An AHP approach to evaluate the implementation of WEEE management systems

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Abstract: This paper presents the Analytical Hierarchy Process as a potential decision making method for the evaluation of implementation of WEEE management systems. The proposed model is based on the analysis of political, economical, social, technical and environmental issues that may affect a successful implementation of WEEE management systems. The proposed model can help WEEE managers to understand more closely the decisive factors implied in the implementation of WEEE management systems.

Key-Words: E-waste, WEEE/E-waste management systems, AHP, Criterion

1 Introduction

Each wave of technological advances in electric and electronic industries determined economic growth and improved people's lives [7]. The side effect of this improvement is the growing number of electronic wastes in the waste streams. Therefore, proper treatment of this type of waste is important.

Waste Electrical and Electronic Equipment (WEEE) directive is an effort to reduce electronic and electrical waste at European level to and improve its recovery and recycling. The proposal, along with the complementary Directive on the Restriction of the use of Certain Hazardous Substances in Electrical and Electronic Equipment (ROHS) and the EcoDesign Requirements for Energy Using Products (EuP) Directive, seeks to reduce the environmental impacts of WEEE throughout all stages of the equipment's lifecycle [11], [12].

Understanding the mechanisms and functioning principles of WEEE management systems can be possible after a careful identification and analysis of life cycle of EEE from production phase until final disposal phase [6], [8]. In this regard, many researchers have performed systematic analysis of the various aspects concerning the management of WEEE. For example, Rousis et al. [15] used the MCDM method for the determination of the best WEEE management scenario in Cyprus. Bereketli et al. developed a fuzzy LINMAP model for evaluation and selection of a waste treatment strategy for EEE in Turkey [1]. Che [5] explored problems concerning production and delivery in a green supply chain, and constructed an optimal mathematical model for the selection of green partners when establishing a supply chain.

2 Problem Formulation

The decision to implement a WEEE management system is a difficult one because is based on a lot of criteria. The various criteria used for evaluation of WEEE management systems use a multitude of measurement units. So, it is very difficult to express them all in a single unit. A possible solution to this problem is AHP method (Analytic Hierarchy Process) [16], a method largely used in economic research [9], [4], [13]. It will not replace the decision-making process itself but it will generate information needed to make the decision and will present it in a structured way. The critical component of such decision-making is what the weights ought to be for the different criteria of evaluation.

The AHP is a method of solving problems that involve prioritisation of alternative solutions and is based on the evaluation of a set of criteria. Since a decision-maker bases judgments on knowledge and experience and then makes decisions accordingly, the AHP approach agrees well with the behavior of a decision-maker. Therefore, our purpose was to test the AHP as a potential decision making method for the evaluation of implementation of WEEE management systems. The proposed model is based on the analysis of political, economical, social, technical and environmental (PESTE) issues that may affect a successful implementation of WEEE management systems.

The determination of evaluation criteria took place on the basis of the existing experience from other applications and achievement of sufficient coverage of all characteristics of WEEE management systems. 18 individual criteria were selected in total, categorized in five groups, as described below.

Political and legislative criteria

Compliance with EU legislation

Availability and implementation of regulations is an important aspect of WEEE recycling.

For a country of the EU is necessary that the WEEE management scheme adopted to be adjusted as the structure and mode of operation with the WEEE Directive, but also with the other European directives that are related directly or indirectly with the management of WEEE.

The development of legislation and compliance structure as per EU directives is an on-going process in all EU countries. The member states have to guarantee minimum collection, recovery and reuse/ recycling targets as specified in the directive.

Harmonisation of national legislation

The WEEE legislation is very complex and includes regulations regarding WEEE collection, producer responsibility, collective systems, export/import rules, dangerous substances and treatment methods, etc. Harmonization of WEEE national regulations and their implementation are major challenges in WEEE management across Europe.

Harmonisation of all regulations regarding WEEE management contributes to increasing its efficiency by eliminating the possibilities of breaking the law.

Incentives to reduce environmental impact

This category includes producers incentives to develop products with reduced environmental impact at end-of-life and consumer incentives to buy environmentally friendly products.

