Is green a grey area? Sustainability and inclusivity; recycling and the ageing population

Joe Langley

Lab4Living, Sheffield Hallam University

Abstract

There are growing pressures (political, legislative and environmental) to increase the UK recycling rate.

There have been numerous studies about recycling behaviour, participation and motivations much of which has been summarised by Tucker (2003). There are disagreements over the impact that age has on ability and inclination to recycle. The author believes that there are significant effects that age and the ageing population has and will have on ability to recycle and overall UK material recovery rates.

This positioning paper examines literature regarding barriers to recycling and relationships with age. A hypothetical scenario is outlined for the impact of the ageing population on future material recovery rates in the UK, present the initial results of a survey and the potential role that design can play to eliminate these barriers is described along with the authors' activities within this area in this project; 'The Grey Areas of Green Design'.

Keywords: recycling, ageing, waste, sustainability, inclusive design

Introduction

In this paper we will be exploring the collision between two mega-agendas; ageing and sustainability. From these two we will be specifically focusing on Inclusive Design and Recycling.

The British Standards Institute (2005) defines inclusive design as *"The design of mainstream products and/or services that are accessible to, and usable by, as many people as reasonably possible ... without the need for special adaptation or specialised design."*

In the context of the sustainability agenda, recycling is almost a Cinderella theme. It is often over awed by other strands of the sustainability agenda such as renewable energy technologies, more efficient car engines or domestic homes and so on. Yet this hugely underestimates the importance of recycling and its impact on our ability to be sustainable. As consumption continues to increase, natural resources will

continue to be depleted, the quantity of 'stuff' made will increase and whilst efficiency efforts might decrease the quantity of waste per unit, the total number of units will increase to such a level that the total waste produced will actually increase. Hence, waste reduction or minimisation at the design front end will ultimately reach an asymptotic value of real waste reduction. Greater efficiency is the drive for much of the sustainability agenda, often described as making things more sustainable. But the semantics of this description hide what is effectively nonsense. Sustainability is black and white. Something is either sustainable or it is not. If something is not sustainable it has an end point to its life; it runs out of resources, overflows, or fails. Making something more efficient and 'more sustainable' does not stop this end point; it merely delays the end point, putting it off for another generation to deal with. Being more efficient does not address the root issues. Recycling is not an efficiency drive. It is more than that. It can address the root issues and both the points mentioned above; deceasing the pressure on demand for virgin natural resources and decreasing waste at source, before it even becomes waste. This forms part of the closed loop and cradle-to-cradle theory expounded by McDonough and Braungart (2002) and demonstrates the importance of recycling not just to meet government targets but at a much deeper philosophical level and in a true sustainability sense. One suggested alternative to recycling is to design products that have a longer lifecycle. However, this isn't strictly an alternative as very little can be designed to last forever so even those products designed to last longer should still be considerate to potential recycling at the end of life scenario. The successes of recycling schemes rely on the combined activity and contributions of an entire population. Hence, in the context of significant demographic changes, it becomes important to consider how involved the different and rapidly changing elements of the population are.

Society is ageing. That ageing brings a host of problems - amongst them, a population where the majority are likely to have some form of impairment. By 2020, 50 percent of our population will be over 50, and 25 percent will be over 65 (ONS, 2010). 20 percent of the total population have some disability. People aged over 70 usually have 2 or 3 chronic conditions and by 75, 90% have some clinical diagnosis. Melzer *et al* (1999) state that for older people *'…disability is not present or absent, but rather a matter of degree…'*

Some evidence has been put forward to suggest that older people are no less likely to recycle than younger age groups (Owens, 2000) and that in fact, there is even a positive correlation between age and recycling (Perrin & Barton, 2001. Jenkins, 2003).

However, other studies (Lake, 1996. Aadland & Caplan, 2003a & 2003b) contradict these findings to suggest a negative correlation between age and recycling behaviour. Collins *et al* (2006) found a deeper, but negative correlation between age, income and recycling suggesting that past the age of 40, for those on incomes below £14000 pa, increasing age will increase the probability of recycling, whilst higher

earnings for older adults (males especially) will have a decreased probability of recycling. Further Collins *et al* also found that car ownership and mobility played a significant part in the probability of recycling. Recycling participation was likely to decrease as the number of cars owned by the household decreased. Collins goes further to suggest that, to a slightly lesser extent than car ownership, physical ability and disability has a similar relationship to recycling in that as physical ability declines so does the inclination to recycle.

This disparity of understanding is confirmed from the authors work indicating that waste and recycling behaviour are complex issues. Previous work (Langley et al, 2009 & 2010a & 2010b) and initial indications of this project demonstrate complex relationships between current older householders, future older householders, income, physical ability, mobility and access to recycling facilities.

Research Position

The position we are taking in this programme of research is that of 'age proofing' recycling schemes so as to ensure that material recovery rates are not affected by the ageing population.

The work in this project, ‘The Grey Areas of Green Design’, will combine engineering and ergonomic analysis with social and design research techniques to identify physical and perceptual barriers to recycling for older people. This will be divided into the two categories specific to the two different schemes; kerbside and bring-sites. We will be working with Sheffield City Council (SCC), Veolia who are waste management service providers for SCC and Taylors who are a recycling equipment manufacturer. This comprehensive programme of cross disciplinary work has just been started. It terms of collecting and analysing data, it includes:

- a programme of surveys targeting recyclers and non-recyclers with a skew towards older people and the 'future old'
- a portfolio of photographic evidence
- ergonomic analysis of bins, banks and boxes
- ergonomic analysis of users (adults, older adults, wheelchair users) looking at reach, grip, grasp, height etc
- motion capture analysis of users (adult, older adult and wheel chair user) using bins, banks and boxes
- engineering analysis of weight (of waste), force, strength and effort required to lift, push, pull and open wheelie bins, recycling banks and boxes

In terms of generating solutions, the work will utilise design-led user focus groups tasked with developing schemes, bins and banks that attract recycling participation. The fundamental aim of these groups will be to develop solutions in a co-design

process similar to the co-design strategies used in the EPSRC funded Future Bathroom project (Burton, 2010). In this sense these groups will differ from regular focus groups in that they will be steered through a design process in terms of reviewing the existing services/products, defining the problems that they face, developing open-minded conceptual ideas to solve these before finally reviewing the prototyping and refining processes to develop the concepts into workable solutions. In order for them to be led through this design process, these groups will be mentored by design researchers who will employ strategies such as critical artefact strategies (Bowen, 2007) in efforts to encourage participants to think differently about the identified issues and subsequent solution(s).

