F, and G. Reduction includes eco-efficiency elements A, B, and C. Therefore, all elements of improving eco-efficiency are integrated with the variables of the 3Rs.

One of the objectives of this study is to determine the correlation between TRIZ 10 engineering parameters and eco-efficiency elements in Table 1. However, it did not identify the priority of each parameter. In this paper, the priority is identified by the method of fuzzy membership function. It means that different priorities—H (High), M (Middle), and L (Low)—will be applied into the mentioned correlation.

Table 1. Correlation of eco-efficiency elements and engineering parameters.

TRIZ Engineering Parameters	**Eco-Efficiency Elements**						
	A	**B**	**C**	**D**	**E**	**F**	**G**
#1–39							

3.3. Phase III

The RFM-based QFD 10phase is to establish eco-efficiency based on RFM value in order to quantify the so-called business value. Their RFM values are defined as follows: R measures how long they have been using the green product; F measures how frequently they use the green product; M measures how much money they spent.

The RFM values were normalized as follows:

$$R' = (R - R^S)/(R^L - R^S) \tag{2}$$

where R' and R represent the 1normalized and original recency values; R^L represents the largest value of all numbers; and R^S represents the smallest value of all numbers.

The RFM values of each cluster were normalized, and denoted as R', F', and M'. Let W_I, inferred by the implications, be the integration of the cluster. They are computed as the weighted sum of R', F', and M' as follows:

$$W_I = W_R R' + W_F F' + W_M M' \tag{3}$$

where W_R, W_F, and W_M are the relative importance of the RFM variables.

We use an AHP or fuzzy AHP in the relative importance of the RFM variables. The AHP method was used to determine the relative importance of the RFM variables, R', F' and M'. Data were gathered by interviewing the evaluators from customer feedback for VOC items of the 3R categories using a questionnaire with a scale of importance such as 1 (Equally), 3 (Weak), 5 (Strong), and 7 (Extreme).

When using AHP analysis for evaluation, it is easy to find the weight of each performance index subjectively. However, the weights for performance indices are not the same from different experts. Thus, the fuzzy number is suggested for AHP analysis, and is called fuzzy AHP. Data were gathered by interviewing the evaluators from customer feedback for VOC items of the 3R categories using a questionnaire with triangular fuzzy number scale importance such as (0.5, 1, 2.5) (Equally), (1.5, 3, 4.5) (Weak), (3.5, 5, 6.5) (Strong), and (5.5, 7, 8.5) (Extreme). These data are expressed in the form of a pair-wise comparison matrix such as R:F = 2.3, R:M = 3.9, and F:M = 1.7 according to best fit for consistency. According to the evaluation, the relative weights of the RFM variables are 0.591, 0.257, and 0.151, respectively.

4. Case Study

A case study was used to discuss the proposed approach. It concerns a notebook computer retailing company.

4.1. Phase I: Customer Feedback Product Problem & Purchasing phase

This phase consists of the following two sub-steps:

Step 1: Customer feedback

The proposed eco-innovation design procedure will be presented with a customer complaint for the notebook computer case. Eco-innovation considers both the R&D thinking and the environmental impact. In the notebook computer case, this is a problem. The notebook computer suddenly stopped working, according to a customer's vague description. The customer does not understand why this has happened or how to handle it. For the maintenance engineer, he must continuously rule out errors to find the cause of the problem in order to solve it. The R&D designer needs to develop a new product that responds to this problem and avoids recurring problems. In this case, four problem elements are chosen: "power light extinguished", "shut down", "M" (Middle), and "power empty".

Step 2: Customer feedback product purchasing

Based on the MIR model, literature review, and expert interviews, this study constructs an AHP model and uses a notebook computer as an example to probe the influences of notebook computer purchase on the 3Rs from customers' perspective. An AHP framework of customers' perspective is shown as Figure 7 from the MIR model.

- Layer 1: The main target is to identify how customers impact on the 3Rs with respect to purchasing a notebook computer.
- Layer 2: Group factors that customers would consider in determining which notebook computer to buy fall into two categories, "product features" and "purchasing behavior". Notably, other considerations are those not related to the specifications of a notebook computer.
- Layer 3: Evaluate "product features" and "purchasing behavior". "Product features" include items such as the "storage/capacity", "size", " weight", "multi-functionality", "battery life", and "durability" of notebook computers. Meanwhile, "price", "brand", "packaging", "sales service", "recycling channel", and "green image" are elements to be assessed under the category of other considerations.
- Layer 4: Examine the relevance of factors identified in Layer 3 against the 3Rs.