Green consumer behaviour can be very strong engine to reduce the environmental impacts caused by WEEE [7]. Examples of green consumer behaviour are listed below:

- To buy long lifespan products;
- To buy products with less harmful chemicals;
- To buy products with the decent recycle system;
- To buy products of eco-friendly company;
- To utilise the leasing service.

It is essential that consumers should be informed about the environmental issues related to what they buy and the fact they can change producers'attitude through their consumption pattern.

Economical criteria

Contribution to the national economy

Contribution of the WEEE management system to national economy is reflected in the GDP and state budget revenues. WEEE management is an important area of activity in terms of employment and the creation of full-time and part-time jobs; this implies an increase in contributions to social security budget. It is characterized by propagation effects, with sector-specific values and intensities, which give a differential importance to economic and social contribution.

Investment, operation and maintenance costs

This criterion looks at the cost efficiency of the WEEE management scheme according to 2 parameters. The first of these is the cost per kilogram of WEEE collection and recycling. The second is concerned with how revenues are budgeted, allocated and spent.

There is a conflict between ensuring maximum compliance and lowering costs. The lowest cost solution may compromise the desired environmental outcome. There a many false economy traps to fall into and it is important that there are acceptable and realistic ambitions for volumes, costs and standards [18].

Smaller distances dramatically reduce transport and logistics costs. Countries with higher populations and urban population densities are able to generate economic efficiencies and economies of scale through the concentration of facilities and their ability to generate higher WEEE volumes relative to costs. A system that handles greater volumes of waste will be able to obtain greater economic efficiencies through rationalising its contracts with suppliers and using its market power to negotiate better rates.

Weight of informal sector

Some of the major stakeholders, identified along the WEEE flow include importers, producers/ manufacturers, retailers (businesses/ government/ others), consumers (individual households, businesses, government and others), traders, retailers, scrap dealers, dissemblers/ dismantlers and recyclers. At each step in the flow, business transaction defines the movement of the electronic item in the flow. In many developing countries, a majority of stakeholders in this category fall under unorganized/ informal sector [18].

The current informal WEEE-recycling system has significant impacts on the economic development of WEEE system. Since low level of investment is required in informal sector, small investors find WEEE trade as attractive business proposition, where the main incentive is financial benefit irrespective of environmental, occupational and health issues.

The main obstacle to better manage existing WEEE recycling system in the developing countries is reforming the informal sector. Moreover, as a result of its negative impacts on the environment and human health in the industrializing countries, the informal sector is definitely a crucial and emerging issue, which is needed to be better governed [6].

Obsolescence rate

The efficiency of an waste recycling system in terms of output is dependent on quantity and quality of input raw material (WEEE). The quality of raw material is dependent on the type and obsolescence rate of the WEEE item, which is dynamic in nature.

The increased consumption pattern leads to an increased obsolescence rate of these products, which will result in the higher generation of electronic waste. The key to estimate WEEE is fixing of obsolescence rate based on market research data, industry data or on consumer behaviour.

Social criteria

Consumer awareness and attitude

Ultimately, all existing European WEEE schemes owe a great deal of their success to the prevailing consumer attitudes and recycling behaviour in a given country. The level of WEEE recycling awareness in relation to specific product groups is also a key driver of success. Even in those countries that have a strong track record in WEEE recycling, it is proving difficult to influence disposal behaviour in relation to new product categories such as small ‘bin-size’ items and items with perceived economic value such as mobile phones, where collection rates are significantly lower than in other categories.

The success or failure of a WEEE programme will be in part dictated by the clarity with which it can be explained to the consumer, and the ease with which the consumer can engage with the collection and financing system. All experts and managers recognize the need to improve the level and quality of communication and public awareness of WEEE and WEEE recycling remains an issue in all countries.

Generally, producers and importers are seen to be more concerned about controlling costs than increasing WEEE volumes, so long as their legal obligations are met, there is little enthusiasm for excessive spend on consumer awareness and public relations activities

Local municipalities bear some responsibility in all of the countries for informing residents about local waste and recycling opportunities and there is the opportunity for a lack of clear responsibility.