It is intended that this programme of work will culminate in evidence of both the physical and perceptual barriers to recycling that older people face and to go on to explore service and bin/bank designs that both reduce these barriers and give some added value to the recycler to aid motivation in participation.

This research is undertaken in the Sheffield region, within the context of 1 weekly general waste collection (wheelie bin) and 1 monthly paper waste collection (wheelie bin). In recent months Veolia have introduced a fortnightly plastic bottles, glass and metal waste collection (wheelie bin) and transferred the monthly paper and card wheelie bin collection to a fortnightly box collection on the same day. Sheffield also provides a network of bring-sites. There is no standardisation across these sites. There are approximately 218 of these sites at the current time. 18% at shops, 9% located on car parks, 17% in school premises, 5% at leisure or community centres, 7% in residential areas, 27% in pub grounds and the remaining 17% of an assorted mixture not fitting into these categories. Some of the sites have only one bin or bank and others have up to 10 but only collect three materials between them. There are examples of two sites directly opposite each other on the same road, both with one bank for the same material. It does not appear as though there is a strategic approach to the collective, overall distribution of these sites and the facilities they offer and a key part of our initial research is to evaluate infrastructural factors in the planning and specification of these sites.

The work has been subject to research governance and ethical review within Sheffield Hallam University's own internal review boards. Permission is requested from all participants and the research work and context is explained to them.

This paper sets out the background and context to the subject and will include a few pieces of indicative evidence that have been collected so far from this study.

Barriers to Recycling

Reduce, reuse and recycle is the national mantra for resource efficiency to minimise the environmental impact of the plethora of consumer products (and their packaging) that overflow our shop shelves and internet web pages.

With recycling, the UK has traditionally lagged behind other EU countries in its material recovery efforts. Campaigns, legislation and investment have all had an impact. *Figures 1 and 2* (Eurostat 2008a and 2008b) illustrate landfilled and recycled waste in five EU countries. They show improvement in the UK figures but still much more could be done and needs to be done if, we are to meet and maintain government targets on material recovery and household recycling (defra 2008). Understanding both what motivates and discourages people to do any activity from exercise to socialising and recycling specifically is the first step towards increasing participation in this specific activity.

