CENTRE FOR REMANUFACTURING & REUSE

Designing office furniture to aid remanufacture

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1 Introduction

Remanufacturing can be defined as: "A series of manufacturing steps acting on an end-of-life part or product in order to return it to like-new or better performance, with warranty to match." In the case of end-of-life office furniture, this process could take different forms such as:

- Stripping down a product into its components, evaluating them, replacing where necessary and re-assembling into a similar product
- Stripping down a product into its components and making different products with them

Such processes could potentially be undertaken by the original product manufacturer or by a third party and a number of benefits can result:

- Avoiding the wastage of resources: there is a finite supply of material in the World. Remanufacturing can help to preserve the resources embodied within products and components. It can also preserve the energy used to create the components.
- Reducing the generation of waste: end-of-life furniture is thought to generate 2 million tonnes of wood waste alone in the UK, with wood accounting for around 60% of the weight of furniture[a]. Historically, around 90% of this material has been disposed of to landfill. Remanufacturing prevents the need for such disposal
- Generating wealth through service provision rather than material consumption: the traditional business model involves manufacture and selling. Furniture manufacturers need to sell twice as much product to double their profits and this will consume twice as much resource. Remanufacturing, refurbishment, repair and reuse offer opportunities to create profit through the provision of services to prolong the useful lifetime of furniture with an existing client or through selling it to a subsequent user
- Responding to stakeholder pressures: improved ability to sell to organisations requiring a furniture product with improved environmental performance

[a] WRAP (2004) Evaluation of the market development potential of the waste wood and wood products reclamation and reuse sector. A report prepared by BFM Ltd

2 Barriers

A range of barriers exist to the remanufacturing of office furniture. Those which can potentially be influenced by product design include:

2.1 Manufacturer barriers

- Cost implications associated with the logistics, storage, handling, sorting, dismantling and remanufacture of end-of-life product: potentially addressable through:
    - Use of original product designs which rationalise component numbers and which facilitate quick disassembly and the swift identification, sorting and evaluation of components
    - Design for off-site refurbishment which can occur on the customer site. This will require simple methods of fixing for sacrificial elements – i.e. those which are most likely to need replacement
    - Design which facilitates third party remanufacturing. Products will need to be designed with obvious methods of dismantling
- Generation of costly waste through the receipt of furniture with unusable components:
    - As above, ensuring dismantleability and the reusability of components. The rationalisation of component numbers and the types of materials will aid the process as will the use of higher durability components which are suitable for a range of models
    - Design which avoids short term trends in favour of timeless designs will improve the usability of remanufactured components by avoiding elements which are obsolete due to aesthetic concerns
- Quality concerns associated with the reuse of components:
    - Design with an emphasis on the use of proven, durable and appropriate quality components which are suitable for remanufacturing
    - The use of sacrificial elements – with the preservation of the higher value core and the easy replacement of parts which are most prone to failure (e.g. the covering on a chair)
- Product / component identification: ensuring design encompasses labelling, especially for plastic components
- New product displacement: there is often a concern amongst manufacturers that the process of remanufacturing will harm their

business as it will reduce the market for new goods. By integrating alternative product service systems into the business model, this threat can be turned into an opportunity.

Rather than just focussing upon the sale of the original product, manufacturers need to consider the addition of value throughout the life-cycle. A suitably designed product will faclitiate this process by ensuring that value can be added through cost effective updating and refurbishment. If the product service system allows the manufacturer to retain ownership of the furniture, there is an even greater incentive to incorporate design for remanufacture in the original product.

2.2 Furniture buyer and end-of-life furniture disposer barriers

- Dated appearance / stigma: most desking and chairs sold 15 years ago will appear old fashioned, in addition to which, corporate users may object to “second-hand” goods. The exceptions will tend to be higher value products which focussed upon design and these will often still be desirable and have a good market value after many years.

- Mismatch of supply and demand: office furniture may be sold in batches of a single unit up to several thousand units at a time. Designing with common components will help to ensure that end of life product can be cannabalised to generate usable parts without the requirement for an unfeasibly large inventory of stock

3 Reasons for Product Disposal

In order to know how best to deal with discarded furniture, it is necessary to consider some of the reasons why it reaches end-of-life.