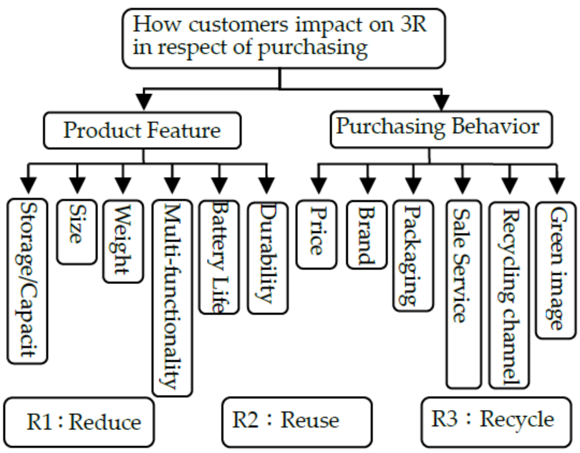

Figure 7. AHP framework of customers' perspective.

This study aims to analyze notebook computer purchasing preferences in the market by conducting a multi-layer questionnaire. How customers weigh the product features and purchasing behavior before making a decision is examined in Layer 2, where product features and purchasing behavior are compared. The significance of each element can be isolated and a reasonable inference of purchasing preference obtained. Also, how heavily the purchasing preferences could impact on the environment is shown in Layer 4. Both customers' purchasing preferences and the 3Rs are taken into account.

The questionnaire includes two sections. The first section covers the influence of customers' preference for a notebook computer and its use on the 3Rs. The study conducted a pair comparison between the attributes according to customers' instinctive reactions. The second section collects basic information on the subjects, including sex, age, educational level, occupation, and monthly income.

The study distributed a total of 100 copies of the questionnaire, of which 96 copies were valid. As shown from the usable returned copies, the number of female customers (67.6%) is higher than that of their male counterparts (32.4%); their ages are mostly in the range 21–25 (70.8%) or 26–30 (15.1%). Also, 78.4% of the respondents were college graduates, while 'student' made up the vast majority (63.3%) in terms of occupation. In addition, 74.1% of the respondents' monthly income was below $20,000.

The AHP procedure used Expert Choice computer software 2010 package (http://www.expertchoice.com). This study is conducted by the means of AHP. That is, analyzing how end users' consideration can affect the 3Rs with regard to purchasing a notebook computer. After Expert Choice running, we obtain Reduce, Reuse, and Recycle priority values of 0.416, 0.384, and 0.200, respectively. Taking end users' consideration into account in the case of buying a notebook computer, the result shows that "Reducing" would be the best solution, followed by "Reusing". "Recycling" is least favorable to end users.

A notebook computer is an entertainment product. According to the analytical results of AHP, we find that customers treat the product suitability (such as endurance, saving capacity, battery endurance, and functions) as the priority. The difference of the specifications significantly influences customers' decisions and reduces the effect of green appeals on consumption.

With regard to customers' preferences, customers' consideration factors have the most bearing on Reduce (0.416) and Reuse (0.384). In other words, when firms can design products according to customers' preferences and consider the materials and endurance in manufacturing, the products could reveal the best reduce and reuse effects. In addition, according to the research findings, the score on Recycle (0.2) is the lowest. This means that when customers select a notebook computer, they do not consider the issue of recycling. However, if companies or the government can set up a complete recycling system, the recycling of notebook computers would be effectively increased. In addition, the government should promote the importance of green consumption to reinforce people's environmental consciousness.

4.2. Phase II: TRIZ-Based QFD Phase

This phase consists of the following sub-steps.

Step 1: An eco-design engineer constructs a QFD matrix from the abovementioned problem elements within the 3Rs. These VOC items divided by 3R and VOE items are shown in Figure 8, and the top matrix shows the negative relationship denoted by "X".

Step 2: Analyze the VOE items based on the abovementioned negative relationship among them using a TRIZ contradiction matrix. These VOE items should not only comply with environmental impact standards—reducing materials, and making the battery body lightweight and recyclable; they also need to consider the necessity of the spray paint. Extra painting improves the whole notebook computer body's look to attract customer attention; on the other hand, it also generates problems such as extra weight and increased energy consumption due to weight overload. This is an example of the contradictions between product innovation and environmental protection.

