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A New Design Methodology for Manufacturers of Electrical and Electronic Equipment

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ABSTRACT

The European directive for Waste Electrical and Electronic Equipment directive (WEEE) is currently expected to be translated into UK law in early 2006. A key aim of this legislation is to reduce the amount of e-waste going to landfill, by requiring companies who manufacture or import electrical and electronic equipment to take responsibility for it at the end of its life. Despite this approaching deadline, research indicates that many companies are still unclear about the implications this legislation will have on the design of their products. Although the Department of Trade and Industry are working at raising general awareness there are currently few practical tools to guide product design decisions so that the financial implications of the legislation are minimised.

This paper introduces an on-going project which aims to create a strategic web based tool to help design teams meet the requirements of the WEEE directive. SortED, which is being developed with input from a wide range of stakeholders throughout the supply chain, is being designed to help companies quickly identify the implications of the new legislation on their products and explore the options available to them. Created to be ‘designer friendly’, the tool guides the development team through the types of questions that they should be asking to ensure that they meet the requirements of the WEEE directive, whilst minimising costs and maximising any potential revenue.

1 INTRODUCTION

This paper introduces an on-going project being carried out by the Department of Design and Technology at Loughborough University with funding from a HEROBC Innovation Fellowship. The aim of the SortED project is to develop a web based tool to help design teams comply with the requirements of the impending European Waste Electrical and Electronic Equipment (WEEE) directive, which aims to dramatically reduce the amount of e-waste going to landfill by making producers responsible for recovering, reusing and recycling large percentages of the electrical and electronic equipment they sell.

Although the literature [1,2] advocates a much more proactive and holistic approach to promoting and encouraging ecodesign practice in industry, and legislation is notoriously restrictive, the WEEE directive is here to stay and as such is a real issue for companies. Despite this it is commonly recognised by those working in the area that “businesses have been extremely slow to think about these issues, even though they have been on the agenda for
decades.” [3] The authors have also found that many companies (including large multinationals) are still unclear about this legislation and the implications it will have on the products they design. A key problem for companies is knowing how best to develop products so that they meet the specific requirements of the WEEE directive which only endorses the use of certain end of life strategies such as components reuse, and energy recovery.

Through the activities of Envirowise (www.envirowise.org.uk), the Department of Trade and Industry are working at raising companies’ awareness of the WEEE directive by running business seminars at local and regional levels, publishing reports [4-6] and providing free business support in the form of the ‘designtrack’ programme which entitles businesses to a visit from a consultant who will help them reduce the environmental impact of their products. However, there are currently no practical tools which empower design teams to identify the implications that the WEEE directive will have on the products they design nor any which guide them to refocus their design efforts to meet these new requirements and minimise the financial implications of the legislation. Increasingly this means that many companies especially SMEs have to rely on dedicated consultants to help them review their design processes. This might not always be the most appropriate mechanism for companies nor is it especially sustainable. “A critical feature of successful teams... is that they are invested with a significant degree of empowerment, or decision-making authority.” Employee empowerment encourages “broad-based thinking, visioning, and nurturing.” [Ten3 BUSINESS e-COACH , 2005 #824] In other words “If you understand something you own the process.” [7]

In recognition of this, it was felt that there was a need for a strategic tool, specifically developed for design teams, which would provide a basic introduction to the WEEE directive in a way which they would understand and engage with. Findings from previous work carried out by the authors have shown that in order to encourage companies to think about WEEE it is important to sell a clear message and make the process of implementation as easy as possible. As such the tool should help clearly demonstrate to companies how the WEEE directive will affect the products that they manufacture/ import and go on to show them which design issues they should be considering to get the most out of their chosen end of life strategies.