3.1 Organisational Change

Organisational change is an inevitable fact of corporate life: restructuring, relocating, mergers and downsizing all result in major upheaval of lives, buildings and products. Changing the number of staff, the profile of staff or even the managerial chain of command frequently results in the drafting of a new office floor plan that requires more product, less product or just a different type of product. End-of-life product associated with organisation change is often perfectly usable in its existing form.

3.2 Regime Change

Even if the arrival of a new leader does not trigger the sort of structural changes described above, it is common for him or her to announce their presence by a physical alteration of the office landscape: out with the old; in with the new. A revitalised décor is used to signal a fresh approach to work: open plan space is replaced by cellular office; clusters are replaced with bench desks and so on.

Sometimes the change will be logistic; other times it will be simply an issue of imposing a style that better reflects the new managerial approach: something more assertive or more consensual or something more democratic . . . products are used to project the new corporate ethos. End-of-life product associated with regime change is often perfectly usable in its existing form.

3.3 Technological Change

Furniture that supports technology is prone to the same short life expectancy as the technology itself. For example, ever since the introduction of computers into the New York Stock Exchange in the 1970's, their rapid evolution has had a continuous impact on office products, leaving manufacturers and designers struggling to catch up and meet the ever-changing demands of IT managers.

The deeper desks and corner workstations developed to accommodate CRT monitors have had to make way for the slimmer, more spatially efficient products that support flat screen technology and just as the industry is starting to address the issue of heat gain from multiple tower units the next big thing has already appeared on the horizon: cloud computing and blade computing seems likely to shorten the useful life of the latest water-cooled workstations.

The chief designer of SBFI, Chris Coles, describes the banking sector as an industry 'driven by competition, where a fractional second's delay means the difference making or losing a deal'. In such an environment, it is the processing speed of the system that trumps all other issues and it is that which drives the turn over of the technology and the furniture in which it is housed.

Consequently product that it is designed with a physical longevity of twenty years or more is commonly replaced within four. Although this obsolete stock is used to equip the Disaster Recovery Floor - a contingency space intended to maintain business flow in emergencies – it generally lingers there, unused and redundant, for a further four year period before making its way to the recycling chain.

End-of-life office furniture associated with technological change will typically be a number of years old and will require a greater degree of effort to make it suitable for resale – with remanufacturing being a potential option.

3.4 Office Refurbishment

Not all business cultures are prone to constant change. Some institutions are inherently conservative and in these environments, it is simply the wear and tear of prolonged daily use that causes office furniture to reach end-of-life.

Even in the most stable business cultures, surfaces, fabrics and finishes inevitably start to look tired and need to be rejuvenated or replaced. End-of-life office furniture associated with refurbishment will typically require a greater degree of effort to make it suitable for resale – with remanufacturing being a potential option.

3.5 Product Failure

Some of the redundant furniture removed from offices is simply broken – either in part or entirely. This might be the result of too many years faithful service, a careless porter or a particularly raucous Christmas party.

The waste that results from breakage will tend to be occasional and comprise of single pieces, rather than the many pieces that are due to office restructuring or closure. Therefore, there are less likely to be the economies of scale required for off-site remanufacture. In addition, product failure can occur in a range of ways, so a greater input of time and effort (and hence cost) will be required to identify the problem and solution in additional to obtaining any components necessary for repair.

4 Design best practice to facilitate remanufacture

As demonstrated above, design for remanufacturing is an essential first step if the maximum environmental and economic benefit is to be obtained from the process. A series of considerations are listed below to aid in this process of design.

4.1 Product service systems

For most businesses, there would be no point in investing heavily in a well designed product which maximises the value of its end of life components, if someone else is going to get the benefit. This would be the case with a traditional business model of make, sell and wash your hands of the item. If a company wants to double its profits, twice as much furniture will need to be sold. This will consume twice as much raw material, meaning that increased profit essentially leads to increased environmental impact. Such a system concentrates on the product rather than whole life service package.

Alternative product service systems involve different ways of configuring the manufacturer and customer relationship. They seek to add value through service rather than material consumption. If successful, they will decouple profit from resource consumption, a vital element of sustainable production.