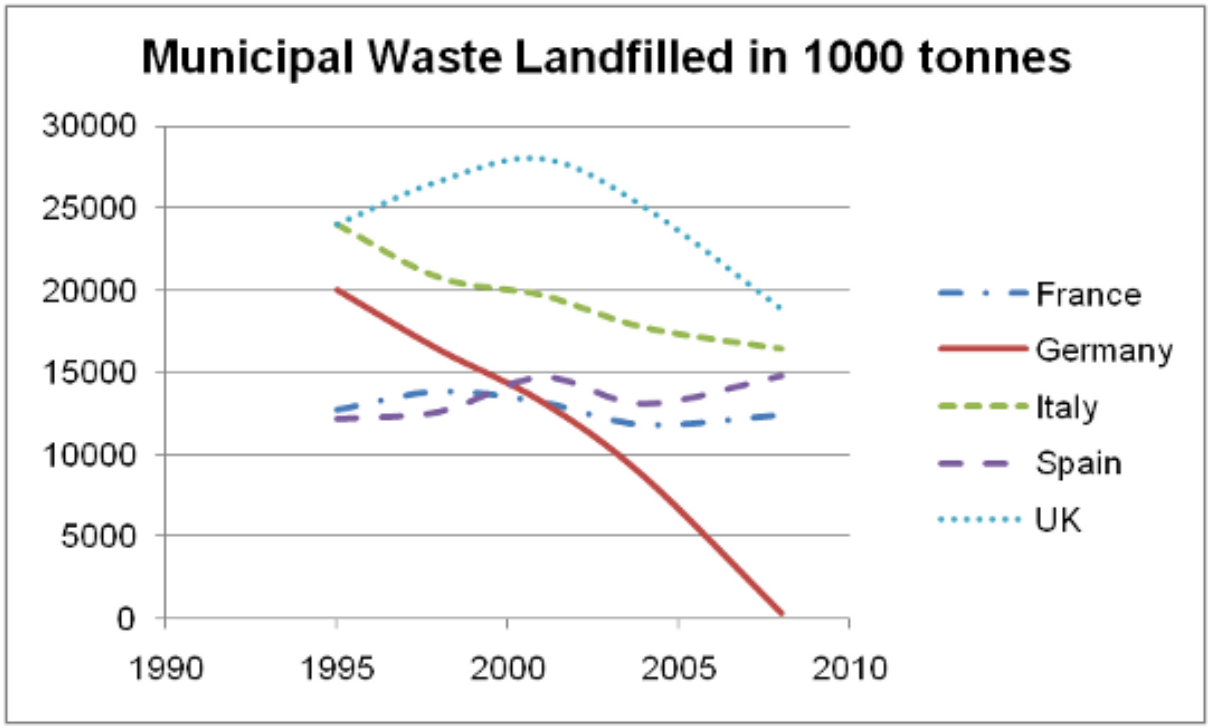

Figure 1: a graph of landfilled waste tonnage for 5 EU countries

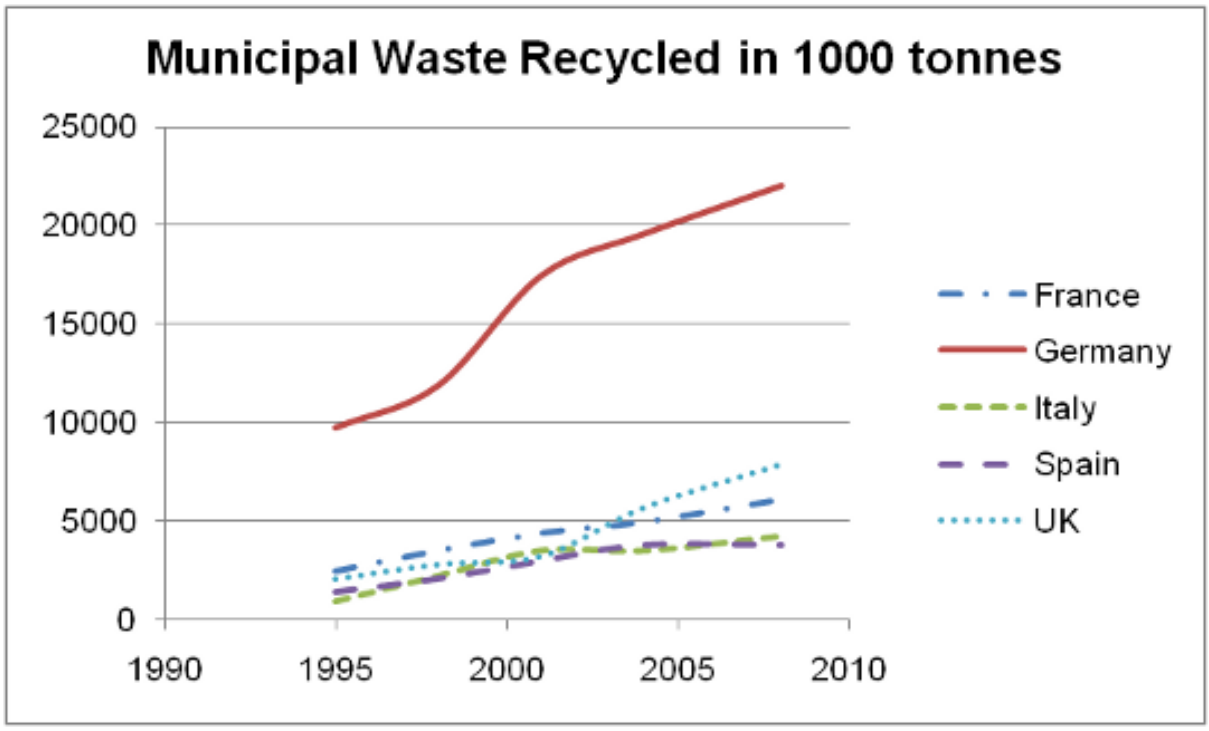

Figure 2: a graph of recycled waste tonnage for 5 EU countries

Recent research (WRAP 2008) from the Waste & Resources Action Programme (WRAP) has found four main barriers which stop people recycling more. The study outlines a series of simple steps to help local authorities overcome these. The same study shows that in the last ten years recycling rates have increased from 7% to 33% and two thirds of English households are now committed recyclers but this study shows there is great potential for those numbers to go higher if barriers can be overcome. The study found that these barriers are:

Physical:

when containers for collecting recycling are unsuitable; when there is no space for storage, when collections are unreliable; when people have no way of getting to recycling sites, when bins and banks are difficult to use ergonomically

Behavioural:

if people are too busy; if they struggle with establishing a routine for sorting out recycling; if they forget to put it out, if they find bring sites dangerous, unsafe, dirty and unnecessary.

Lack of knowledge:

not knowing which materials can be recycled; not understanding how their local scheme works People's knowledge of how and/or what to recycle is linked to their level of participation. As expected, those who are less knowledgeable about how and what to recycle are less likely to participate, or tend to recycle less material.

Attitudes and Perceptions:

not believing recycling is good for the environment; not wanting to sort waste; not feeling personally rewarded for recycling. WRAP found that very different messages and actions are needed by local authorities to overcome these barriers. These will include: improving recycling collection services, providing better information and practical advice on how to use the service, and showing why taking part is worthwhile.

We will present a background against these four categories to demonstrate the need for this programme of work.

Lack of Knowledge

Of the four, the highest profile category is lack of knowledge. Highly visible efforts have gone into awareness and educational campaigns in an endeavour to increase recycling participation. The Government has a long history of such campaigns from safe sex, to obesity and healthy eating, recycling and waste minimisation and so on. These campaigns utilise billboards, TV and radio adverts and educational schemes, and for the large part, are aimed at children such as the Dan Can mascot in Torfaen (2008). The influence of enthused children has dragged parents into recycling activity and Torfaen has become the best recycling local authority in South Wales.

There is a belief that these campaigns will be most successful amongst population groups with a defined sense of social responsibility while any amount of information will not change other groups such as those with lower perceptions of social responsibility or people who are physically unable to participate. Amongst these groups campaigns may be perceived as instructional, for others benefit oras coming from an authority figure, re-enforcing the 'nanny state' syndrome.

In focus groups conducted in the USA in the Boston area in 2001, it was found that most 'partial recyclers' and 'non-recyclers' in the groups were unaware that preparation requirements for recyclables have become less stringent over the years. For example, these individuals believed that it is still necessary to flatten cans, to remove bottle neck rings and to remove labels from cans and bottles. Further, erroneous beliefs about preparation requirements loomed large in people's perception of recycling as inconvenient (Aceti Associates, 2002).

Clearly, while having access to recycling information is essential, it is also necessary that residents use the information in order to become more knowledgeable about recycling. Research shows that recycling information can often be communicated more effectively than it is, but that providing information alone is often not enough to change behavior (McKenzie-Mohr & Smith, 1999 & Schultz, 2002).

Attitudes and Perceptions

There has also been research in the area of attitudes and perceptions regarding recycling with broad agreement across this research whether it comes from local government surveys or academic research. Generally speaking, the more concerned people are about the state of the environment, the more likely they are to participate or to recycle frequently (Gamba & Oskamp, S, 1994 and Oskamp *et al*, 1991). People are motivated to recycle by actual pressure they receive from family and friends to do so. Furthermore, simply knowing that family, friends and neighbours recycle increases the likelihood of recycling (Gamba & Oskamp 1994, Oskamp *et al*, 1991 and Werner & Makela, 1998).

In another study researchers in California explored the link between observed recycling behaviour and individuals' "belief in/knowledge of the benefits of recycling." These benefits include:

- Extension of the supply of natural resources
- Litter reduction
- Improvement of environmental quality
- Preservation of landfill space
- Energy conservation and
- Resolution of a national problem

The researchers concluded that residents who believed more strongly in the benefits of recycling were more likely to be participants in the recycling program (Oskamp *et al*, 1998)

In yet another study, when members of focus groups in Waltham, Massachusetts were asked what would be most likely to motivate residents of the City to recycle, both, recyclers and non-recyclers indicated that feedback from the City on the amount recycled and money saved would be motivational. In addition, recyclers suggested that providing people with information on what products are made from recyclables would be a good idea (McKenzie-Mohr & Smith, 2002).

