WEEE RECYCLING – PASSPORT AND IDEALITY BASED METHODOLOGY

Nicolae IONESCU[1], Mihaela ULMEANU[2,] Paula SPÂNU[3]

[1,2,3]*POLITEHNICA University of Bucharest, e-mail: ionescu_upb@yahoo.com, mihaela.ulmeanu@upb.ro, pauspa16@yahoo.com*

Abstract: *The paper presents the authors' contributions on the design and implementation of two working tools in the recovery of Waste of Electrical and Electronic Equipment, respectively the recycling passport and the product recyclability assessment methodology based on ideality. The design of these two instruments has led to the development of two applications that enable easier connection between recyclers and producers in an eco-innovation hub that also includes other instruments.*

Keywords: *WEEE recycling, passport, ideality, methodology*

1. Introduction

Currently, at European level there is an emphasis on recovery Waste of Electrical and Electronic Equipment. The amount of products which are out of use and must be recovered, register a rapid growth, from 9t million in 2005 to 12t million projected for 2020 [Waste, 2017].

As key EU legislation which increased the percentage of recovered materials, the following can be mentioned [Waste, 2017]: the first WEEE Directive (Directive 2002/96/EC) entered into force in February 2003, replace in 2012 with the new WEEE Directive 2012/19/EU, the RoHS Directive 2002/95/EC) entered into force in February 2003, revised and replace by RoHS Directive 2011/65/EU which became effective on 3 January 2013, regarding the use of hazardous substances in electrical and electronic equipment etc.

In this paper the authors present some contributions regarding a product recycling passport as well as a methodology for evaluating recyclability of a product based on comparison with the ideal recyclability [Hîncu, 2008].

These two instruments are part of a larger research which will be completed by the end of this year and is intended to create a virtual hub of eco-innovation that will allow an easier connection between producers, recyclers and authorities.

In addition to the two instruments presented in this article, the eco-innovation hub also includes a methodology for multi-criteria analysis, a library of eco-innovation and a discussion forum.

2. Recycling passport

The recycling passport is constructed as a computer application which contains two main sections, respectively, Section I - for the manufacturer and Section II - intended for the recycler.

The section for the manufacturer contains several modules: a module that allows manufacturer account setting, if the manufacturer does not have an account; a module that allows the manufacturer to sign in, if the manufacturer has already created an account; a module that allows password recovery for the manufacturer account; a module that allows the creation of a product recycling passport by a manufacturer; a module which enables the bill of materials/ recycling data; a module which receives requests access, enables agreement generation and ID and password transmission.

The recycler section contains several modules made in the software application, like: list view manufacturers module; list view product visualization module; first page of the recycling passport visualization module; request access to passport module; receive agreement from the manufacturer module; designation and transmission agreement to the manufacturer module; receive ID and password from the manufacturer module; application access module; print passport and obtain reports and statistics module.

Based on the above specifications the interfaces of recycling passport were designed in a complex but easy to use application included in the eco-innovation hub.

In the manufacturer section, he can create an account which he can then access whenever a recycling passport is loaded. Within the application the manufacturer can create recycling passport which is comprised of the header, the general definition of the product, the definition of the entire product, assembly drawings and detailed definition of hazardous materials, disruptive materials definition and profitable materials definition.

Within the recycler section of the application, any interested recycling company may view the list of producers who have uploaded recycling passports and the list of products for which each producer uploaded recycling passports. Also, the recycler may initially view only the first page of the recycling passport. After requesting access he can view and use the entire recycling passport, and he can also generate various reports and statistics on the amount of materials obtained from recycling.

Other important specifications of the application are: the application must be available and operational 24 hours/ day; stand-alone operation of app, so that it runs on the eco-hub website without other add-ons; feature to archive the results for a user specified time and generate reports according to both the producer and the user. The most important information is related to quantities of materials and, primarily, potential profit-making materials.

3. Recyclability evaluation methodology

In order to generate the global indicator of the level of recyclability, an application was made using the operating environment LabView [Savu, 2014]. It was designed as an interactive questionnaire allowing the user to select responses from a user-friendly central panel. The application is divided into two units: the Front Panel or user interface and the Block Diagram or programming interface.

