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DESIGNING PRODUCTS FOR MULTIPLE LIVES

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ABSTRACT
If we are to make more efficient use of our investments in producing new materials, it will be necessary to find ways to make further use of products after they reach the end of their life in service. If efforts are made during the design of a product to incorporate features to expedite further use, the process can be made easier, returning further value and reducing our dependence on scarce resources. There are many opportunities to incorporate such considerations into education courses for both engineers and product designers. Currently there is little in textbooks or course materials to help students or practitioners to understand these opportunities and challenges. The British Standards Institution has produced general guidance on the points to be considered by designers in a new standard BS8887 Part 3 Guide to choosing an appropriate end-of-life strategy [1]. This paper reviews that standard and considers the potential impact on design practice and education.

Keywords: BS8887, end-of-life strategy, circular economy

1 INTRODUCTION

There is a need to be more pro-active on the end-of-life question and its overall implications, and how it relates to the management of the design process [2]. The series of British standards, known as BS8887 *Design for manufacture, assembly, disassembly and end-of-life processing* [1, 3-5], has been developing for some years with detail work in a number of areas. For convenience, this series of standards are termed the 'MADE' standards. They are advisory, recommending best practice – they are standards to aspire and not adhere to. Bringing these parts together with more general guidance, work on several broader based documents is now bearing fruit. The first general standard has now been published as Part 3 *Guide to choosing an appropriate end-of-life strategy* [1]. This is intended as guidance for designers to make the most efficient use of the investment in extracting and processing new materials by giving the product greater value by further use. It is important that this is not simply seen as a trendy or timely addition to a Product Design scenario but incorporated into the design process as an early decision.

At the end of a life in service, the decisions on how to use a product, or its components, for another period of service can be made much more easily and cheaply if the original design incorporates features intended to aid one of several options available. Any extra costs incurred in the initial production can be recovered several times, over further lifecycles.

The paper seeks to demonstrate that these choices are not easy. They are not an automatic “Plastic is bad” answer but need to be a carefully considered process where each option is part of the designer’s consideration at the earliest design stage – and at all subsequent stages.

1.1 Designing products for multiple lives

A particular aspect of designing for multiple product lives is that introduced by Stewart Brand in his book on how buildings learn [6]. Brand’s thesis is that most buildings are designed for shorter lives than they actually have. They have multiple lives. They are generally redesigned several times during their life spans. What he suggests is that the better buildings are those that are more suitable for their range of future purposes and uses. He complains about buildings that win architectural awards for their stunning visual effect that isn’t translated into a useful building for the end user – who may not be the user for whom the building was designed. He suggests that many architectural awards ignore those later users. The book suggests two ways to achieve an effective building for multiple lives. First is what he calls the ‘low’ route – design the building as if it were a shed that can easily be reconfigured

to be something other than what it was designed to be when that initial use has expired. This is achieved by making the building flexible, modular and changeable – and deliberately ignoring high visual merit. There is an alternative, he suggests, which is the ‘high’ route. Here the building forces its occupants to modify their lives to accommodate the appreciated character of the building.
But other products are seldom considered in the same manner. Many consumer products that are deliberately designed to make servicing, modifying and adapting them difficult or impossible. We, the product designers, do not generally design for multiple lives: we do not consider how others might wish to adapt, modify, change our products so that they have a life beyond their considered product lifespan. Things need to be designed to have many use periods. In practice, the product lifespan will be likely to be longer than the designer envisaged. Which parts need to be changeable, adaptable, and easily modifiable? How do we ensure compatibility with novel, yet to be invented technology that might be incorporated into the product? Where is it likely to be necessary? Perhaps the ‘systems’ parts of the product where the adaptability needs to be greatest – the control systems, the electrics, and even mechanics rather than in the main structural specifications of the product.
This approach has fuelled the development of the end-of-life choices that have been incorporated within the British Standard 8887 Part 3 [1].