2 LITERATURE REVIEW

2.1 What is the WEEE directive
The WEEE directive has come about in response to growing concerns about the amount of waste electrical and electronic products (e-waste) entering our regular waste stream. “As many as 15 (million) mobiles are replaced each year in the uk, which equates to 1,500 tonnes of potential landfill ...enough to fill the Millennium Dome 14 times over. And more than 70% of us in the uk own a mobile phone.” [3]

Under the WEEE directive all electrical and electronic equipment with voltages up to 1000 AC and 1500 DC has been grouped in to one of ten categories for which a minimum recovery and recycling has been set (see Table 1). Any company which does not meet the recycling and recovery targets and do not comply with the WEEE Directive by Jan 2006 will not be able to sell their products in the EU member states. [8]
## Table 1 Recovery, reuse and recycling targets for the different categories of e-waste and a summary of the typical make up of each category [8]

<table>
<thead>
<tr>
<th>Category</th>
<th>Recovery target</th>
<th>Reuse/Recycling target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category 1: Large Household appliances (e.g. Refrigerators, Freezers, Washing machines, Clothes dryers, Dish washing machines, Cooking, Electric stoves, Electric hot plates, Microwaves, Electric heating appliances, Electric fans, air conditioner appliances)</td>
<td>80%</td>
<td>75%</td>
</tr>
<tr>
<td>Category 2 – Small Household appliances (e.g. Vacuum cleaners, carpet sweepers, appliances for sewing, knitting, weaving, irons, toastiers, fryers, grinders, coffee machines, equipment for opening or sealing containers, electric knives, appliances for hair-cutting, hair-drying, tooth-brushing, shaving, massage, clocks, watches, scales,)</td>
<td>70%</td>
<td>50%</td>
</tr>
<tr>
<td>Category 3 - IT and telecommunications equipment (e.g. mainframes, minicomputers, printer units, personal computing, personal computers, Laptop computers, Printers, Copying equipment, Electrical and electronic typewriters, Pockets and desk calculators, Facsimile, Telephones, answering systems)</td>
<td>75%</td>
<td>65%</td>
</tr>
<tr>
<td>Category 4 - Consumer equipment (e.g. Radio sets, Television sets, Videocameras, Video recorders, Hi-fi recorders, audio amplifiers, Musical instruments)</td>
<td>75%</td>
<td>65%</td>
</tr>
<tr>
<td>Category 5 – Lighting equipment (e.g. Luminaires for fluorescent lamps with the exception of Luminaires in households, straight fluorescent lamps, Compact fluorescent lamps, High intensity discharge lamps, including pressure sodium lamps and metal halide lamps, Low pressure sodium lamps)</td>
<td>70%</td>
<td>50%</td>
</tr>
<tr>
<td>Category 6 - Electrical and electronic tools (with the exception of large-scale stationary industrial tools) (e.g. Drills, Saws, Sewing machines, Equipment for turning, milling, sanding, grinding, riveting, nailing or screwing or removing rivets, nails or screws, welding, soldering, spraying, spreading, mowing)</td>
<td>70%</td>
<td>50%</td>
</tr>
<tr>
<td>Category 7 - Toys, leisure and sports equipment (e.g. Electric trains or car racing sets, Hand-held video game consoles, Video games, Computers for biking etc., Sports equipment with electric or electronic components, Coin slot machines.)</td>
<td>70%</td>
<td>50%</td>
</tr>
<tr>
<td>Category 8 - Medical devices (with the exception of all implanted and infected products) (e.g. Radiotherapy equipment, Cardiology, Dialysis, Pulmonary ventilators, Nuclear medicine, Laboratory equipment for in-vitro diagnosis, Analysers, Freezers, Fertilization tests)</td>
<td>70%</td>
<td>50%</td>
</tr>
<tr>
<td>Category 9 - Monitoring and control instruments (e.g. Smoke detector, Heating regulators, Thermostats, Measuring, weighing or adjusting appliances for household or as laboratory equipment)</td>
<td>70%</td>
<td>50%</td>
</tr>
<tr>
<td>Category 10 – Automatic dispensers (e.g. Automatic dispensers for hot drinks, bottles or cans, solid products, money)</td>
<td>80%</td>
<td>75%</td>
</tr>
</tbody>
</table>

The WEEE directive encourages product take back at the end of life rather than incineration or landfill. Following take back it encourages product reuse, repair or disassembly and recycling. For each of these end of life strategies there are different design implications. For example if you design for reuse you need to consider how to get the product back, how to clean it, where it will be reused, whereas if a product is designed for disassembly there are design decisions about how to group components, how to take the product apart, whether to/where to reuse components or materials, what type of recycling is needed.
2.2 Design for disassembly literature
Since the 1990s there has been a large amount of research which has focused on design for disassembly (DFD), recovery times, strategies to ease disassembly and identifying appropriate end of life approaches for different product categories [9-13]. However, this data tends to be technical in nature and generally inaccessible to companies and design teams in particular, as it is buried in academic papers and reports. Research has shown that designers prefer information to be presented in a non technical language [19,21]. If this wealth of information could be translated into a palatable format for design teams, it would an excellent basis for the development of an end-of-life focused tool which could support compliance with the WEEE directive.

