Malaya Journal of Matematik, Vol. 8, No. 1, 222-224, 2020

https://doi.org/10.26637/MJM0801/0037

# Decision making on E-waste management methods using minimization of regret with interval-valued intuitionistic fuzzy sets

Nivetha Martin[1]*, P. Pandiammal[2] and N. Ramila Gandhi[3]

**Abstract**

In this era of technology, the markets of electronic appliances are flooded with new products which make the existing obsolete and stimulate the customers to become the users of the recent electronic devices. The life of mankind on this earth is highly integrated with certain inevitable gadgets and it has to be updated periodically for sustaining the sustenance. The high replacement rate of these electronic products contributes to the accumulation rate of E-waste at global level. The alarms of environmental conservation have fostered the nations worldwide to monitor the management of E-waste through stern legislations. The impact of imposing such canons have made the industries to adopt several methods of managing E-waste and this is the root of chaos in the decision making process on compatible methods of waste management. To derive an optimal solution, the method of minimization of regret with inter-valued intuitionistic fuzzy sets is used to design a decision making model. The proposed model will lend a helping hand to the decision makers in handling the hurdles of ambiguity.

**Keywords**

E-waste management, Reduction, Disposal, minimization of regret, inter valued intuitionistic fuzzy sets.

**AMS Subject Classification**

03E72.

[1] *Department of Mathematics, Arul Anandar College , Karumathur-625514, Tamil Nadu, India.*

[2] *2Department of Mathematics, GTN Arts College, Dindigul-624005, Tamil Nadu, India.*

[3] *Department of Mathematics, PSNA College of Engineering and Technology, Dindigul-624622, Tamil Nadu India.*

***Corresponding author**: [1] nivetha.martin710@gmail.com

**Article History**: Received **24** October **2019**; Accepted **17** January **2020**



## Contents



## 1. Introduction

One of the ultimate intentions of every nation's environmental movements is waste management, especially E- waste, as the generation of this type of waste is reaching higher altitudes. The composition of this kind of waste is electrical components which are both valuable and hazardous. The concern towards E- management is growing, owing to its dreadful consequences. The primary sources of this E-waste are large, small household appliances, electrical tools, equipments of Information technology, telecommunications, consumer, lighting, medical systems and instruments of monitoring and control. The aggregation of E-waste in a developing nation is the resultant of import from developed nations, as countries like China, India and Pakistan runs recycling and disassemble centers. E-waste contributes to the solid waste in metropolitan regions and it comprises of several harmful metals which are the threat to the survival of living organisms. Daniel et.al. [2] in his research on the characteristics of E-waste has presented the detailed description of E- waste. He has also emphasized on the need of managing E-waste. Udhayakumar [6] carried out a survey on managing E-waste exclusively in Chennai and stated certain recommendations on promoting the notion of eco-friendliness in E-product designs. Vidhya Lakshmi [5] presented the methods of reduction and disposal of E-waste at global and national level. The management of E-waste was broadly classified into two categories of reduction methods and disposal methods. The description of the methods is presented in Table 1.1. In addition to the disposal methods described by Vidhya Lakshmi[5] three more methods are also considered in this research work. The theoretical conceptualization of the probable reduction and disposal methods were presented by the researchers. But the comparative analysis with validation of ranking methods was not yet undertaken to the best of our knowledge. This intended us to formulate a decision making model to determine the most suitable methods of reduction and disposal of E-waste.

| E Waste Reduction Methods | Description |
|---|---|
| Life Cycle Assessment | A tool to enhance the environmental performance of the products |
| Multi Criteria Analysis | It encompasses several criteria in phases of planning and designing |
| Material Flow Analysis | An assessment means of product's environmental, social and economic values through software-based simulation modeling |
| Extended Producer Responsibility | The manufacturers play a vital role in fulfilling the environmental goals of the product |

Table 1.1 Description of E waste Management Methods

Decision making is a complicated and multi staged process comprising the consideration of several attributes and the consensus of the experts in arriving at an optimal decision. As the role of expert's qualitative opinion on the attributes is the decisive factor in the process of ranking the methods of reduction and disposal of E-waste, it is expressed as inter valued intuitionistic fuzzy sets. Atanssov,the forefather of intuitionistic fuzzy sets introduced inter valued Intuitionistic fuzzy sets in association with Gargov [1] This kind of fuzzy sets representation reflects the opinion of the experts in the way they ought to be. Decision making models based on minimization of Regret have been constructed by many researchers, adding to it a decision making model to determine the most suitable E-waste reduction and disposal method fulfilling all the essential attributes based on inter-valued intuitionistic expression of expert's opinion is proposed in this research work.