2 AN EXAMPLE

More than sixty years ago, in 1956, the first prototype Routemaster bus was built [7]. The story is documented well in the BBC2 programme series *Perpetual Motion* from 1992 [8]. This bus was somewhat unusual. It was designed as a bus from the outset, owing little to any commercial chassis. The main structure was an integral aluminium construction, and the front suspension was independent, giving a more comfortable ride than the previously used solid front axle.

Figure 1. Routemaster bus – picture taken during its last week of regular service in London in November 2005. This example is of the slightly later, ‘long’ version with an extra 3 feet of length

But perhaps the most crucial design characteristic of the bus was how its end-of-life scenario was developed. The specification, developed by the operator, defined the vehicle’s life as 30 years, with a major replacement overhaul after every ten years. Then the main wearing surfaces of the seating and similar items were to be replaced, and the bus refinished before returning to service. Also, all major mechanical items were designed for ease of maintenance. Each was replaceable during a single eight-hour shift, giving minimal time for servicing. The engine and gearbox were thus separate units, each connected by a shaft, so that they can be removed independently, and they were arranged so the rear axle was not disturbed during the process so the vehicle could still be moved within the workshop.
History has been kind to the Routemaster. Although designed for a thirty-year life span, several of the buses are still in operation today, sixty years after the model’s original conception, and the bus has become a recognisable symbol of London. This example demonstrates that many alternative end-of-pathway choices might be envisaged.

3 THE CHOICE

The ranges of choices for end-of-life treatment were articulated in BS8887 Part 1 [3]. These are shown as the major headings in Table 1.

Table 1. End-of-life pathway choices [3]

	REMANUFACTURE: Returning the product to the market in as good or better condition as the original, with an equivalent warranty.
Requirements	A functional market requirement likely to remain stable for several life cycles (perhaps with cosmetic changes).
Advantages	Makes the maximum advantage of the initial investment in energy, materials and manufacturing facilities. Later product cycles may be upgraded.
Disadvantages	May be overtaken by new technological or legal developments. Requires a long-term commitment to the product line at company level.
	RECONDITION (REFURBISH): Returning the product to the market in a similar state to the original, but with a lower level of warranty.
Requirements	A functional market requirement likely to remain stable for several life cycles (perhaps with cosmetic changes) but with competing products likely to be available as time passes.
Advantages	Makes a significant advantage of the initial investment in energy, materials and manufacturing facilities.
Disadvantages	Further product cycles will inevitably lead to some degradation and increasing competition. The design may be overtaken by new technological developments, legal developments or changes in aesthetics or fashion.
	REUSE: Returning the product to the market with a lower level condition and warranty.
Requirements	A functional market requirement likely to remain stable for several life cycles, with no expectation of functional improvement.
Advantages	Some recovery of initial investment in energy and materials. Less likely to be overtaken by new technology or legal developments.
Disadvantages	Vulnerable to market changes, technological advances, and competition.
	REPURPOSE: Using the product, or its components, as part of another product.
Requirements	The product, or a significant number of its components, needs to have interface standards which take advantage of its capacity for further use within a new market. A modular design system should be considered.
Advantages	Some recovery of initial investment in energy and materials. New potentials for re-purposing may become apparent during its lifetime.
Disadvantages	New uses, envisaged during the initial design, may not materialize, particularly with longer life-cycles.
	RECYCLE: Recovering the materials used in the product for further use.
Requirements	Product needs to be easy to disassemble into its component materials with minimum degradation. There needs to be a clear recycling route.
Advantages	Some recovery of initial investment in energy of material extraction.
Disadvantages	No recovery of initial investment in manufacture and assembly.
	DISPOSAL: Safely disposing the product as landfill, or similar, or using as fuel.
Requirements	A short-term market, significantly less than a product life expectancy, or may be vulnerable to rapidly changing technologies, market expectations or competition. Any hazardous materials should be clearly identified.
Advantages	No requirements for an end-of-life capability. Materials should be chosen for safe and easy disposal by the customer.
Disadvantages	The entire investment in manufacturing energy and material (as well as design and development costs) has to be recovered in a single product cycle, resulting in a higher cost or a reduction in perceived quality (throw-away).