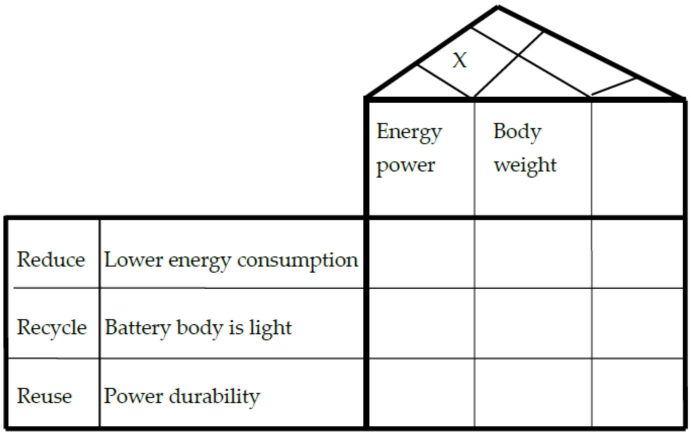

Figure 8. The QFD matrixes for 3R.

Further, the VOE items are related with TRIZ engineering parameters *1, *3, *22, and *25. That means we need to reduce battery energy waste and decrease the weight of the notebook computer through classifying problems and developing efficiency elements. The desired function may be related to the parameters "waste of energy" and "waste of time" (rows 22 and 25 of the contradiction matrix), which should be reduced. The harmful factors may be transformed via "weight of moving object" and "length of moving object" (columns 1 and 3 of the contradiction matrix), which should be decreased.

Step 3: Integrating eco-efficiency elements into QFD with a TRIZ contradiction matrix. Applying the correlation of engineering parameters and eco-efficiency elements, the relationship between TRIZ engineering parameters and eco-efficiency elements can be determined. In this case study, the most important TRIZ engineering parameter is the relationship between "A—Reduce the material intensity of its goods and services" and "B—Reduce the energy intensity of its goods and services" of eco-efficiency elements. Both items have high (H) priority, as shown in Table 2.

Table 2. TRIZ engineering parameter vs. eco-efficiency elements.

TRIZ Parameters	Eco-Efficiency Elements						
	A	B	C	D	E	F	G
#1 weight of moving object	H	H	-	-	-	-	-

From Table 2, we should select engineering parameters *1 and *22. Further, these two parameters are classified and matched to the corresponding inventive principles. In the problem, inventive principles 15, 6, 19, and 28 are proposed by the contradiction matrix. Some design considerations:

(i) Replacement of the body substance with an aluminum–magnesium (Al–Mg) alloy;
(ii) Replacement of the electrical system with an energy-saving system.

4.3. Phase III: RFM-Based QFD Phase

This phase is to establish six clusters based on RFM value in order to quantify so-called business value. The 110 consumer transactions records were collected within one year. RFM values of 100 green products were extracted from the records. The market values were linked to evaluate their respective purchased green products for eco-efficiency criteria.

Table 3 presents the six clusters, each with the corresponding number of green product usage for R, F, and M values from customer feedback. The last row also shows the overall average for all numbers.

Table 3. Data for eco-efficiency clusters.

Cluster	No of Green Product Usage	Recency (Days)	Frequency (Times)	Monetary (Hundred US)
1	20	29	7	148
2	21	33	8	347
3	9	38	11	487
4	16	39	13	518
5	15	40	15	519
6	19	43	19	529
-	Overall Average	37	12	425

The 3Rs are expressed as a percentage between 0 and 100 as a fuzzy set of symptoms in Table 4. Reduction, with a score of less than 100%, is relatively important. Recycling and Reuse, with scores closer to 0%, are relatively important. The AHP and fuzzy-based AHP method were used to determine the relative importance of the RFM variables R', F', and M'. These are shown in Table 4.

Table 4. The normalized RFM ($W_I = W_R R' + W_F F' + W_M M'$).

Cluster	R'	F'	M'	Reduction	Recycling	Reuse	W_{AHP}	$W_{Fuzzy-AHP}$
1	0.32	0.22	0.06	66	15	10	0.27	0.26
2	0.40	0.28	0.55	75	21	11	0.37	0.39
3	0.49	0.44	0.89	55	23	15	0.51	0.54
4	0.51	0.56	0.97	50	25	17	0.56	0.59
5	0.53	0.67	0.97	47	27	18	0.61	0.63
6	0.58	0.89	1.00	43	29	21	0.71	0.72

Multiple linear regressions (MLR) were explored to predict the 3R values using eco-efficiency.

However, the parameters of the classical regression model with AHP and fuzzy-based weighted AHP are estimated by MLR and shown as follows. The adjusted R-squared and p-values of the regression model for the AHP method are 0.993 and 0.004, respectively. The adjusted R-squared and p-values of the regression model for the fuzzy-based AHP method are 0.982 and 0.01, respectively. They mean that the forecasting model reaches the significance level in green product usage. Substituting the 3Rs from the (R, F, M) values such as (80, 15, 10), (75, 20, 15), (70, 25, 20), (65, 30, 25), (60, 35, 30), (55, 40, 35) into the regression will yield the business value shown in Figure 9 for comparison.

