The Use of Decision Support Systems for The Handling of E-Waste in a Circular Economy

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Electronics have become an integral part of everyday life. However, they have become a double-edged weapon; with the constant advancement of technology and electronics and its involvement in most daily tasks leading to the continuous upgrading of electronic devices and equipment while discarding of used ones and consequently bringing about the problem of electronic waste. E-waste contains a mix of materials, over one thousand different materials (Lahtela et al., 2022), with varying properties; some of which are non-degradable, hazardous materials, ferrous and non-ferrous or ozone-depleting chemicals. Among the materials included are heavy metals, precious and rare earth metals as well as plastics, glass and persistent organic pollutants (Habib et al., 2022; He et al., 2022; Tansel, 2017). This complicates the safe handling of e-waste and gives rise to the continuous optimization of the handling process with the goal of minimizing waste.

In order to have an efficient and cost-effective handling process of e-waste, it is important to determine precisely the possible gains from each type and component of e-waste handled. Computational sustainability, a field that uses the recent advancements in computation and modelling in order to help solve the complex problem of sustainability with its numerous variables, can be used in the development of Decision Support Systems (DSS) which consider the various constraints and the relations between the various factors to recommend scenario-based solutions (Foo et al., n.d.; Muñoz et al., 2013; Sinha & Couderc, 2012; Yang et al., 2020). DSS can help support policy and decision-makers in making a more profound decision based on the suppositions of the multifactor model. Computational sustainability combined with material science can help achieve a circular economy and approach zero waste through a more holistic vision to the e-waste problem.

One way of developing DSS is using ontologies to build the framework. For this purpose, the work done in this research aims to investigate existing ontologies for e-waste and integrate or develop an ontology that can be used as the core of the DSS, in addition to investigating and modelling the various types and components of e-waste and their respective material content as well as the various handling and treatment techniques and categorizing the impacts of various handling techniques in terms of their sustainability.

These data would then be used to build the different layers of the DSS. The base layer which represents the core of the DSS consists of the ontology which models the components, handling techniques and their impacts. The ontology is then queried for data based on inputs from the user such as the type of waste, impacts to avoid and materials sought, and the data retrieved from the ontology would then be shown in a simple GUI program to the user.

The outcome of this work was the crafting of the e-waste ontology that was developed from scratch using Protégé software. Guided by the methodology provided by Keet (2018) and implemented by Hou et al. (2015), the ontology was narrowed down to cover in its natal phase only solar PVs; however, the ontology remains modular to promote reusability and integration of the ontology for future phases and work. Within the ontology, the materials which constitute solar PVs along with their quantities as reported in the literature were loaded. In addition, the various handling techniques and processes were constructed. Finally, the reasoning rules for the ontology were defined to automatically derive relations between various components and processes. A snapshot of the developed ontology from Protégé can be seen in Figure 1.

During the study of the literature to extract the material quantities in e-waste, accurate data on the different types and models of e-waste was scarce. To that end, an additional phase of experimental work was added with the aim to map the materials content of some of the components of e-waste. The goal was to provide more accurate data to then be integrated with the created model and render the decision-making process better informed.

For this purpose, various types of waste Printed Circuit Boards (PCBs) were collected; namely, Motherboards, RAMs, and CPUs. These components of various models were analyzed by means of ICP-MS, ICP-OES and XRF. The data obtained from the analysis responded to the doubts regarding the material content variation among different models of the same e-waste component, shown in Figure 2, as well as the variation among different components (Figure 3). Further work on optimising the waste treatment process is still under investigation.

Figure 1.The general structure of the e-waste ontology developed using Protégé

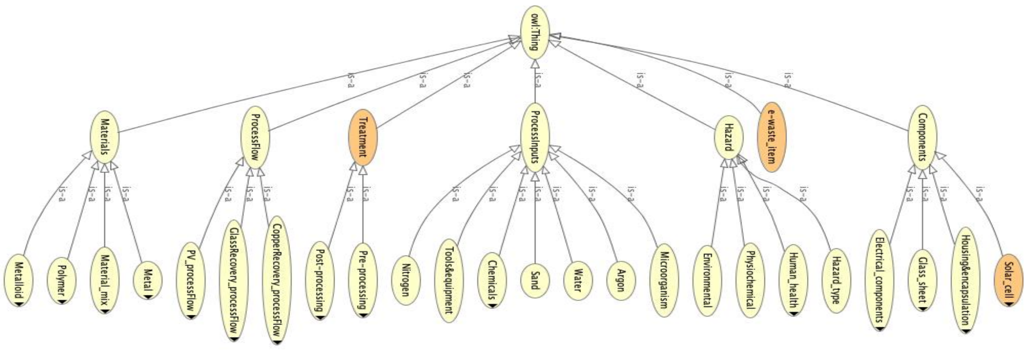


Figure 2. Percentage of material content among various models of Motherboard PCB

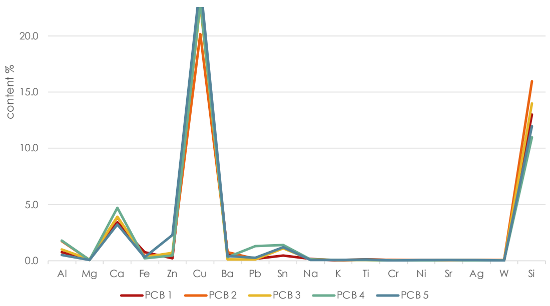
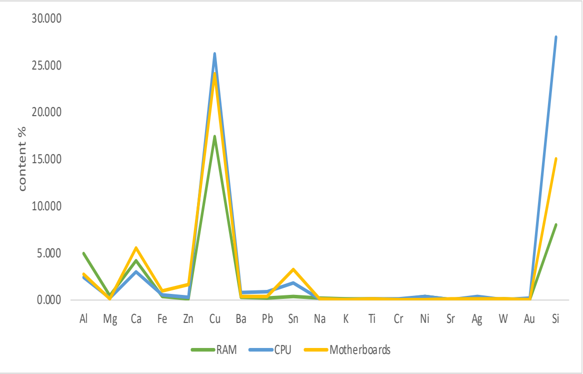


Figure 3. Comparison of material content among different types of PCBs



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