Social acceptance of the WEEE management system

The degree of social acceptance of the proposed solution for WEEE management is dependent on many factors, such as: the environmental repercussions that are caused by the existing management practices; the prevention/reduction of environmental repercussions that will be achieved via the adoption of new management practices; the awareness level of citizens on WEEE subjects, the educational and professional level of citizens; the tax and legal obligations that will be introduced by the implementation of WEEE management system. [15].

CSR and NGOs initiatives

CSR and NGOs can contribute to the effectiveness of WEEE management system by: number of education campaigns / awareness of consumers, the volume of WEEE collected through voluntary activities; number of partners (authorities, producers, distributors, representatives of consumers, professional associations, etc.) involved in running projects on WEEE.

Creation of new jobs

Collection, treatment and sorting are highly labour intensive activities and contain a significant labour component. WEEE-recycling comprises four major stages: collection, disassembly, material recovery and final disposal. In every phase of WEEE management can create new jobs, but these depend on the size of the informal sector. While collection (and some disassembly) is carried out in decentralised systems following the occurrence of e-waste, the major part of disassembly and recovery of materials is widely centralized in WEEE-recycling factory.

Technical criteria

E-waste Treatment Systems

Technologies are vital in the e-waste

management chain to maximize the material recovery and minimize the risks. The WEEE Directive defines ten specific categories of waste and each of which has its own distinct and evolving compositions. So it is essential that an appropriate recycling technology to be chosen for each category. From this point of view it is important to determine layout and equipment specifications for WEEE treatment facility.

Location of collection point/ storage facility

Location of WEEE collection points/storage facilities is an important factor in e-waste systems. The location may have an important impact because the population of an area and the geography could affect the type and the quantity of WEEE that is brought to site. Different criteria could be used to identify these locations.

Area of collection point/ storage facility

Area of collection point and storage facility is an important feature for fixing up layout of storage area.

Environmental criteria

Environmental effects on air, water and ground pollution

Electrical and electronic products can affect the environment throughout their life cycle – from when raw materials are extracted from the earth to when materials from the products are reused, recycled, recovered or discarded. As the materials contained in different WEEE are substantially different, the environmental impact of WEEE depends on both the type of WEEE and the way it is treated. Potential impacts comprise emissions of toxic substances as well as inefficient use of materials and energy. They can contribute to global problems (ex. climate related impacts) as well as local impacts (ex. eco-toxic emissions, damage to human health).

Waste generation

Many products are disposed of as they still possess their full functionality simply because expanding performance and functionality is presented to the customer in the shape of new products [10]. The effect of this rapid innovation is an extremely high turnover of hardware and software which result in an increased amount of electronic waste. Therefore, WEEE is the fastest growing waste stream in the EU constituting 4% of the municipal waste today, increasing by 16-28% every five years - three times as fast as the growth of average municipal waste [11], [12]. Studies of existing e-waste systems have suggested that their environmental efficiency can be substantially increased by simply increasing the percentage of e-waste recovered. [14], [17].

Resource use

Resources use was highlighted as an important environmental criterion. Electronics contain substantial quantities of precious metals such as gold, silver and platinum. The concentration of gold in a circuit board may be 40 to 800 times greater than that found in natural gold ore [3]. Therefore, mining e-waste for such metals can be more efficient than mining the earth. However, despite the potential for inherent environmental benefit in mining e-waste, historically, the high costs of separating the aggregated materials in e-waste have limited the growth of e-waste recycling markets.

As a result of WEEE recycling, greater levels of limited physical resources will be available for use because they will not be disposed of in landfill, and there will be less need to mine or produce virgin materials.

Energy consumption

With the goal to solve the negative aspects induced by WEEE, in August 2007 entered into force in EuP Directive 2005/32/EC. The directive aims to reduce the energy use and other negative environmental impacts throughout the life cycle of products powered by electricity, fossil or renewable fuels.