2.3 Understanding how to communicate to design teams
In order to meet the objectives of this project it was important that the output was suitable for both industrial designers and design engineers and as such it was important to recognise that tools which are designed for design engineers are not necessarily appropriate for industrial designers [14].

Traditionally environmental issues were considered to be the realm of technologists, and were dealt with at the production or engineering stages of the product development process (PDP). As a result of this, many early ecodesign tools were designed for later design stages, commonly addressed by design engineers [14]. Research then identified that to be successful, ecodesign should be considered at the early stages of the PDP, where the brief is most flexible [15]. These early stages include the discipline of Industrial Design (see Figure 1) [16].

![Figure 1 Simplified illustration of different disciplines in the product development process [16]](image)

However observations showed that using these inappropriate tools had the effect of alienating industrial designers from ecodesign [16]. It was identified that the different problem solving approaches utilised by industrial designers (divergent) and design engineering (convergent) appeared to explain why tools developed for one discipline was not automatically suitable for the other [17].

“Divergent thinking is characterised by ideation and a fluency with unusually associated ideas… any one of the ideas generated may be acceptable…[whereas]… convergent thinking progresses toward the production of a single, right answer to a problem… characterised by a logical, analytical approach to problem-solving” [18].
So although both disciplines deal in problem solving through ‘design’, they each approach it in very different ways; industrial designers are trained to communicate through design using...
sensory language and visualisation skills, where as design engineers focuses on integrating methods to achieve a final goal. Hence design tools, which are appropriate to one discipline, can not automatically be transferred to another [14].

Subsequent research which aimed to identify a better understanding of the types of support mechanisms that industrial designers require for ecodesign [19], has lead to the development of a model which presents a holistic framework on which to base the development of ecodesign tools for industrial designers. The framework identifies 7 key criteria which need to be combined together to met the needs to industrial designers [20].

![Holistic Framework](image)

**Figure 2 A holistic framework for Industrial Design focused ecodesign tools [20]**

The research which led to the development of this model [19,21] identified that industrial designers need tools that combine guidance, education, information and inspiration via an interface which is dynamic, visual and uses non scientific language.

More specifically it was identified that the guidance should be simple and be provided in the form of a ‘short and punchy’ lists of issues. The information should be relevant and product focused with a similar focus to that which they would use in regular design projects (i.e. materials information, fixings opportunities, relevant legislation). Education should be through the provision of demonstrators which raise awareness by illustrating ways in which others have been successful. Linking together information and guidance ensures neither is provided in isolation and allows users to identify issues and then easily follow them up. It was recognised that case studies have a valuable role to play in supporting designers and allowing them to build up tacit knowledge that they can draw on later. The research showed that combining information and inspirational case studies helped make the information more interesting and bring the examples alive [19,21].

The research findings emphasized the importance of presenting information creatively in a way which appeals to designers, with maximum use of graphics (pictures and colour) and minimal text, and that content should be communicated in a non technical language. In terms of accessibility, it was identified that Industrial Design focused tools need to be take up as time as possible and be dynamic in nature. In general the culture of Industrial Design does
not support or embrace the use of structured ‘tools’ as an engineer might but rather have a “hands-on approach to learning” for example “CAD training is generally delivered in a hands-on way where the designers use the package under the supervision of a trainer for a specified number of hours.” [19,21,22].

One of the deliverables of the research referred to above was the development of a web based tool called 'Information/Inspiration' which was designed in accordance with the holistic framework. Over the last four years 'Information/Inspiration' has also been successfully used by many industrial designers but also by a number of design engineers and engineering students who reported the tool to be very useful. Although this has not been rigorously tested initial indications suggest that tools built on the holistic model in Figure 2 would also be appropriate for design engineers to use.