At present, the studies referred to above indicate that there is a dislocation between people recycling and visibility of the benefits of their efforts. Whilst information is readily available on the internet and often via other media regarding quantities of material recovered and recycled at local and national levels, these figures often have to be searched for and do not appear to be accompanied by tangible benefits for the recycler; the benefits remain abstract in nature to recyclers.

One method of rewarding recyclers has been the inclusion of an element of novelty or fun into the use of the bins themselves. The Bottle Bank Arcade Machine (*Figure 3*) is an initiative by The Fun Theory (Glass Packaging Institute). A bottle bank was built with design modifications adding sounds, lights and 'points' to behave in a similar fashion to an arcade machine. The user had to be quick enough to put their

bottles in the highlighted hole and if they were, they were rewarded with game points. Over one evening, this machine was used by 100 people as opposed to the two people that used the nearest 'normal' bottle bank.

Figure 3: the bottle bank arcade machine by The Fun Theory

Similarly, the 'Feed the Cows' project in Lewisham. (Onyx, 2006) in which four Continental bins donated by Taylors were painted in a black and white style as Cowbins™ (*Figure 4*). The pavement of the sites they were located on were painted a 'grass green' and billboards decorated with grass, meadow flowers and cows were situated behind the bins (*Figure 5*). The site itself was chosen as a highly visible site. A campaign of 'Feed the Cows' was targeted specifically at children. Over a three month period in early 2006 there was a 61% increase compared to the same period in 2005. In addition, there was no graffiti or vandalism.

Figure 4: a Cowbin™ from the project funded by Onyx Environmental Trust

Figure 5: the Cowbins in situ at the bring-site

One of the problems with these initiatives is that of the durability of novelty. Novelty is by definition in the Oxford Dictionary *'…(1) the quality of being new, original or unusual…(2) a new or unfamiliar thing or experience…'* and hence can be a short term incentive that wears off with familiarity. Some things do retain originality for longer and this would be an interesting dimension to explore in future interventions. Another issue can be breadth of appeal. The Cowbins campaign was targeted specifically at children. This project would be more concerned with developing solutions that had appeal across the age spectrum and across cultural differences and may even act as an intergenerational and/or cultural point of connection.

Behaviour

There has been considerable academic and local government research about recycling behaviour to establish views about danger, safety, dirt and 'ick' factors though to patterns, routines and habits relating to recycling whether they are opposing recycling participation or participating in recycling (Langley 2011, WRAP 2008). Work in this area has covered kerbside and bring-site schemes, whether people make special trips to bring-sites or combine it with shopping trips and what recyclers do to prepare material for recycling.

Initial evidence from the pilot study has found significant physical evidence that will help to build perceptions of recycling being a dangerous and dirty task. *Figure 6* shows a hypodermic needle that was found at one recycling bring-site located on a supermarket car park whilst *Figure 7* shows a bring-site located in a residential area between houses that was found to be overflowing. All the bins were overflowing and there was a considerable pile of recyclable material that householders had clearly made the effort to bring to the site yet been unable to put it into the bins and bank provided because they were so full.

Work in this area has also considered activity priorities in householders from family and life demands to pleasure and leisure opportunities. A conclusion that Collins (2006) comes to is that single males on higher incomes may have a lower propensity to recycle due to the opportunity cost of their leisure time.

Figure 6: an image of a hypodermic needle found at the edge of a bring-site on a supermarket car park

Figure 7: an image of an overflowing bring-site on a supermarket car park

Physical

Kerbside schemes are often favoured over bring-sites by councils and waste management providers to maximise material recovery partly because of the perception of convenience to the householder compared to bring-sites. However, this does not always follow on to eliminating barriers to recycling participation. Provision of the 'special collection' services inherently indicates that wheelie bins are difficult for some people to move. For many people, they are also unsightly; an eye sore that detracts from the appearance of their property. For others, garden sizes are so small that additional bins and boxes can ultimately deprive residents and children of usable garden space for socialising and playing. And for nearly all people, recycling at home for kerbside schemes is still viewed as a chore; an obligatory task that at times, in the background noise of daily family life, will be pushed down the priority list.

Figure 8 shows a city centre recycling bring-site. The car park that used to allow vehicular access to the bring-site has recently had a barrier post erected in the entrance. This has had the result of restricting access. People now have to either park on the road and carry their waste into the site or walk with their waste from further away.

Figure 8: a city centre bring-site with a barrier post blocking access to the car park

Figure 9a shows an older woman that was interviewed at a bring-site. During the interview she said that she didn't enjoy recycling. She did it out of a feeling of obligation. When asked about the physical aspect of it, her comment was *'…well its not hard is it…'*. However, observing her actually putting the recyclable material into the bins, it was apparent to the researchers that it was a physical effort for her. *Figure 6a* shows her balancing a box of recyclable material between her body and the bin whilst trying to hold the bin lid up with one hand and put rubbish into the bin with the other. At several points through the process, the bin lid nearly slipped out of her hand

and fell shut. *Figure 9b* shows an elderly man with a walking stick, struggling to juggle his stick, his bag with recyclable material and putting the recyclables into the appropriate bank. This man almost dropped glass bottle out of his bag as he opened it and said that he would have been unable to bend down to pick them up if he had. What this tells us is that there are some strong relationships between the physical barriers, behavioural barriers and perceptual barriers, some of which are counter intuitive. In these examples (*Figures 9a and 9b*), whilst the physical barriers are significant, the perceptions of the individual in the spotlight are such that they are not even considered as barriers. And yet could this be a barrier to progress and wider inclusion? If no one used these bins because of these physical barriers, then the chances that they would be re-design and changed to make them more accessible would increase. However, as there is just enough of a population using them despite the barriers, could this very attitude from a minority be enough to limit innovation and reduce the drivers for change and hence exclude a proportion of society?

Figure 9a: an older woman recycling at a supermarket bring-site

Figure 9b: an elderly man recycling at a supermarket bring-site

So far only one study has been found that examined the design criteria for disability friendly bins and banks (Jensen *et al*, 2001). This study covers age related disabilities and wheel-chair users along with sight, hearing, mental and allergic impairments.