Technology is the most important source of energy saving. Less energy is needed to produce the same amount of product, using the same amount of equipment [2]. So, the technological progress has led to an improvement of energy efficiency [7]. On the same time a bigger pool of electronic products appeared due to lower prices on electronic products, which has the consequence of increase of energy consumption. Stimulating different energy saving measures will have to be complemented with recycling actions to tackle this rebound effect.

3 Research Methodology

The aim of the model is to build a tool to help policy makers or other stakeholders in the assessment phase of e-waste management projects. Based on the facts presented in the previous chapter, we present in Fig. 1 the structure of the model.

In the next step, was calculated the weight of each criterion using AHP method.

Given a set of n evaluation criteria, we note with cij the relative importance of criterion i to criterion j. Pairwise comparation was made using the scoring scale (adapted from [16]) in Table 1.

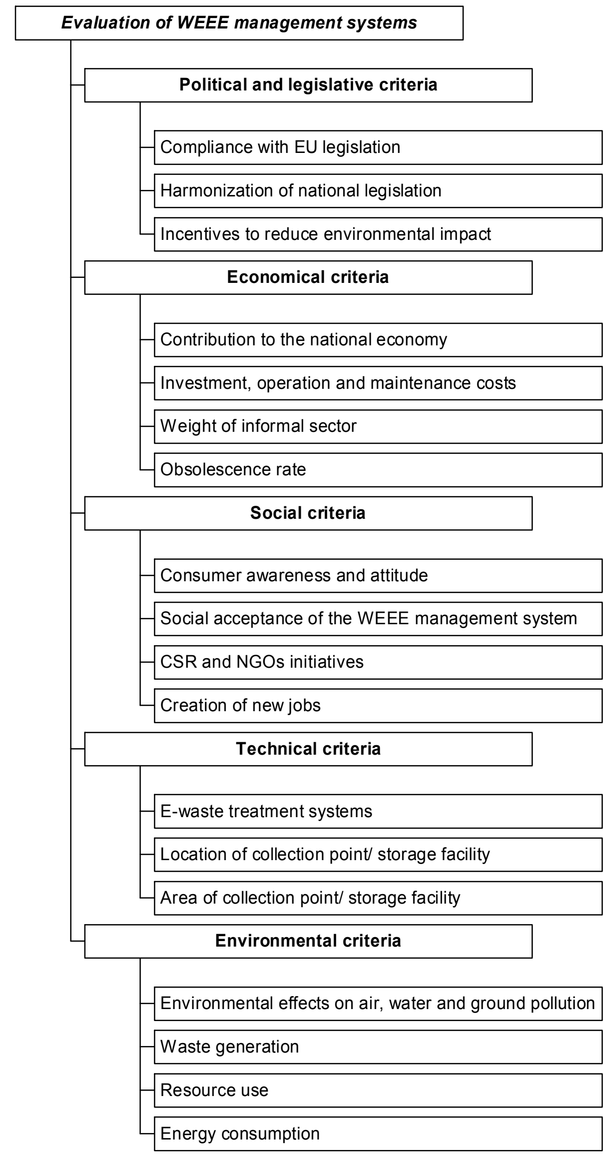

Fig. 1 – The structure of the model

Table 1 - Scoring scale for criteria comparison

Intensity	Evaluation	Explication
1	Equal importance	The spedified criteria contribute equally to objective
3	Weakly importance	A criterion is slightly favored compared with other
5	Essentially importance	A criterion is clearly dominates the other in importance
7	Very strongly importance	A criterion is strongly favored compared with other
9	Absolutely importance	A criterion is unquestionably more important than other
2, 4, 6, 8	Intermediate values	When compromise is giving between two adjacent judgments

Based on the succesive comparasions, results a n*n matrix (the matrix of relative importance of criteria) with the following structure:

$$C = \begin{bmatrix} c_{11}\ c_{12} \dots\ c_{1n} \\ c_{21}\ c_{22} \dots\ c_{2n} \\ \vdots \quad \vdots \ddots \\ c_{n1}\ c_{n2} \dots c_{nn} \end{bmatrix}, c_{ii} = 1, c_{ji} = 1/c_{ij}, c_{ij} \neq 0 \quad (1)$$

After normalization ($\overline{c_{ij}} = \frac{c_{ij}}{\sum_{i=1}^{n} c_{ij}}$) the weight of each criterion is calculated:

$$w_i = \frac{\sum_{j=}^{n} \overline{c_{ij}}}{n} \quad (2)$$

The presented algorithm was applied to each level in the tree of criteria.