2.4 Ecodesign strategies
A number of authors refer to ecodesign strategies in the literature [23-25], and use them to organise the way that teams think about ecodesign. Ecodesign strategies are simply approaches which have the potential to lead to a reduced environmental impact. They include approaches such as; materials reduction, energy reduction, component reuse, life extension, repair, local suppliers, alternate energy supplies and so on. 'Information/Inspiration' contains 22 different ecodesign strategies [23]. However, as the WEEE directive only recognises energy recovery, remanufacture, reuse of parts, components recycling and materials recycling, it is these specific strategies that companies need to be focusing on. However it should be recognised that these approaches are limited in the impact and there might still be benefits to considering other more holistic approaches, such as product life extension. These may not help companies to meet the requirements of the WEEE directive but they could lead to economic savings in the end.

3 METHODOLOGY

A key requirement of this project is to develop a tool which will appeal to design teams and help them to understand the requirements of the WEEE directive and what it means for the products they develop. To ensure this aim is met and in recognition of the holistic framework, illustrated in Figure 2, the team have sought to concentrate on two critical elements, the content and the approach.

In order to develop the content for the tool, the project team put themselves in the position of the designers and carried out a range of disassembly activities on different products, to better understand the types of issues that they would face when looking at their products from the perspective of WEEE for the first time. These activities helped with the development of the downloadable worksheets (described later) and also highlighted a range of interesting findings which could be fed back in to the tool, to benefit the end user. Other appropriate content was compiled with the help of a wide range of stakeholders from the supply chain (including dismantlers, recyclers, logistics suppliers and manufacturers), who provided information via semi structured interviews and design reviews. It is interesting to note that the process of sourcing the content for SortED has further illustrated the need for a tool such as this, as it has been a time consuming process to identify the requisite questions and gather the required answers, though much of the information is available, it is widely dispersed and often difficult to access.
At different stages during the development of the tool, different elements have been and will be tested with ‘typical’ users. For example, the downloadable worksheets were tested on the 2nd year Industrial Design students at Loughborough who selected to undertake an electrical and electronic equipment brief for their Sustainable Design module project.

During the next stages of the project, the SortED prototype will be used to test both the quality and nature of the content, and the appropriateness of the delivery mechanism. The tool will be presented to a number of design teams as a working prototype, primarily developed as a mechanism for collecting data and not a finished product. As with previous projects [19] this is a deliberate decision which is intended to encourage discussion and enhance the development process. “Prototypes are a fantastic way of evoking new insights... and of checking what works and what doesn’t... If a prototype is too finished, it actually stops people from commenting.” (p.118) [26] Mock-ups of this nature are regularly used in design practice, and as such are something which industrial designers are familiar with. It is anticipated that this type of mechanism would produce a mixture of positive and negative feedback that would provide a rich insight into the designers’ needs and benefit further development.

A number of design teams will be observed using SortED to tackle a number of exercises and then interviewed afterwards to encourage them to reflect on their experiences. In a previous project this approach was found to be a very effective way of generating useful feedback and intuitive design changes [19].

4 SORTED: A STRATEGIC TOOL FOR DESIGN TEAMS

SortED is a web-based tool designed to be used at the development stage of a project when the team have an idea of the nature of the materials to be used, component numbers and types, product size, product value and the expected product life span.

Two routes of access have been created. Users can follow the structured approach which guides the team through the different questions that they need to ask to ensure that electrical and electronic equipment is WEEE compliant. Alternatively, if users are searching for more specific information they can dip into the relevant section using the side navigation bars or site map.

Following the structured route, users are encouraged to ask three key questions:
1. Which category of WEEE does your product fall into and what are the targets?
2. What’s going to happen at the end of the product’s life?
3. How are you going to get the product back?

It was felt that this simplistic approach would help to make the content of the WEEE directive more accessible. Users can follow hyperlinks within each section to access more guidance and information. This is explained in more detail in the sections below.