Whatever is done now for recycling has to be accessible to older people, so that as they increase as a proportion of our population, this will not be a factor counting against our overall material recovery rate. The hypothetical impact of the ageing population on our national material recovery rates is outlined as follows:

Older people will be less able to carry material to bring-sites or, if they can, they will not be able to carry as much material to bring-sites. If they are fortunate enough to

own a car, they still have to carry the material from the car to the bins and banks. Similarly they will be less able to move their own wheelie bins and recycling boxes for kerbside schemes. This is evidenced by the fact that waste management service providers are providing ‘special' or 'assisted' collections for those that are no longer physically able to put their own bins out on the kerbside. In the Sheffield area, this service for the larger general waste bins, has varied between 9.58% and 8.7% of the total collection service between March 2006 and March 2010. In general there has been a very slight decline of 0.7% of the service population, in this time frame. For the slightly smaller blue bin collection over the same time period, the variation has been between 8.14% and 8.42% of the total collection service. This equates to a marginal rise of 0.1% of the service population[i]. However, it is anticipated that demand for this service will rise. This service inherently slows down the rate of Refuse Collection Vehicles (RCV’s) ultimately meaning that more vehicles will be required to visit the same number of houses in the same time period thereby increasing the carbon footprint per tonne of material recovered.

Visits to Bring-Sites

The initial survey was kept to a very simple set of questions and targeted specifically at people who do recycle at bring-sites. The questions were kept short so that the A5 sheet of encapsulated paper outlining the questions could be shown to a potential participant and they would immediately perceive that it would not consume a significant portion of time and hence they would be more willing to participate. Further, at this stage we were not looking for in-dept understanding, but indicative trends that would inform a more detailed later survey. The researchers visited over 51 different bring-sites and took photographs. The intention is to ‘hit’ a variety of sites from supermarket car parks to small sites between houses in residential areas simply because we do not know for sure if we will get different response for different kinds of sites. However, at present, whilst the photography work has visited a full range of sites in different locations, the survey data has only been collected at supermarket car park sites. This work is on-going. The researchers waited at each site to meet recyclers. The recyclers were informed of the research and asked for their time to answer the survey and permission to take and use photographs.

The survey recorded the date, time and weather conditions, the recycling point name and number, the age, gender and first part of the participants' home postcode.

The survey went on to ask how often the participant recycled and whether they had any regularity to their recycling habits such as day of the week or time of day. This was followed by queries about combing recycling trips with shopping trips or whether they were special recycling trips and if they used a car or not. They were asked what materials they recycled and whether they separated the materials at home.

The participant was then asked if they enjoyed recycling, if they found the bins and banks easy to use, of they thought the site was clean and safe and if the bins and banks were emptied regularly enough.

So far, the survey population stands at 116 people with 51 female and 65 male participants. The age and gender demographic is shown in *Figure 7*. This paper is not going to break down the results in great detail as the work is on-going. At this stage we will simply highlight the interesting and indicative trends along with anecdotal observations that support these.

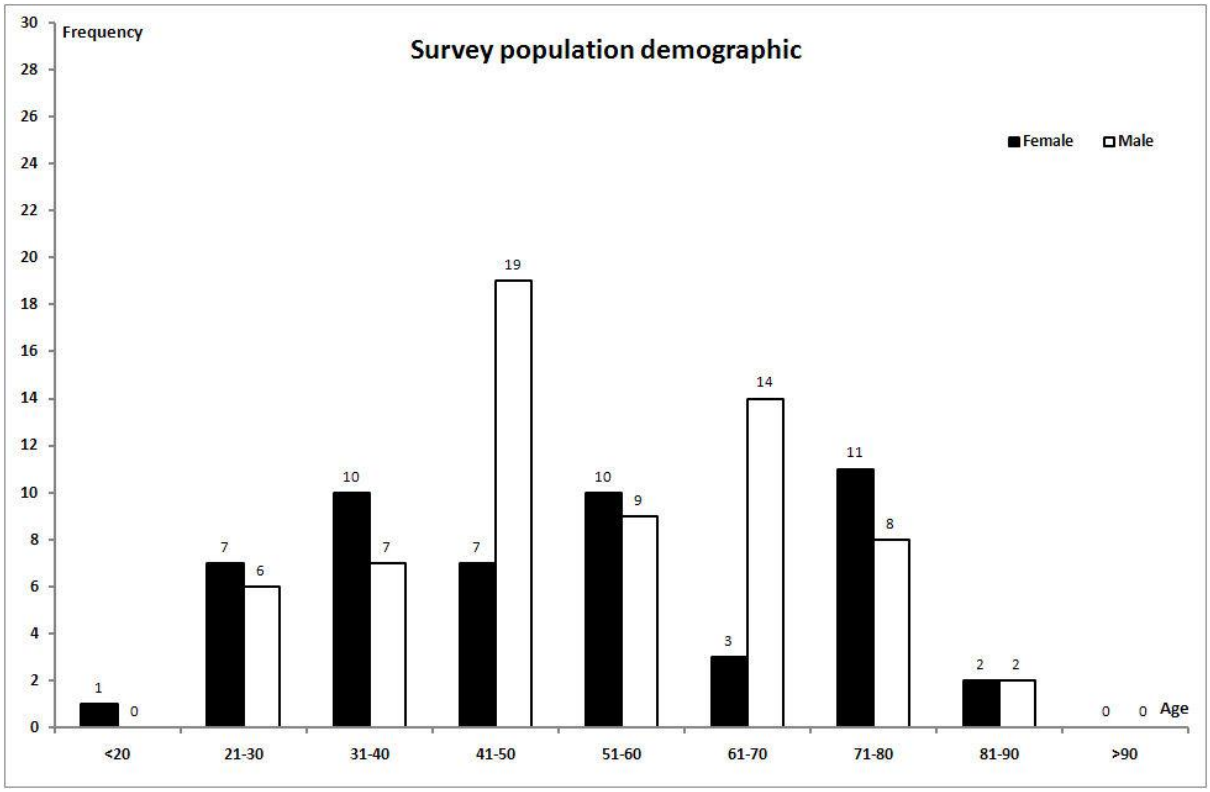

Figure 7: Population of survey targeting bring-site recyclers

The majority of those questioned recycle once a week (60%). Similarly, the greater majority combine recycling with shopping trips (85%). One participant described it as *'…I bring my rubbish back to where it came from…'*. This comment should be contextualised by the location being a bring-site on a supermarket car park.

When asked if they enjoyed recycling, 68% said yes. However, a large number of these affirmative respondents then proceeding to qualify their response with comments such as *'…recycling is necessary…'* or *'…I've just got to do it…'*.

When asked if they found the recycling easy, 85% said yes. However, yet again this was very often qualified with comments such as *'…these shutters are a bit difficult to open sometimes…'* referring to the shutters on the continental bins (Figure 7) often found on paper and plastic banks or bins. In other cases there were references to

the height of the slot or hole in the bin or bank generally along the lines of it being too high.