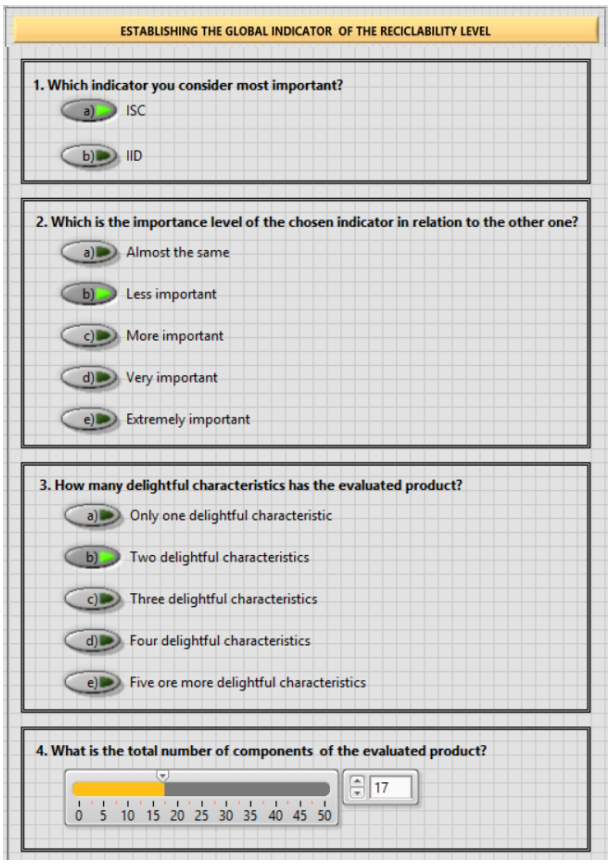
The model for assessing the recyclability of the products is based on the calculation of the global indicator of recyclability performed by summing two weighted indicators, the recyclers' satisfaction indicator, I_{SC} and the ideal recyclability indicator, I_{ID}, with the relation:

$$I_{NI} = I_{SC} \cdot p_{SC} + I_{ID} \cdot p_{ID} = I_{SC} \cdot p_{SC} + \left(\sum_{k=1}^{26} i_k \cdot q_k \right) \cdot p_{ID} \quad (1)$$

where p_{SC} and p_{ID} are the weights of the two indicators, i_1, i_2, …, i_{26} are the indicators of the recyclability degree, q_1, q_2 …, q_{26} are the weights of the recyclability degree indicators. Setting the weights for the two indicators p_{SC} and p_{ID} is done by programming of Boolean structures as a set of questions regarding the significance of an indicator in relation to the other. Selecting the appropriate answers the application generates values for the two weights, thus influencing the designed structure of the program. After running the above mentioned sequential structures, the weights values of the two indicators are generated in the front panel of the application (figure 1).

Within the proposed methodology and application, the recyclers' satisfaction indicator, I_{SC}, refers merely to the delightful characteristics from Kano's model [Hîncu, 2012]. Considering the abovementioned, a Boolean structure is proposed for the generation of the questions. The sequential structure is run by selecting the appropriate answer.

Running iteratively of the sequential structures must generate the value for the recyclers' satisfaction indicator, I_{SC}.



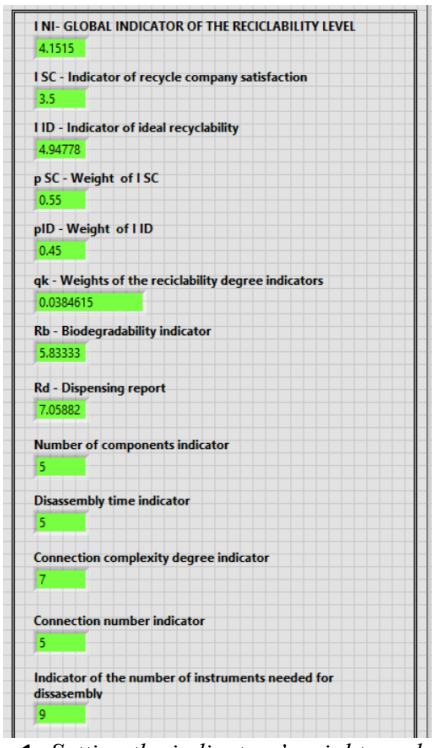


Figure 1: *Setting the indicators' weights and values*

The ideal recyclability indicator, I_{ID}, takes into account the products' ideal degree of recyclability. The methodology proposes to quantify the products' ideal level of recycling with 26 indicators, which are used for measuring the ideal recyclability, assigning them gradeds on a scale from 1 to 10.

The biodegradability indicator is calculated as the ratio between the number of biodegradable items and the total number of dispensable elements. This is done by programming in the front panel two numerical structures which offer the possibility of being set from the keyboard with values desired by the recycler.

When selecting appropriate values, the program runs the sequential structures in real-time, displaying in the Front Panel the calculated ratio of biodegradability.