5 experts from from all Romanian actors involved in the field (such as companies, association of producers, local authorities and researchers) did the evaluation of the criteria. The values calculated for the weight of each criterion is shown in Figure 2.

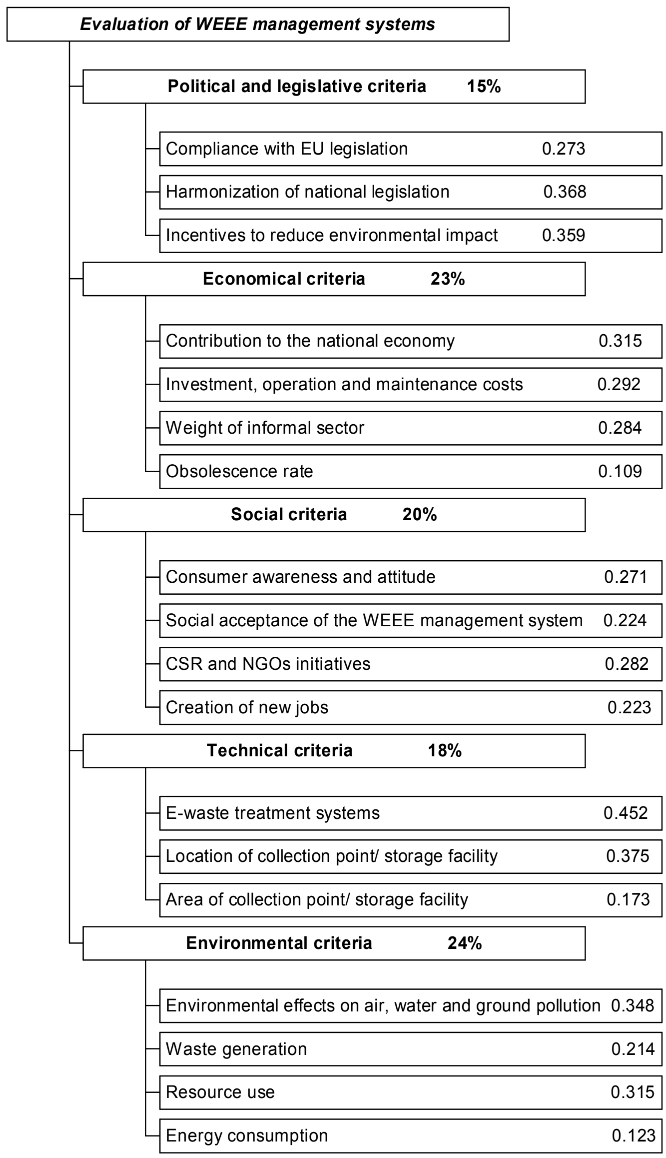

Fig. 2 – The weight of each criterion

4 Conclusions

The AHP analysis led to the following ranking of the evaluation criteria: environmental (24%) economical (23%), social (20%), technical (18%), political (15%), giving to implied experts a way to include their opinion concerning the political, economical, social, environmental and technical impacts of WEEE. The AHP makes group decision-making possible by aggregating judgments in a way that satisfies the reciprocal relation in comparing two elements.

There were several ways we could use the information from the rankings. The most natural one would be to choose those actions that contribute the greatest relative weight to the overall objective

The proposed model has helped the WEEE experts to understand more closely the decisive factors implied in the implementation of WEEE management systems. This also helped the experts themselves to gain more knowledge about the WEEE field as they interact with their peers.

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