It is intended to add to the data of this survey targeting people at recycling bring-sites and to conduct other surveys. One of these will attempt to target specifically those people that don't recycle especially older people. We will be visiting social groups for older people in Sheffield and talking to the participants about their recycling habits. Further surveys will enquire about the ease and effort required to move wheelie bins and recycling boxes at home for kerbside schemes.

Ergonomic Analysis of Bins and Banks at Bring-Sites

The bins and banks at each bring site were photographed and measured. The photograph of a typical glass bank is shown in *Figure 8*. The dimension terms are specified in this image and the dimensions themselves are detailed in table 1 for glass, paper and plastic recycling banks with paper and plastic banks illustrated respectively in *Figures 9* and *10*. This is only 3 of the results we have gathered to date and are shown for illustrative purposes. Measurements were also taken of space between bins and banks for the purposes of access for wheelchair users. The interesting figures to keep an eye on from *Table 1* is the column of figures about Slot Height; 1380mm for Paper banks, 1475mm for Glass banks and 1370mm for Plastic can banks.

Figure 8: Dimensions of glass recycling bank

Figure 9: Dimensions of paper recycling bank

Figure 10: Dimensions of plastic and cans recycling bank

	Bank Height [mm]	Bank Width [mm]	Slot Height [mm]	Slot Diameter [mm]	Slot Length [mm]	Slot Width [mm]
Paper Bank	1420	1510	**1380**		950	100
Glass Bank	1700	1200	**1475**	160		
Plastics Cans Bank	1460	900	**1370**		550	140

Table 1: table of current bank dimensions

Ergonomic Analysis of Users

The ergonomic analysis of users is presented in *Table 2*. This is taken from the Older Adultdata Handbook (Norris, 2000) In the context of inclusive design, the ability range of a population for 'reach' (how low or how high a person can stretch) is

made up of the highest lower hand limit (everyone else should be able to reach lower than this) and the lowest upper hand limit (everyone else should be able to reach higher than this). This will be the two figures highlighted in bold in *Table 2*; the lower hand limit for males aged 65-69 and the upper hand limit for females age 85+. In terms of reach for a recycling bank, this is illustrated in *Figure 11* below. This image is not to scale.

When comparing the two pieces of data; the ergonomic analysis of banks and of users, it can be seen that whilst the slot heights for paper and plastic recycling banks fall within the upper reach limit of the older user, the hole for the glass recycling bank does not. It is 9mm higher than the upper reach limit of the older user whilst the holes for paper and plastic banks are 86mm and 96mm respectively, within the upper reach limit.

It should be clarified that the upper reach limit is defined as effortless reaching; without holding anything. The act of recycling will require the user to lift recyclable material to the bank slot or hole. There is also a high probability that they will have to repeat this action several times to unload all their recycling materials. The heaviest of these is likely to be a glass bottles that could weigh in at up to 0.5kg for a litre bottle. The energy required to lift this bottle from the ground up to the recycling bank hole could be simplified to potential energy to lift this mass up to the height of the hole. This would equate to *mass x gravity x height (mgh).* In the example taken from details in this study, this would be 0.5 x 9.81 x 1.475 = 7.23 J. If this activity is then repeated *n* times for a several bottles, the energy or effort required is simply *n x 7.23*. In this context one might find that the upper reach limit is more restricted than the data found in the Older Adultdata Handbook.

Table 2: table of older adult reach ability

	65-69 Years	**70-74 Years**	**75-79 Years**	**80-84 Years**	**85+ Years**
Lower Hand Height male [mm]	**907**	915	890	905	881
Lower Hand Height female [mm]	849	859	870	864	838
Upper Hand Height male [mm]	1720	1678	1692	1680	1633
Upper Hand Height female [mm]	1565	1535	1520	1479	**1466**
Shoulder Height male [mm]	1399	1408	1380	1381	1364
Shoulder Height female [mm]	1274	1291	1280	1250	1224

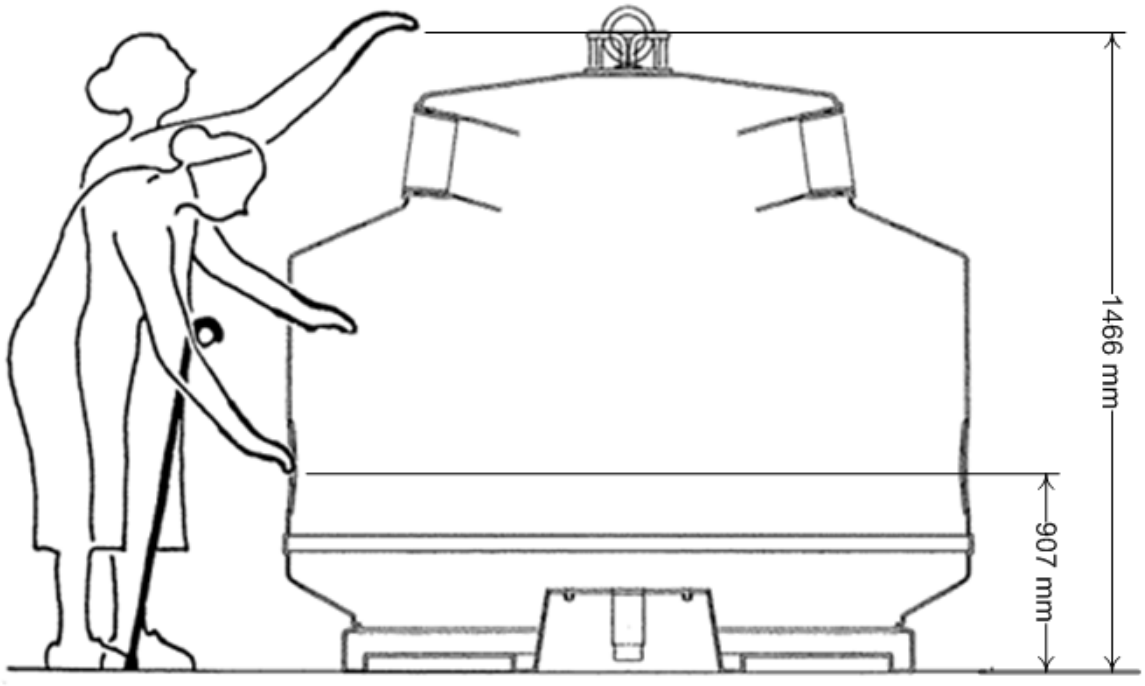

Figure 11: upper and lower hand reach limits in the context of recycling banks

Motion Capture Study

Using data from the two ergonomic analyses, a pilot study was set up of a mock recycling bank was design with slots and holes representing the existing bins and banks and a range of holes put in at varying alternative heights. In all there were a total of 10 holes put in identified by a letter from A-K. The mock bank is shown in *Figure 12*.