For more complex products, separate sub-assemblies or components may be dealt with differently. This includes parts normally replaced during routine maintenance and packaging or transport pieces.

4 IMPLICATIONS FOR DESIGN

Decisions taken at an early stage in the design have profound effects on the potential for recovering end-of-life value and reducing environmental impact of the product, especially as it has been estimated that up to 80% of products environmental impact is decided at the design stage [9, 10]

It can be seen that for complex products, different parts of the product may well reach their end-of-life at different points. Thus, end-of-life for the main structural elements might involve reconditioning after a certain period, whilst the switchgear and wiring needs replacing completely and thus has to have a different end-of-life option. So the overall product is refurbished whilst parts are disassembled to their component parts for material recovery or fuel (in preference to landfill, perhaps).

4.1 Making the choice

The reasoning for a choice for end-of-life treatment is detailed in Table 1. Once a choice has been made, the design may be focussed on including those requirements as part of the design specification. These requirements will need to be examined to find the requirements for the specific product.

If full advantage is to be taken of the availability of components, designing to incorporate components or sub-assemblies which have been used before should be taken into account, rather than assuming all parts are novel.

4.2 Information retention

With longer lifecycles, provision should be made to retain the information necessary to process end-of-life options efficiently.

Information should include:

a) the design specification, including material specifications, with reference to specific features incorporated to aid further use;

b) any additional information on specific batches or products, which deviate from the main specification for any reason (customised products, upgrades, manufacturing or material changes, etc.);

c) details of jigs, fixtures and tooling necessary to disassemble and reassemble the products for the next cycle.

For products designed to be recycled, only the retention of material specifications is necessary.

5 IMPLICATIONS FOR EDUCATION

Since the standard was only published recently, there has not been time to incorporate its guidance into existing courses. However, the thinking behind it has influenced those involved and some of that has been introduced in a few current courses and in planning for the future. Here only projections of how courses may be modified can be given.

5.1 Product Design

End of life choices needs to be an integral part of a product design course. Evidence from those who have set up specific environmental courses and even modules generally point to this. If a separate course or module is provided, the topic will migrate into that course or module and be ignored within the rest of the course or in other more general courses, unless it is specifically included in module marking criteria, as it has been at the University of Sussex. How can students effectively demonstrate understanding of the end-of-life choices? It is clear that parroting the standard does not demonstrate this. Another method needs to be found to cover the complex end-of-life options.

An assignment designed to demonstrate how a product is manufactured might be reconfigured to include how it is disassembled and select its various end-of-life choices. Here the learning aspect is developed beyond recall of the options and becomes their application in an exercise.

Within a design course the most obvious exercise to embed the learning is a design exercise, where students are required to make effective end-of-life choices. The exercise might range from the minor ‘redesign a product to show that effective end-of-life choices have been made’, to the requirement to incorporate end-of-life choices within the major final year project.

This requirement as part of a final year project is a practice which has been adopted at the BSc Product Design at the University of Sussex, which has a module, entitled 'The Role of Design in the Circular Economy' as part of the final year content.

5.2 Engineering Design

Much of the above would also be considered within an engineering course. Design considerations will probably form a lesser part of the course than on a product design course. The exploratory kind of assignment might be more appropriate for this kind of course, but the topic needs to be within the design modules as well – as part of the product life cycle and may also be incorporated into a module with sustainability as a theme.

5.3 A suggested student exercise

Given such a course with perhaps a specific environmental module, how might an assignment is written to incorporate these end-of-life issues?

An individual exercise carried out at London South Bank University in 2016 and described in a paper presented to E&PDE [11] was part of a manufacturing module and thus took more of an overview than is required here. Only 10% of the marks were assigned to that aspect, and the assignment was not a redesign exercise. It produced a reasonable overall approach to the whole of the MADE scenario, but end-of-life options were not investigated particularly well.