The paper is structured as follows: section 2 presents the methodology; section 3 consists of the application of the methodology to the decision making problem, section 4 discusses the results and section 5 concludes the work.

## 2. Methodology

This section considers the following steps in determining the optimal ranking of the methods of reduction and disposal of E-waste.

**Step I:** The attributes related to E- waste reduction and disposal methods are decided based on the consent of the experts in the related field.

**Step II:** The agreement matrix A consists of inter-valued intuitionistic fuzzy sets $\{[[\alpha,\beta],[\gamma,\delta]]\}$ as elements representing the degree of satisfaction of the attributes by the methods considered for ranking.

**Step III:** The score matrix $S_{ij}$ is determined by $[[\alpha-\gamma]+[\beta-\delta]]/2$ and the weights wj are determined by optimizing the single objective programming model.

**Step IV:** The cumulative score S is obtained by $S_{ij} * w_j$.

**Step V:** The optimal ranking is attained based on the value of $S$ of each alternatives.

## 3. Optimal ranking of E-waste reduction and disposal methods

The E-waste disposal methods and the attributes [2–4] of the disposal method are represented in Table 3.1.

| Methods of Disposing E-waste | Attributes of E-Waste Disposal Methods |
|---|---|
| 1. Incineration (I) [ Burning to ashes]<br>2. Land Filling (LF) [Dumping to land]<br>3. Acid Bath (AB) [ Chemical treatment]<br>4. Reprocessing (RP) [ Recovery]<br>5. Reusing (RU) [ Putting into usage] | E1 Expediency<br>E2 Safety<br>E3Generation of Energy<br>E4 Less Secondary pollution<br>E5 Zero contamination<br>E6 No emission of Methane<br>E7 Declination in waste quantity<br>E8 Elimination of hazardous instincts<br>E9 Operational flexibility<br>E10 Provision of Monitoring System<br>E11 Economic Feasibility<br>E12 Recovery of utility materials<br>E13 Eco friendliness<br>E14 Minimal Resource utilization rate<br>E15 Conservation of Energy |

Table 3.1 Methods and Attributes of E-Waste Disposal Methods

The agreement matrix $A$ is represented as follows:

| | Incineration | Land Filling | Acid Bath | Reprocessing | Reusing |
|---|---|---|---|---|---|
| E1 | [[0.5,0.6], [0.2,0.3]] | [[0.6,0.8], [0.1,0.2]] | [[0.2,0.3], [0.7,0.9]] | [[0.7,0.8], [0.1,0.2]] | [[0.6,0.7], [0.2,0.4]] |
| E2 | [[0.4,0.6], [0.1,0.3]] | [[0.2,0.4], [0.6,0.8]] | [[0.3,0.4], [0.6,0.8]] | [[0.8,0.9], [0.2,0.3]] | [[0.7,0.8], [0.1,0.3]] |
| E3 | [[0.6,0.8], [0.2,0.4]] | [[0.5,0.7], [0.1,0.3]] | [[0.1,0.3], [0.6,0.9]] | [[0.8,1], [0.1,0.3]] | [[0.7,0.9], [0.2,0.4]] |
| E4 | [[0.5,0.8], [0.1,0.2]] | [[0.4,0.5], [0.7,0.9]] | [[0.2,0.4], [0.7,0.9]] | [[0.6,0.8], [0.1,0.3]] | [[0.7,1], [0.1,0.3]] |
| E5 | [[0.6,0.9], [0.3,0.4]] | [[0.5,0.7], [0.1,0.2]] | [[0.1,0.3], [0.8,1]] | [[0.7,1], [0.1,0.2]] | [[0.8,1], [0.2,0.4]] |
| E6 | [[0.5,0.9], [0.2,0.3]] | [[0.8,1], [0.2,0.3]] | [[0.3,0.6], [0.7,0.9]] | [[0.8,1], [0.2,0.3]] | [[0.9,1], [0.2,0.3]] |
| E7 | [[0.5,0.7], [0.1,0.3]] | [[0.2,0.4], [0.7,1]] | [[0.5,0.7], [0.8,1]] | [[0.7,0.9], [0.2,0.3]] | [[0.7,1], [0.3,05]] |
| E8 | [[0.1,0.4], [0.7,0.9]] | [[0.3,0.5], [0.9,1]] | [[0.9,1], [0.2,0.4]] | [[0.8,1], [0.1,0.4]] | [[0.7,0.9], [0.3,05]] |
| E9 | [[0.6,0.8], [0.1,0.3]] | [[0.5,0.7], [0.2,0.4]] | [[0.7,0.9], [0.1,0.3]] | [[0.6,0.9], [0.3,0.4]] | [[0.7,1], [0.1,0.3]] |
| E10 | [[0.8,1], [0.2,0.3]] | [[0.5,0.7], [0.2,0.4]] | [[0.7,0.9], [0.1,0.3]] | [[0.6,0.9], [0.3,0.4]] | [[0.5,0.7], [0.3,0.4]] |
| E11 | [[0.6,0.8], [0.1,0.3]] | [[0.8,1], [0.2,0.3]] | [[0.4,0.5], [0.8,1]] | [[0.9,1], [0.1,0.2]] | [[0.7,1], [0.2,0.3]] |
| E12 | [[0.8,1], [0.2,0.3]] | [[0.6,0.8], [0.1,0.2]] | [[0.1,0.3], [0.7,1]] | [[0.8,1], [0.2,0.3]] | [[0.7,0.9], [0.1,0.2]] |
| E13 | [[0.9,1], [0.1,0.2]] | [[0.7,0.9], [0.2,0.3]] | [[0.2,0.3], [0.8,1]] | [[0.8,0.9], [0.1,0.2]] | [[0.9,1], [0.1,0.2]] |
| E14 | [[0.8,0.9], [0.3,0.4]] | [[0.8,1], [0.1,0.2]] | [[0.2,0.4], [0.7,0.9]] | [[0.7,0.8], [0.1,0.2]] | [[0.6,0.9], [0.3,0.4]] |
| E15 | [[0.7,0.9], [0.1,0.2]] | [[0.7,0.9], [0.1,0.4]] | [[0.1,0.2], [0.9,1]] | [[0.8,1], [0.4,0.5]] | [[0.9,1], [0.1,0.2]] |