This could work at a number of levels for the furniture sector. At its simplest, a manufacturer would sell its product as normal, with the addition of services such as:

- Refurbishment: occasional cleaning and repair of products either in-situ or when returned to base. This refurbishment might extend to changing the upholstered sections of chairs to remove stains &/or update product colours.
- Extended warranty: an extended period of providing repair in the case of breakage or damage
- Take-back: the provision of a trade-in value for old furniture when the customer purchases new product from the same supplier

The next level of complexity would involve selling the use of the product rather than the piece of furniture itself. Typically through an arrangement with a finance house, the customer will effectively buy a service such as the provision of office desking and seating for a set number of people. The furniture will remain the property of the manufacturer &/or the associated finance house. By retaining ownership of the product, the manufacturer has a vested interest in designing, manufacturing and servicing the product in a manner which preserves the value of the embodied resources and energy within the product.

Successful product service systems require:

- A clear picture to be developed regarding the market for the remanufactured item
- Adequate incentives for all stakeholders along the value chain with respect to the end of life product
- Concurrent design of the product, its service system and business model so that they work effectively together

4.2 Optimising the amount of material used

It is often environmentally beneficial to minimise the amount of resources needed for a given product. Two key areas in which this might be achieved are the avoidance of duplication (where two parts are doing a job which could be performed by one) and the over-specification of material gauge.

For example, an office pedestal unit might have a solid base to the lowest drawer and a solid base to the unit as a whole. The duplication of material would be reduced if the solid base was replaced by a couple of strips of board. However, in the case of remanufacturing, such changes would not always be beneficial. For example, from a dismantling perspective, it would mean the removal of two components rather than one.

Reducing the existing gauge of material or "light-weighting" can result in a requirement for less material per product. As well as the direct benefits of lower material consumption, the reduction can lead to lower transport costs and impacts as well as a need for less packaging as the amount of drop protection will be lowered. This will normally be a good thing in a world of finite resources. However, in the case of remanufacturing, we would not want to reduce the gauge to a level which reduced the expected lifespan of the product or which compromised the ability of the components to be used again.

4.3 Optimising the choice of materials

One of the most common reasons for the disposal of office furniture is *change* whether of leadership, premises, managerial structure or technology. The 'waste' furniture generated by this type of event, is frequently not waste at all. On the contrary, it is often of a very useable quality - it has been discarded, not because it is obsolete or broken, but simply because it has failed to keep pace with the organisation – ideologically, technically or aesthetically.

Furniture that responds most flexibly to change will have the edge over that which is conceptually static. For this reason, furniture should be able to be reconfigured to reflect a new managerial culture; it should be able to be dismantled, stored and reassembled during the office refurbishment or move and it should be able to adapt to changes in technology. Key considerations include:

- Simplicity: it is frequently the most simple of products that are the most flexible to plan, the most easy to reconfigure and the most likely to find a

useful second life. When overseeing the design of a new range of furniture for the public sector, Peter Liley, then Design Director of The Crown Suppliers, would repeat the mantra 'simple as a building brick' at every progress meeting. As an architect he understood the value of a building component so simple and intuitive to use: no instructions required, no limitations imposed; just desk, chair, storage and screen - each item self explanatory, self contained and recognisable.

What seemed at the time like a perversely unambitious approach, turned out to make complete sense in terms of ordering, delivery and installation. However, the real benefit of the strategy only became clear as time went on and it could be seen how simply floor plans could be rearranged, added to or reduced in size.

- Physical durability: will the material degrade over time? For example certain types of plastic may discolour whilst the colour of real wood furniture tends to change after prolonged exposure to daylight

- Aesthetic durability: furniture fashions come and go. The grey desks of the 1980s gave way to the beech colour of the 1990s and 2000s. In 2008-10 there is a trend for white and coloured desking. Such trends prove problematic from a remanufacturing perspective as the number of uses of outdated material is much reduced.