4.5 Which category of WEEE does your product fall into and what are the targets?

Within this section users choose a specific route to follow based on their product category, e.g. Large Household appliance (category 1), Lighting equipment (category 5) and then access information only on that specific category. The aim of this approach is to minimise confusion regarding category targets and make the information as specific as possible to the
design teams. By clicking on their selected category users can then access the recovery, reuse and recycling targets for their specific category and the options available for meeting those targets e.g. remanufacture, components recycling and materials recycling. More detailed information on the advantages and disadvantages of each approach can be accessed by following the hyperlink. All of this information is presented in a graphic style as illustrated in Figure 3, in order to enhance accessibility and make the tool more user friendly for design teams.

![Figure 3 Illustration of the graphic communication used within SortED](image)

Within this section users can also download a series of worksheets which form a ‘Disassembly and analysis workshop’ and guide them through an end of life focused analysis of their own product (see Figure 4).

![Figure 4 Sample worksheet for IT and telecommunications products](image)

The workshop aims to give users the opportunity to:
- experience of taking products apart,
- learn what makes things easy to disassemble,
identify whether their product currently has the potential to meet the requirements of the WEEE directive, and
identify where improvements need to be made to promote disassembly / where design changes are needed to meet the requirements of the WEEE directive.

During the disassembly procedure they are encouraged to:
• note any difficulties that they have,
• record the combined weight of the all components made of the same material,
• identify any components that needed to be removed to help them meet their targets,
• record any obvious ways in which disassembly could be improved, and
• where appropriate identify how the product might be redesigned to ensure that it will meet the end of life targets.

Within the section, links are also provided to detailed product Case Studies which allow the users to review the compliance issues associated with the products in that category (see Figure 5). These Case Studies are presented in the format of the worksheets and therefore provide the dual function of demonstrating how they should be filled in and providing detailed analysis information of other similar products. Users have access to detailed images of disassembled products, suggested design improvements identified from practical activities, any specific problem areas which the team identified with the Case Study product and information on product composition, and the typical end of life scenarios that are appropriate to these compositions.

![Figure 5 Example of the type of Case study information provided within SortED](image)

**4.6 What’s going to happen at the end of the product’s life?**

This section of the web tool introduces the different end of life options that designers have and explains how the options that they will select will be influenced by the type of product they are dealing with. It encourages the users to ask questions such as:

- Can you remanufacture your product?
- Can you or anyone else reuse any or your parts?
- Which components could be easily recycled?
- Which materials can you recycle?

Each of these questions links to further information on the selected topic, as well as more detail on the related design and business implications of a selected approach. Users can also access links to suppliers who for example, provide a remanufacturing service and links to
illustrative Case Studies which outline how other companies have successfully used the selected approach. The theory behind including this type of information is the belief that it will help users get a better understanding of types of business models that others have used to make end of life responsibly economically viable and demystify the process for them.

Throughout this section links are made to the Disassembly area, which provides information on the different types of disassembly (e.g. manual, brute force and active disassembly) and the design techniques which can be used make the process more economically viable.

4.7 How are you going to get the product back?
Currently this section outlines what is known about the collection procedure, and provides examples of how others currently handle business to business, and business to consumer collection. However, the WEEE legislation was originally expected to become British law in August 2005 and has now been pushed back to January 2006, this lag has also delayed the release of information regarding the types of collection mechanisms which will be used to make the WEEE directive operational. More information will be added to this section when decisions have been finalised by government.

In the future area an additional area which outlines the requirements for covers reporting sales, recovery and compliance might need to be added to SortED.

5 NEXT STEPS
At present the project is in the developmental stage and work continues to focus on identifying and collating relevant content for the site, and translating it into a format which is appropriate for the intended user. Once the development has reached a stage where users can be asked to evaluate the effectiveness of the tool, the testing stage will get under way. Designers and product managers will be observed using the tool and then be interviewed to assess whether or not the felt the tool effectively answered their specific needs. Findings will be fed back in to the design in an iterative process.

Running in parallel with the development of the physical tool, a business plan on which to base applications for further funding, is being developed. The aim in the future is to develop SortED into a commercially viable tool, which will be available to help design teams identify and manage the requirements of the WEEE directive.

6 REFERENCES