A better approach would suggest a group exercise will produce a more useful learning experience, and that much student learning will take place when they carry out the exercise, which needs to be of a practical, collaborative nature and not an essay-based work. A 'deconstruct and redesign' exercise includes opportunity for learning to take place. For a product design course, a strip-down and redesign of a common household product (such as the kettles used in 2016 [11]) would, with the right questions asked, constitute a suitable basis. For engineering courses the only significant difference would be in the kind of product that was chosen for the exercise. The product must not contain too many parts, and the parts must be varied, particularly in materials and end-of-life possibilities. Each group of students must be supplied with an example of the product concerned, and asked to strip the product down, producing a diagram similar to those in the *Things Come Apart* book [12]. For instance, a small model servo motor such as shown in Figure 2 would contain many of the elements required. Electrical components and assemblies are realistic but complicate the end-of-life arrangements.

The exercise would focus on redesign to enhance the end-of-life scenario. This might include altering materials for improved recycling, incorporating modular construction to allow for reconditioned and replacement parts. Whilst a group report would be a suitable assessment tool, asking students to do a presentation might enable other students to learn more, and this can be carried out in a contrived way to cut down on assessment timing by using approaches such Pecha Kucha [13]. An individual reflective element might be considered. What had each student learnt from the exercise?

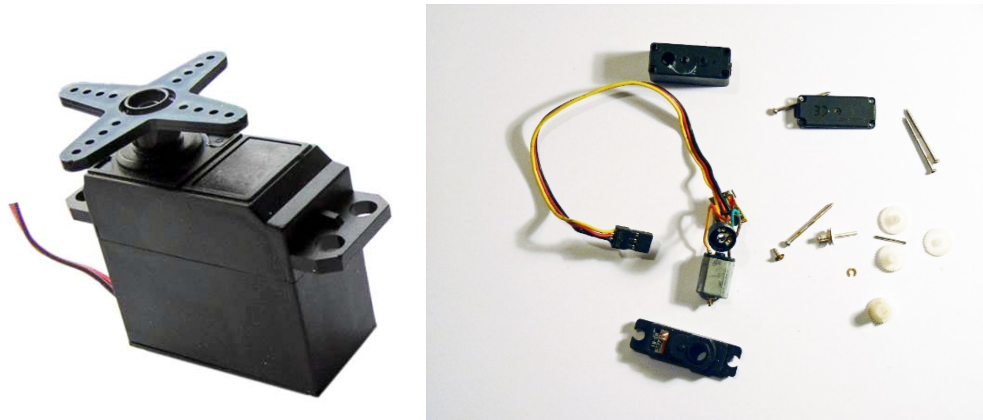

Figure 2. A small model servo motor suitable for a deconstruct and redesign exercise.

The assessment criteria would need to be concentrated on the learning aspects from both working out the possibilities for the end-of-life and the redesign aspects.

The exercise would probably be best aimed at senior level students where high level learning outcomes were required, as it is clearly aimed at producing this kind of learning experience – in the

UK this would be either the final year of a BSc or BEng course or one of the last two years of an MEng or MDes course, or perhaps within an MSc course.

A similar project was recently run at the University of Sussex in the module ‘Design for Manufacture’, undertaken by both second-year undergraduate engineers and product designers, working in groups of five or six. Each group was free to select a consumer product, to the value of £15-20, then analyse and redesign by applying principles, methodologies and techniques for Design for Manufacture. During lecture sessions the students receive an introduction to designing for the Circular Economy, which covers design for disassembly, design for multiple lives and selection of materials. As part of their redesigned product, many groups demonstrate how they have altered the design to take these elements into account. As Autumn 2017 was the first time this project ran, it is too soon to discuss whether this is the best to demonstrate student understanding of designing for multiple lives; however, the above suggestions could be included in future to gather deeper insight.

6 CONCLUSIONS

End-of-life considerations are important for designers. They are not to be regarded simply as faddy and peripheral, but specifically included within both initial degree training and professional practice. Much of this needs to be couched within a design framework, as it is at this stage that the greatest benefits can be achieved. These aspects will always produce personal tensions within designers and users – not simply on how they design things and systems, but also on how they consume, use and operate in their daily lives.

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