The dispensing report is calculated as the ratio between the total number of dispensable elements and the total number of elements. ***The number of components indicator*** is evaluated using sequential structures and is posted in the Front Panel in real time. ***The disassembly time indicator*** is calculated by programming in the block diagram of a Boolean structure. When the user selects the appropriate answer, the structure runs in real time and shows the calculated value in the front panel of the application. All other indicators are generated in the same way as the disassembly time indicator (the main differences are in the number of available options and the number of the reference intervals): Connection type – Connection complexity degree, Number of connections indicator, Instruments necessary for disassembly indicator, Object segmentation indicator, Space segmentation indicator (degree of "porosity"), Surface segmentation indicator, Rhythm coordination indicator, Action coordination indicator, Dynamization indicator, decrease of the degree of human involvement indicator, controllability indicator, Mono-bi-poly-similar objects indicator, Mono-bi-poly-various objects indicator, indicator of the nature, type and dimensionality of system functions, System complexity indicator, number of energy conversion indicator, number of freedom degrees indicator etc. The questions which correspond to each indicator are constructed

by connecting Numeric Control Boolean structures which offer the possibility of being set from the keyboard with values desired by the recycler. A recommended interval for the set values is also available for guidance of the user. For this type of questions, the user needs to both select the corresponding button and type in the value included in the specified range. Other important indicators for measuring the ideal recyclability are: smart materials, density, the macro to nano evolution, usage of colours, asymmetry and the convolution degree.

The convolution degree indicator is evaluated with the convolution coefficient, *Cc*, which is a measure of the ideality degree of a system and is defined as the ratio between the number of fields and the systems' total number of elements – substances and field with values in the [0, 1] interval.

In this stage of the application all the components of the ideal recyclability indicator, I_{ID}, must be calculated.

The weights of the recyclability degree indicators, q_1, q_2 …, q_{26}, are calculated in a similar fashion with the p_{SC} and p_{ID} weights.

Using relation (1) the global indicator of the recyclability level is programmed in the Block Diagram and shown in the Front Panel. A small part of the Block Diagram, which constitutes the base of the "SmartRecycle" application, is presented in Figure 2.

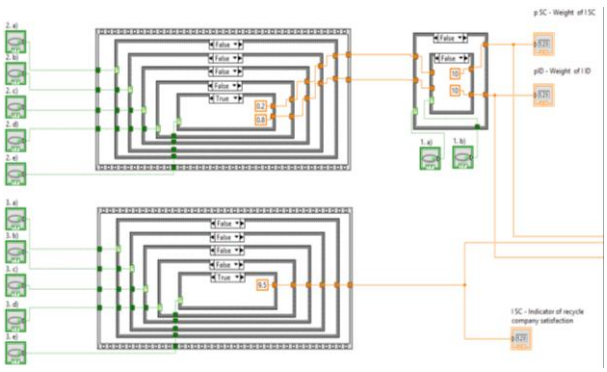


Figure 2: *Section of the Block Diagram which corresponds to the indicators shown in Figure 1.*

The Block Diagram was designed using the LabView 2011 programming environment, by defining all logical structures, virtual instruments (VIs) and toolkits necessary for the accurate calculation of the recyclability level global indicator.

4.3 Conclusions

The recycling passport and the recyclability assessment methodology based on idealism were made as two informatics applications which can run independently on an eco-innovation hub.

In the context of the European directives for disposal of electronic products, the two instruments enable a closer link between producers and recyclers and facilitate the conditions in which the exchange of information on recovered materials can be achieved.

Acknowledgement

The research work was performed under project entitled " Eco-innovation virtual hub for recycling electrical and electronic equipment waste - EcoInnEWaste ", Project no. 320/2014, Cod PN-II-PT-PCCA-2013-4-1400, financed by the Romanian Ministry of Education and Scientific Research, through its dedicated body (MEN-UEFISCDI), in the "Partnership in priority domains - PN II" programme.

References

1. [Hîncu, 2008] Hîncu, D., Andreica, M., Ionescu, G. et al. *Managing the Ideality Concept and the Evaluation of the Innovation Level*, 9th WSEAS International Conference, 2008, Bucharest, Romania.
2. [Hîncu, 2012] Hincu D., Ionescu N., Ciocoiu N., *Influence of Product Design on Urban Environment Quality by Using WEEE Recycling*, 2012 IFME World Congress on Municipal Eng. Sustainable Communities, Helsinki, Finland, June 4-10, 2012,
2. [Savu, 2014] Savu, T., Abaza, B., Spânu, P., – *Reprezentări grafice - Îndrumar de laborator*, Ed. Printech Bucureşti, 2014.
3. [Waste, 2017] Waste Electrical & Electronic Equipment (WEEE), Available from, http://ec.europa.eu/environment/waste/weee/index_en.htm, accessed march, 15, 2017.