The mock recycling bank was put into the Lab4Living user lab and the motion capture system set up around it. In this instance a system of six infrared Hawk Digital Real Time cameras were used. These are essentially a system of infrared LED lights surrounding a camera. Reflective markers are positioned on the components of the system to be captured. *Figure 12* shows the motion capture set up with a close up of one of the cameras.

Figure 12: motion capture set up for recycling

The cameras capture the reflection of the infrared lights. To position each marker in 3D space, at least two cameras are required to capture the reflection of each marker. The recorded motion becomes more accurate the more cameras that capture the reflection of each marker. *Figure 13* shows the position of the markers used in this investigation on the users arm and hand.

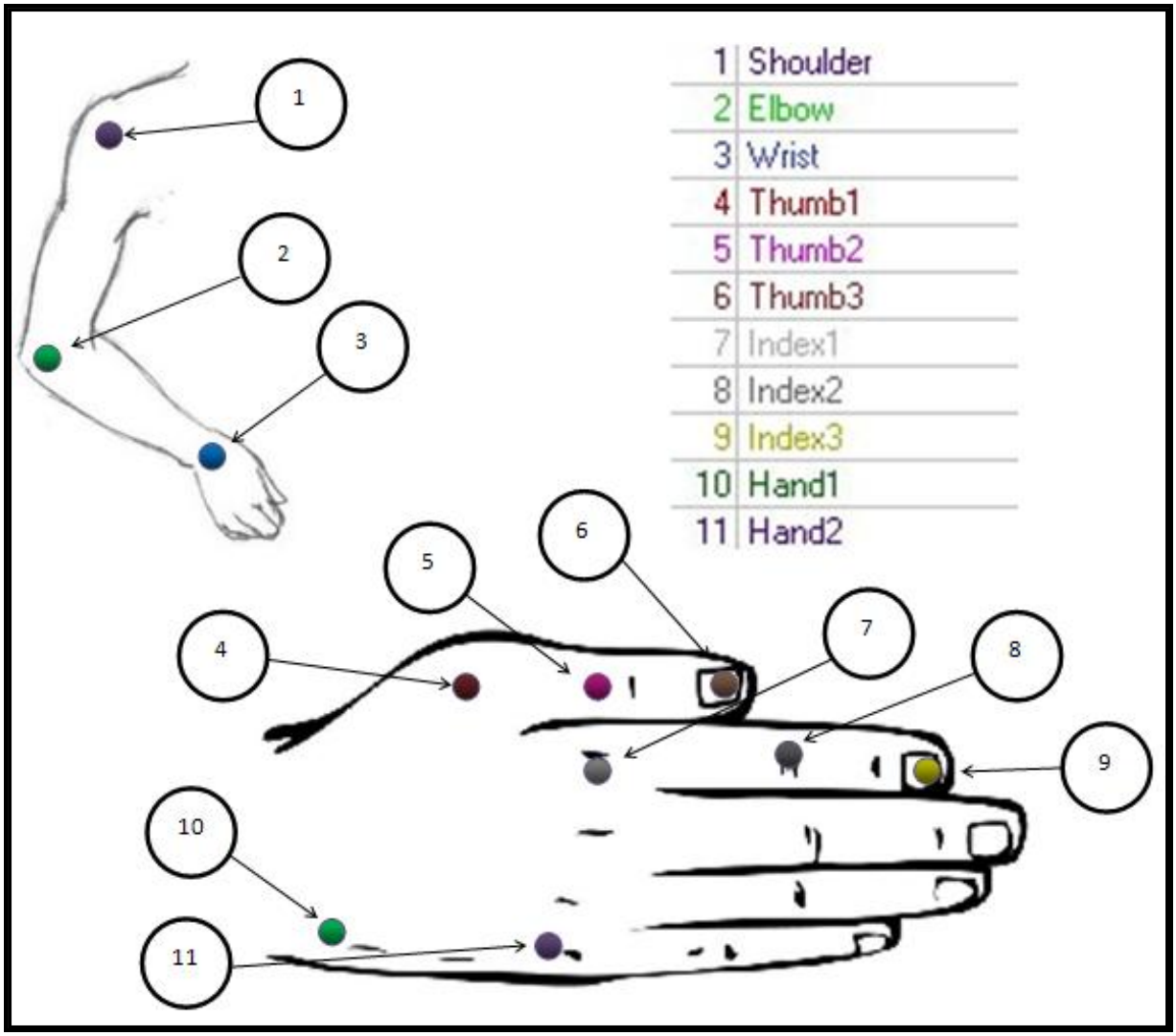

Figure 13: hand and arm marker system for recycling motion capture

Two calibrations are required to set this system up. A static right angle calibration that sets the origin with three fixed markers; one at the junction of the right angle and the other two and known distances along each axis. Following this, there is a dynamic calibration using a wand that has three markers fixed along a straight line at known distances to each other. This is waved around in a random fashion within the capture volume. The system then resolves the two calibrations to define the position of the cameras relative to each other and the capture volume. The final calibration determined the wand length at 500.02mm with a standard deviation of 0.49. The true wand length is 500.00mm. This gives a spatial accuracy of ± 2µm.

This piece of work has just been started and so far only captured 5 people. These people were 2 female (aged 21 and 68) and 3 male (aged 21, 32 and 75). The main purpose of the capture on these five people was to refine the experimental set-up. Hence the data is limited. However, it is now intended to capture a broad spectrum of users with a weighting towards the 50+, over the next 12 months. An example of the data that we can use from this capture is illustrated in the graph in *Figure 14*.