The score matrix $S$ is

| | E1 | E2 | E3 | E4 | E5 | E6 | E7 | E8 | E9 | E10 | E11 | E12 | E13 | E14 | E15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LF | 0.3 | 0.3 | 0.4 | 0.5 | 0.4 | 0.45 | 0.4 | -0.55 | 0.5 | 0.65 | 0.5 | 0.65 | 0.8 | 0.5 | 0.65 |
| I | 0.55 | -0.4 | 0.4 | -0.35 | 0.45 | 0.65 | -0.55 | -0.55 | 0.3 | 0.3 | 0.65 | 0.55 | 0.55 | 0.55 | 0.75 |
| AC | -0.55 | -0.35 | -0.55 | -0.5 | -0.7 | -0.35 | -0.3 | 0.65 | 0.6 | 0.6 | -0.45 | -0.65 | -0.65 | -0.5 | -0.8 |
| RY | 0.6 | 0.6 | 0.7 | 0.5 | 0.7 | 0.65 | 0.55 | 0.65 | 0.4 | 0.4 | 0.8 | 0.65 | 0.7 | 0.6 | 0.45 |
| RU | 0.35 | -0.55 | 0.5 | 0.65 | 0.6 | 0.7 | 0.45 | 0.4 | 0.65 | 0.25 | 0.6 | 0.65 | 0.8 | 0.4 | 0.8 |

The cumulative scores of the disposal methods of e-waste management and its optimal ranking are presented in Table 3.2.

| E-Waste Management Disposal Methods | Collective Scores | Optimal Ranking |
|---|---|---|
| Incineration | 0.43215 | 3 |
| Land Filling | 0.25795 | 4 |
| Acid Bath | -0.3015 | 5 |
| Reprocessing | 0.59965 | 1 |
| Reuse | 0.48575 | 2 |

**Table 3.2 Optimal Ranking of E-Waste Management Disposal Methods**

The E-waste reduction methods and the attributes [3, 4] of the reduction method are represented in Table 3.3.

| Methods of Reducing E-waste | Attributes of E-Waste Reduction Methods |
|---|---|
| 1. Life Cycle Assessment (LCA)<br>2. Multi Criteria Analysis (MCA)<br>3. Material Flow Analysis (MFA)<br>4. Extended Producer Responsibility (EPR) | A1 Compatibility<br>A2 Consistency<br>A3 Cost effective<br>A4 Time Efficient<br>A5 Eco −friendly<br>A6 Flexibility |