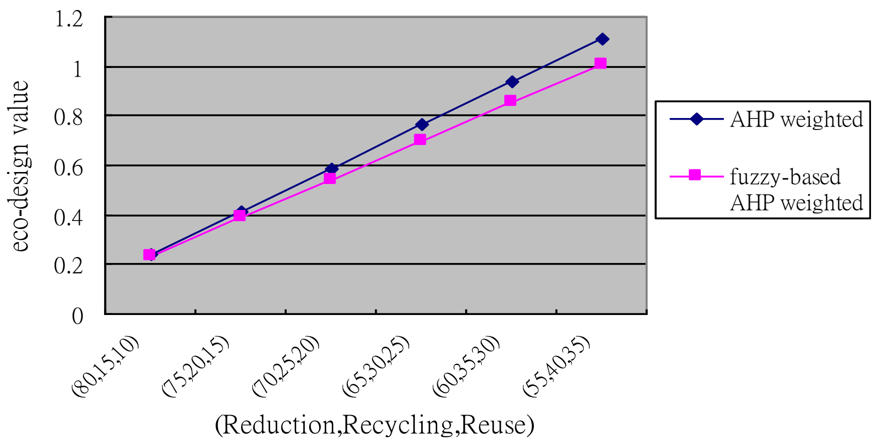

Figure 9. The trend of business value.

This article has considered two competitive RFM weighted methods for forecasting models: AHP and fuzzy-based AHP. Owing to the short product life cycle of notebook computers, rapidly progressing technology, and environmental impact, the forecasting methods are used to evaluate business value. Thus this article uses the proposed eco-innovation procedure, which does not need a large amount of data to construct the forecasting model. According to the MLR method, using data from Table 4, when we are given reduction = 65, recycling = 27, and reuse = 19, the equations are as follows:

$$\text{3R values} = -0.092 - 0.001 * \text{Reduction} + 0.014 * \text{Recycling} + 0.02 * \text{Reuse} = 0.601 \quad (4)$$

$$\text{3R values} = 0.067 - 0.003 * \text{Reduction} + 0.025 * \text{Recycling} + 0.003 * \text{Reuse} = 0.604 \quad (5)$$

It is clear that AHP and fuzzy-based AHP give fairly consistent results. However, fuzzy-based AHP is fairly intuitive, and provides a good forecast of business value. A good eco-innovation forecasting method should be able to consider uncertainties and thus predict the entire trend well.

5. Conclusions

In this paper, I presented an approach to study innovative product development for eco-efficiency based on RFM value. Feedback-based eco-efficiency and TRIZ-based innovation together represent a useful approach for green product development. However, the proposed method has to deal with three issues: (i) customer feedback; (ii) product innovation; and (iii) eco-efficiency.

First, a customer feedback model tried to capture the impact on the product design process based on product problems and customers' purchasing. Second, eco-design engineers must not only avoid recurring problems, but also must continue researching eco-efficiency in related fields. Third, few literature reviews discuss new green product developments based on business value. The business value of green product innovation is very important due to environmental impacts.

In the abovementioned situation, there is a need to develop an innovative green product procedure based on RFM value for the product design. The proposed eco-innovation design procedure consists of three phases: Customer feedback, TRIZ-based QFD, and RFM-based eco-efficiency. A customer feedback-based phase using MIR can identify eco-efficiency by using the RFM value for quantifying eco-design. This phase constructs a MIR model of green products using feedback about product problems and customers' purchasing to explore the influences of the said factors on sustainability management indicators such as the 3Rs through AHP analysis. Designers can thus recognize how to find a balance between consumer satisfaction and the reduction of waste. The TRIZ-based QFD phase is to establish an eco-innovation design. Here, a conflict of VOE items necessitates appropriate problem-solving to come up with an innovative solution. The RFM-based QFD phase is to establish identifying eco-efficiency affection based on RFM in order to explore business value. With business value becoming an increasingly important competence issue, business performance should explore environmental benefits in new green product development decision-making.

A case study concerns a notebook computer retailing company. Multiple linear regression (MLR) was used to predict the business value using eco-efficiency. This case study also shows experimental results in order to highlight the importance of environmental impact for eco-innovation design using RFM and 3R data. The experiment shows the correlation between 3R and RFM variables in Equations (4) and (5). It evaluates business value at 0.601 and 0.604 using AHP and fuzzy-based AHP weighted RFM.

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