- Do products contain a good recycled content where applicable? When remanufacturing a piece of furniture, certain components are likely to become scrap. For these items, recycling is often the best environmental option. However, the demand for materials for recycling will be hindered if there is no demand for the resulting recyclate. Therefore, designers can play their part by choosing components with recycled content where these are available with competitive price and performance

- Are appropriate labels used to identify material types? This is especially important for plastics that are often difficult to identify and which need to be segregated for recycling.

4.4 Optimising the number of components

Rationalisation of component numbers will typically be beneficial for the original product manufacturer and the remanufacturer. Such rationalisation will increase purchasing economies, improve the efficiency of production runs, reduce stock requirements and the potential for mistakes. From the remanufacturing perspective, rationalisation and standardisation will greatly reduce the headache associated with working with materials where each batch is different to the last.

4.5 Optimising the lifespan of components

. . . there is little point designing physical durability into consumer goods that we have no desire to keep Jonathon Chapman: Emotionally Durable Design: Objects, Experiences and Empathy, Earthscan 2005

A longer lifespan is typically beneficial from an environmental perspective as it prolongs the useful lifetime of resources, reducing the requirement for waste generation and virgin raw material consumption. However, there will be certain components where great longevity is not required. For example, if a customer wants an office chair with a traditional foam and fabric covering, these elements are likely to wear much more quickly than the internal mechanics of the chair. We can design fabrics to be cleanable and durable, but after 3 to 5 years of use, many chair covers will start to look worn and the foam will have developed memory. In this case, there would be no point in specifying an extra thick & durable fabric and foam set which will last physically last 20 years, if it will become "uglied out" after 5. Therefore, rather than always designing to extend the lifespan of components, we need to design for the most appropriate lifespan.

Considerations include:

- Design products with a durable core that can be processed by the remanufacturing system many times before requiring repair
- Design using materials, finishes and fastenings with an appropriate durability for the intended lifespan of the product or the component
- Are repair instructions available? For example, a "washing label" approach to product care
- Consider the weakest link. Are any elements more prone to failure? If so, incorporate sacrificial elements (like desk edging) to preserve the value of the most significant components
- Also, integrate short term components in such a way that they can be simply replaced when worn – like the tyres on a car. Embed visual clues into the design that indicate how these components can be removed and replaced.

4.6 Optimising disassembly

> *Did we use common tools to take them apart? Did it take one person more than 30 seconds to reverse a connection? (If it takes longer than that the material might end up in a landfill.)* Herman Miller

Furniture products have traditionally been designed for assembly, to ensure that the products are as efficient to make as possible. If end-of-life opportunities are to be maximised, it is vital that the products are also designed for disassembly. A failure to do so will mean that remanufacturing is not economically viable due to the labour required to dismantle coupled with the low value of the resulting components.

Disassembly will be aided by the following:

- Reduce the number of parts and sub-assemblies in the product
- Use standard dimensions and components

- Minimise the total number of fasteners and types of fastener
- Minimise the number of different materials used (especially plastics)
- Ensure that components are joined in a manner that makes them easy to dismantle, refurbish and upgrade. For example, a chair cover attached using a drawstring and single staple will be much easier to replace than one which is stapled the whole way around. In addition, there will be benefits for the manufacturer in terms of the speed of production
- Ensure materials joined in an optimal manner. Gluing, lamination and other hard to dismantle fixings should be avoided where possible. Examples of easy to disassemble fixings include clips and drawstrings.
- Ensure high value components/subassemblies can be accessed easily (even if this means lesser value materials/components are sacrificed in the process)
- For table tops, avoid drilling into the surface (use alternative fastening methods)

4.7 Recording the location of products

The maintenance of a database of product types and location can facilitate remanufacture by allowing manufacturers to be proactive in offering upgrades, take-back and other value added services to customers and at the same time gathering products for remanufacture

4.8 Choosing the most appropriate end-of-life treatment

Different components are likely to have different end-of-life treatments. Even with the best preparation, it is impossible to retain complete control over what will happen to a product at its end-of-life. Therefore it is important to design for as many possible proactive end-of-life scenarios as is feasible – such as reuse, remanufacture, recycling and recovery.