**Table 3.3 Methods and Attributes of E-Waste Reduction Methods**

The agreement matrix $A$ is represented as follows

| | Life Cycle Assessment | Multi Criteria Analysis | Material Flow Analysis | Extended Producer Responsibility |
|---|---|---|---|---|
| A1 | [[0.7,1],[0.1,0.2]] | [[0.6,0.8],[0.2,0.3]] | [[0.7,0.9],[0.3,0.4]] | [[0.5,0.8],[0.2,0.4]] |
| A2 | [[0.8,1],[0.1,0.2]] | [[0.7,0.9],[0.1,0.3]] | [[0.6,0.8],[0.3,0.4]] | [[0.7,1],[0.1,0.4]] |
| A3 | [[0.6,0.7],[0.4,0.5]] | [[0.6,0.9],[0.2,0.3]] | [[0.5,0.8],[0.2,0.4]] | [[0.7,0.9],[0.1,0.3]] |
| A4 | [[0.2,0.3],[0.7,1]] | [[0.6,0.9],[0.2,0.3]] | [[0.7,1],[0.1,0.2]] | [[0.1,0.3],[0.7,0.9]] |
| A5 | [[0.9,1],[0.1,0.2]] | [[0.2,0.3],[0.7,1]] | [[0.8,1],[0.1,0.2]] | [[0.5,0.7],[0.3,0.4]] |
| A6 | [[0.8,1],[0.1,0.2]] | [[0.4,0.5],[0.8,1]] | [[0.6,0.8],[0.3,0.4]] | [[0.7,0.9],[0.1,0.3]] |

The score matrix $S$ is

| | Life Cycle Assessment | Multi Criteria Analysis | Material Flow Analysis | Extended Producer Responsibility |
|---|---|---|---|---|
| A1 | 0.7 | 0.45 | 0.45 | 0.35 |
| A2 | 0.75 | 0.6 | 0.35 | 0.6 |
| A3 | 0.2 | 0.5 | 0.35 | 0.6 |
| A4 | -0.6 | 0.5 | 0.7 | -0.6 |
| A5 | 0.8 | -0.6 | 0.75 | 0.25 |
| A6 | 0.75 | -0.45 | 0.35 | 0.6 |

The cumulative scores of the disposal methods of e-waste management and its optimal ranking are presented in Table 3.4.

| E-Waste Management Reduction Methods | Collective Scores | Optimal Ranking |
|---|---|---|
| Life Cycle Assessment | 0.432 | 2 |
| Multi Criteria Analysis | 0.167 | 4 |
| Material Flow Analysis | 0.4927 | 1 |
| Extended Producer Responsibility | 0.3006 | 3 |

**Table 3.4 Optimal Ranking of E-Waste Management Reduction Methods**

## 4. Results and Discussions

The Table 3.2 & 3.4 presents the optimal ranking of the reduction and disposal methods of E-waste management. As reprocessing ranks first in the methods of disposal followed by reusing, incineration, land filling and acid bath, it is evident that the method of reprocessing is more suitable to dispose E-waste. But, the process of reprocessing is quite unsafe, which demands more attention at times of putting into action. The rate of reprocessing can be reduced by practicing E-waste reduction methods. The method of Material Flow Analysis is well suited for reducing the generation of E-waste as it focuses on the environmental, social and economic values of the product and it has the attributes of forecasting the impacts of the product in several dimensions with the support of simulation modeling.

## 5. Conclusion

This research work presents the decision making model of ranking disposal and reduction methods of E-waste. The method of minimization of regret with inter-valued intuitionistic fuzzy sets is used to determine the optimal ranking of the methods. The optimal ranking for the same decision making problem can be determined by using other representations of expert's opinion. The method used in this model can be extended to minimization of regret with linguistic representation to replicate the opinion of the experts in the context of association between the attributes and the alternatives in a more realistic manner.

## References

[1] Atanassov Gargov, Interval valued intuitionistic fuzzy sets, *Fuzzy Sets and Systems* 31(3)(1989), 343–349.

[2] Daniel Mmereki, Baizhan Li, Andrew Baldwin and Liu Hong, The Generation, Composition, Collection, *Treatment and Disposal System, and Impact of E-Waste*, DOI: 10.5772/61332, 2016.

[3] Nnorom, Innocent C, and Oladele Osibanjo, Overview of electronic waste (ewaste) management practices and legislations, and their poor applications in the developing countries, *Resources, Conservation and Recycling*, 52(6)(2008), 843–858.

[4] Ongondo, Francis O, Ian D. Williams, and Tom J. Cherrett, How are WEEE doing? A global review of the management of electrical and electronic wastes, *Waste Management*, 31(4)(2011), 714–730.

[5] Sivakumar, Vidhya Lakshmi, Global and Indian E-Waste Management - Methods & Effects, *13th International Conference on Science, Engineering and Technology (SET)*, at Vellore Institute of Technology, Vellore, 2016.

[6] T. Udayakumar, Disposal methods of e-waste in India Survey conducted in Chennai, *International Journal of Applied Environmental Sciences*, 12(3)(2017), 505–512.

⋆⋆⋆⋆⋆⋆⋆⋆⋆
ISSN(P):2319 − 3786
Malaya Journal of Matematik
ISSN(O):2321 − 5666
⋆⋆⋆⋆⋆⋆⋆⋆⋆