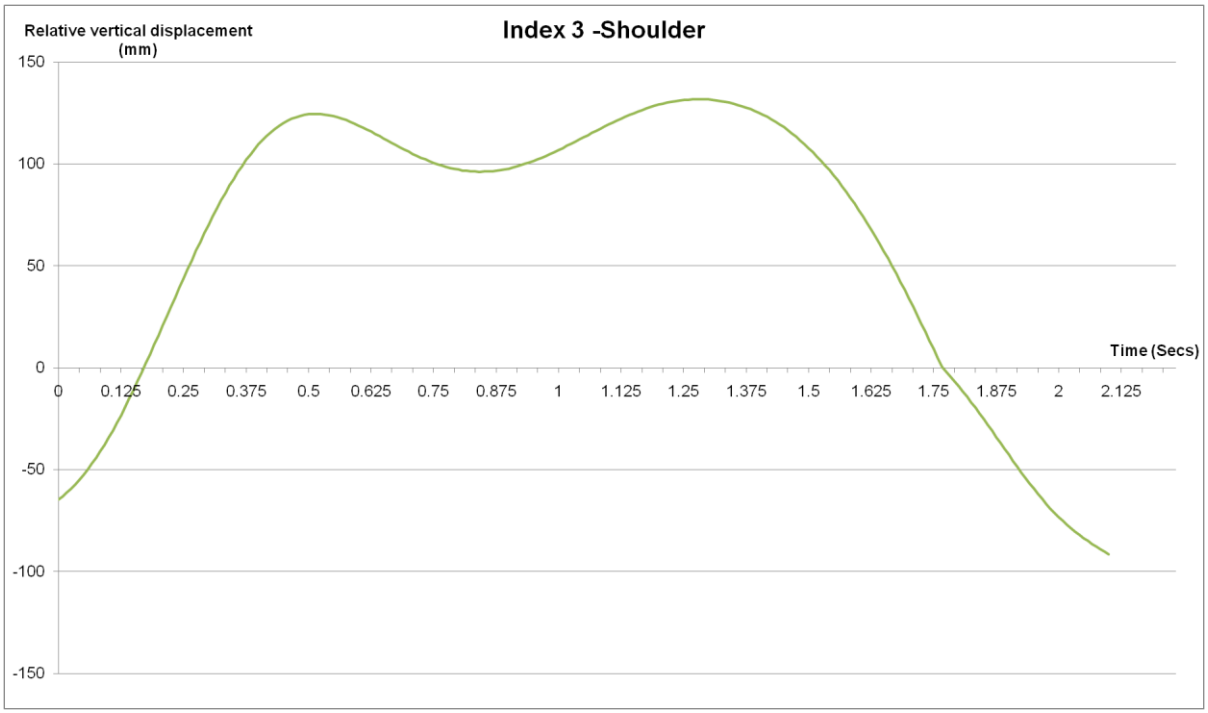

Figure 14: a graph of relative vertical displacement of the finger tip to the shoulder

This shows the vertical movement of the finger tips relative to the shoulder of the user. For the user, the shoulder has little vertical movement. In addition, the shoulder height takes account of the different heights of each user relative to the recycling bank holes. Therefore, this becomes the baseline for the amount of reach that each user has to apply to lift a glass bottle and put it into a recycling hole. This can then be used to calculate the engineering potential energy required to lift the bottle and compared to a perceptual scale of effort asked of each participant. In the example shown the user lift their hand vertically through 195mm but only 131mm above shoulder height and took 2.125 seconds to complete the task. To lift the glass bottle, this equates to 0.96J. On a perceptual effort scale of 10, the user equated this to 3. In another test scenario, we put this same user in a wheelchair and asked them to deposit the same bottle into the same hole. In this case, the user lifted their arm through 368mm, all of which was over shoulder height and took 8.215 seconds to complete the task. This equates to 1.81J and the user ranked it as an effort of 8.

This study will be expanded and refined to add a time factor into the calculated effort and make more of a comparison between calculated effort and perceived effort and between the ergonomic data of effortless adult reach compared to reach when holding an object such as a glass bottle.

Conclusions

It is clear that these categories determined by WRAP that affect the ability to recycle (physical, behavioural, knowledge and attitudes/perceptions) have a complex inter-relationship that is not yet well understood.

The physical barriers are clear when one compares the very simple ergonomic analysis of bins and banks with the ergonomic analysis of older users. Here it can be seen that the access point (hole or slot for putting waste into the bank) is the critical reach height. The data taken from the Older Adultdata Handbook is for effortless reach. Once the motion capture study has been expanded and more data collected, it will be possible to build up a picture of the limits that holding an object such as a glass bottle puts on this reach limit. It will also be possible to compare perceived effort with a calculated effort.

For older householders the physical barriers are likely to be amplified due to reduced strength, dexterity and mobility. Further it is expected that this will in turn affect the perceptual and behavioural barriers that older people have to recycling.

In the context of an ageing society and a need to meet higher material recovery rates, it is essential that these barriers to the older householder are understood, reduced and even eliminated.

There are further benefits to be gained via this inclusive approach, allowing for full engagement of older people in supporting a more sustainable future, thus enhancing self esteem and confidence through inclusion.

What is clear is that whether something is physically easier for the householder or not, there is a need for a fundamental change regarding recycling so that the perception of it as a difficult and ‘icky’ chore is eliminated. In addition, finding some way of relating recycling efforts to beneficial outcomes and of adding some other 'value' to the recycling activity will take away the perceptual barriers and will inherently make more people prepared to do the activity no matter what the reality of the physical barriers.

Considerable research and resources have been committed to the first two barrier categories whilst less has been committed to overcoming physical barriers or exploring the impact of the ageing population on the physical aspect of recycling. In addition, whilst there have been several efforts to communicate the benefits of recycling, there still remains this dislocation between the recycler and the benefits of his or her efforts. There is no means of relating the recyclers activity of putting a can in a bring site bin on a cold, rainy evening in winter with any kind of visible benefit to the recycler that the recycler can participate in. Various different methods to add 'value' to recycling efforts have been attempted such as those examples referred to earlier in this paper in section 'Attitudes and Perceptions'.

Through the application of inclusive design methods with ergonomic and engineering principles, we hope to overcome the physical barriers to recycling participation for

older people, making it easier for the least physically able in our society and hence making it easier for everyone.

Further, the application of design research principles will create a deeper understanding of what motivates people to participate in a range of activities including recycling. This understanding will then be used to add broad appeal, creating a 'timeless novelty' of added value for the participant that in and of itself encourages participation in the activity for the fun and enjoyment value it delivers as opposed to any feeling of obligation or necessary chore. The fact that material is recycled can then almost be a beneficial by-product of the fun activity.

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