Recycling is the most likely end-of-life scenario for many products and for components which are not suitable for further reuse and remanufacture. Key design for recycling guidelines are:

- Build in value for the recycler (design the product so that it is worth recycling)
- Eliminate glues and avoid laminating different materials to each other
- Label the product and components with appropriate recycling symbols to indicate end-of-life destination

- Label all plastics with their type (in standard form)
- Minimise the number of different materials used (especially plastics)
- If more that one plastic is used make sure they have significantly different densities (this helps plastics to be separated)
- Use finishes and labels compatible with the materials
- Make use of recycled materials in new products

Case study

Senator International

Senator International Ltd is the UK's largest manufacturer of office furniture. The company has produced an environmental design protocol for its new products, including requirements such as:

- Avoidance of a range of less environmentally desirable substances
- Selection of material on the basis of its recycled content and suitability for end-of-life recycling
- Lightweighting of components without compromising product integrity

The current production range embraces a number of concepts which can potentially promote remanufacture – though this potential remains largely untapped at the present time.

Desking

There has been a switch in the past decade from stand alone desks to desking systems. The traditional requirement of one set of all components for each desking space has given way to systems which can share certain components.

For example, the "Infinity" desk to the left is a modern interpretation of a more traditional design. This incorporates three sets of legs to support the unit. The presence of non-rectangular shapes in the desking material will also often increase the material consumption of the design through an increase in the off-cuts generated during the initial processing of the melamine faced chipboard panels.

The systems approach to desking can potentially allow the sharing of common components between workstations – thereby reducing the overall amount of material required to provide the service. The example of the “Intrigue” desking system to the right, shows the use of shared support posts, cross rails and screens.

Furthermore, from a remanufacturing perspective the systems approach offers the benefit of flexibility. As needs change within the organisation, there is potential to reconfigure the workstations and extend the useful working life of the embedded resources.

The components are designed to be non-directional to increase their reusability potential as well as reducing start up costs and decreasing the requirement for the storage of component parts (both for the manufacturer and subsequent user).

Although this potential exists, few customers make full use of it. This might stem in part from a fear of working out the puzzle associated with dismantling and then reconstructing a large number of component parts.

For similar reasons, system desking is not currently favoured by third party reuse and remanufacturing organisations. They have the additional concern that crucial components could go missing during the disassembly and transport phase. Furthermore, it is a harder proposition to sell on a collection of loose components than it is to sell on a pre-assembled and recognisable desk, table or screen.

The rationalisation and standardisation of fixings would aid this process by reducing the number of tools required and lessening the likelihood of breakage due to reassembly with the wrong parts. For example, if a product uses 4 types of M4 bolt – with lengths of 16mm, 20mm, 25mm and 35mm – there is a strong possibility that at some point the wrong length will be used for reassembly with associated implications for component damage.

It would also be helpful for all components to be labelled or marked with part numbers, a jargon-free description and, in the case of plastic, the material type. Diagrams of standard configurations would aid reassembly if made available in print or on-line and would encourage buyers of second hand product to establish contact with the original supplier – potentially a future customer for new product. Senator already holds a stock of component parts to help to overcome missing components and the requirement for additional parts during a reconfiguration exercise.

Storage

Pedestal and larger storage units tend to have longer lives than desking and chairs. The number of working parts are limited, with tambour doors being the most likely item to fail – e.g. due to scratches on the front surface if something rubs whilst opening and closing.

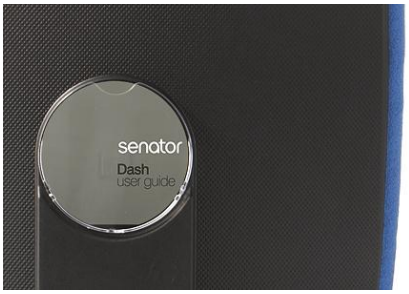
Third party reuse organisations tend to do little to pedestals or larger units. The main hindrance to reuse is missing components. There are so many variations in shelf and hanging shelf dimensions that if a unit is not complete, it is typically scrapped. Loss of keys is another hindrance to subsequent reuse. Labelling could be of use here too showing contact details for replacement locks and keys or a suitable security contractor.

Seating

Task seating is the one area of office furniture which will be prone to surface deterioration due to dirt accumulating in the fabric. Most task seating follows similar principles with a 5 star base, seat unit with a range of adjustability functions and a back. With a chair such as “Dash” (see right), Senator offers the facility to recover the unit at a charge of around £45 per unit – thereby helping to preserve the value of the unit’s core.

Other areas of wear tend to be the armrests, casters and the 5 star base where this is plastic covered.

Remanufacturing would be facilitated by a standardisation of the seat units. However, designers often work in the opposite direction – wanting to differentiate their product through the integration of an expanding array of adjustability levers. In reality, most users spend little time optimising the adjustment of their chair as the function of levers and knobs is rarely intuitive.



Consequently, Senator attaches a small user guide to the rear of certain chairs such as the “Dash” range (see left). As with any technical product, this approach only holds good whilst the object and User Guide remain together. Once separated, the benefit is lost. Publishing a printable version on-line would enable remanufacturing organisations and subsequent owners to access the information.

Case study: Desking surface fixing redesign

One of the issues raised by Green-Works which affects the potential for the remanufacture of desking surfaces, is the presence of a multitude of holes on the underside of a typical desk. Any subsequent reuse has to ensure that these holes do not coincide with the edge of a remanufactured panel and there is a danger that saw blades will be damaged by brass inserts.

The picture to the left shows a range of fixing holes as well as a cut-out for cables. In this case, the fixings holes are less problematic as they are grouped in an area to the side of the desk, rather than being on the main surface as well.

However, the usable surface area would be greatly improved by having cable inserted through a slight cut-out at the rear edge of the desk with no fixing points underneath.

The following three pages provide an illustration of some potential redesigns focussing upon clamping the surface rather than fixing into it. Such a system could potentially allow the surface to be reversed after a few years of service – or could offer the opportunity to have a different coloured top and bottom surface to allow an element of personalisation by the end-user.

Remanufacture checklist

Product service systems	• Have you developed a clear picture regarding the market for the remanufactured item?
	• Are there adequate incentives for all stakeholders along the value chain with respect to the end of life product?
	• Is there concurrent design of the product, its service system and business model so that they work effectively together?
Optimising the amount of material used	• Has unnecessary duplication of structural elements been avoided?
	• Has “lightweighting” been considered where possible?
Optimising the choice of materials	• Is the design simple enough to give longevity?
	• Do materials have appropriate durability?
	• Do materials contain a good recycled content where possible?
	• Are appropriate labels used to identify material types (especially plastics)?
Optimising the number of components	• Have component numbers been rationalised?
	• Can common components be used for a number of products?
Optimising the lifespan of components	• Can the product be designed with a durable core that can be processed by the remanufacturing system many times before requiring repair?
	• Does the design use materials, finishes and fastenings with an appropriate durability for the intended lifespan

	of the product or the component?
	• Are repair instructions available? For example, a “washing label” approach to product care
	• Are any elements more prone to failure? If so, incorporate sacrificial elements (like desk edging) to preserve the value of the most significant components
	• Have you integrated short term components in such a way that they can be simply replaced when worn – like the tyres on a car?
	• Have you embedded visual clues into the design that indicate how these components can be removed and replaced?
Optimising disassembly	• Has the number of parts and sub-assemblies in the product been minimised?
	• Are standard dimensions and components in use?
	• Have the total number of fasteners and types of fasteners been minimised?
	• Have the number of different materials used (especially plastics) been minimised?
	• Are components joined in a manner that makes them easy to dismantle, refurbish and upgrade?
	• Can high value components/subassemblies be accessed easily (even if this means lesser value materials/components are sacrificed in the process)
	• Does the design of table tops avoid drilling into the surface (use alternative fastening methods)?
Recording the location of the products	• Is a database kept of product types and location to facilitate remanufacture by allowing manufacturers to be proactive in offering upgrades, take-back and other value added services to customers?
Choosing the most appropriate end-of-	• Has value been built in for the recycler (design the

life treatment	product so that it is worth recycling)?
	• Has gluing and lamination been avoided for dissimilar materials?
	• Have appropriate labels been included?
	• Has the number of different materials been minimised (especially plastics)?
	• If more that one plastic is used, has it been ensured that they have significantly different densities (this helps plastics to be separated)?