

Dirt, Damage, Servicing and Repair

Understanding motivations for product disposal

Technical Report

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SUMMARY

Sustainable consumption requires increased product longevity, not least because the fast throughput of consumer goods adds to the threat of climate change due to embodied greenhouse gas emissions. Vacuum cleaners are the second largest source of embodied emissions among electrical products in the UK, and today's consumers only expect them to last around 5 years, perhaps a third of typical life-spans in the past.

This report presents the findings of a research project funded by Defra in order to find solutions to inadequate vacuum cleaner lifetimes. The project involved a multi-method research process that led to the development of a practical toolkit with potential solutions.

The first phase of the research comprised a scoping exercise with a literature review, stakeholder interviews, over 100 user interviews and a product teardown exercise. Through this, five themes were identified as the basis for design interventions to increase vacuum cleaner longevity: *Ageing Gracefully*, *Optimal Construction*, *Information Provision*, *Enjoyable Experience*, *Servicing Systems*.

The themes were explored in the second phase through a survey of over 500 consumers, a user co-creation workshop with 30 participants, and a workshop involving the research team and five employees of a leading vacuum cleaner manufacturer. During this phase five final year Product Design undergraduates were recruited to develop product concepts based on the themes. The results of the survey support the view that many vacuum cleaners are discarded after a short period. It suggested that key challenges were: creating the perception of the vacuum cleaner as a pleasant object and vacuuming as an enjoyable task; motivating constant and effective maintenance; communicating information to users effectively, and encouraging periodic servicing and repair. The *co-creation workshop* revealed key elements of vacuum cleaning from a user perspective, including frustrations such as a heavy, noisy or smelly vacuum cleaner, perhaps with an unsatisfactory cord or hose. Through this work product concepts for 'ideal' vacuum cleaners were developed for each of the themes:

Ageing Gracefully: A robust, attractive, high performance product that ages well, offering high performance and retaining an 'as new' sensorial quality (e.g. visual, noise, smell).

Optimal Construction: A long lasting motor body with a convenient recyclable head unit containing typically serviceable elements, e.g. dirt container, filters and brushes.

Information Provision: A product designed to communicate performance levels and assist fault-finding, enhancing user interaction from when first unpacked and assembled, and with wireless internet communication of product status to the manufacturer.

Enjoyable Experience: Enhanced emotional attachment through consideration of material choice, ease of use and storage, and reduced contact with dirt.

Servicing Systems: A leasing system providing users with a high quality machine (either new or remanufactured) at a lower long-term cost, with benefits such as free servicing.

The *manufacturer workshop* revealed that lightweight, easy to use and cordless products are of growing importance in the industry sector. The Information Provision and Optimal Construction product concepts were especially well received and considered most promising.

In the third and final phase, the concepts were refined through a focus group involving 15 users, which provided feedback on prototype products. A toolkit for product development teams was created in the form of cards that display 28 components (i.e. product features) generated through a product concept development process. Each card has information on the type of cleaner most likely to be attracted to a particular product feature and the actor (i.e. industry, policy makers, consumers) most able to influence its implementation. The product concepts and features were then tested through a second survey, again using a consumer panel, which attracted over 550 respondents. This investigated how the concepts and features might influence purchase decisions and whether consumers felt they would influence the vacuum cleaner's longevity. Lastly, the toolkit was tested with five industry stakeholders (four manufacturers and a repairer) to consider commercial feasibility.

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1. INTRODUCTION

Sustainable consumption requires increased product longevity, not least because the fast throughput of consumer goods adds to the threat of climate change due to embodied greenhouse gas emissions (Allwood and Cullen, 2012). Longer product lifetimes is also an integral part of the waste reduction agenda (HM Government, 2013).

The overall aim of this research project was to act on an apparent gap between consumers' attitudes to product longevity and the actual product end-of-life (Evans and Cooper, 2010) with particular reference to dirt, damage and lack of serviceability. The project sought thereby to contribute to reducing negative sustainability impacts caused by frequent replacement of high energy-embedding products – using vacuum cleaners as a case study – by understanding the impact of 'dirtiness' and 'brokenness' on product lifetimes and trialling co-designed strategies for facilitating effective long term maintenance. Vacuum cleaners are the second largest source of embodied emissions among electrical products in the UK (Product Sustainability Forum, 2012), and while today's consumers, on average, expect them to last only 5 years (WRAP, 2013a), 28% of purchases in 2012 replaced a product under that age which had broken down or proved unreliable (WRAP 2013b). The project led to the creation of design concepts that were developed and tested through research and small-scale trials involving consumers, manufacturers, designers and professional repairers.

The project adopted an action research approach (Robson, 2011) in which researchers working directly with households to learn from their vacuum cleaner use, repair, maintenance and disposal behaviours. This approach has been structured around four main objectives:

1. To investigate consumers' perceptions of dirtiness and brokenness, addressing quality, durability, cleanliness, efficiency and performance, and to identify the motivations for replacement and the barriers to good maintenance.
2. To verify the consistency between consumers' perception and the actual status of discarded vacuum cleaners, and to classify perceived dirtiness and brokenness in relation to people's attitudes to cleanliness and maintenance.
3. To plan and trial design interventions to improve the maintenance and longevity of vacuum cleaners, fostering the active engagement of consumers and manufacturers.
4. To make recommendations that relate to other products that are susceptible to dirt and require regular maintenance, based on the findings.

Scoping of research

The first stage of the research gathered knowledge about consumer perceptions of dirtiness and brokenness and attitudes towards servicing and repair from five sources: a literature review, interviews with three stakeholders, 114 consumer on-street interviews, nine consumer in-home interviews, and a product teardown exercise. The findings were collated and are briefly summarised below.

Vacuuming carpets and other flooring is a high priority and a satisfying task for most of the population. However, different amounts of effort and time are allocated to it and conflicting meanings may arise, such as when cleanliness is perceived as a higher priority than environmental impacts. The research indicated that the following are prominent in people's engagement with vacuum cleaners and need to be taken into account when developing design interventions to change their attitudes and behaviour towards vacuum cleaners: economy, effectiveness, ease of use, durability, appearance and style.

While vacuum cleaners are now ubiquitous and comparatively cheap, cost is a significant factor in purchase choice, together with brand reputation and performance. Suction power is the most desirable performance factor in product acceptability, usually (but sometimes erroneously) linked to wattage.

Vacuum cleaner life-spans appear to have declined, and also consumers' expectations of their longevity. Brokenness and loss of efficiency are the most commonly reported reasons for replacement. Vacuum cleaners are liable to be replaced every 2 to 5 years. Maintenance requirements are generally limited to basic tasks such as emptying bags and washing or replacing filters, and yet some users seem unaware of their importance and how they might increase their vacuum cleaner's life-span. Users do not necessarily check instructions even when faced with minor faults. A cost-focussed approach to material selection, design and manufacture makes repair appear impractical or too expensive. Negative attitudes towards repair and maintenance prevail, reinforced by the low cost of new items. As a result, replacement is often preferred, in line with business models pursued by manufacturers.

Owners viewed the visibility of dirt both positively and negatively.. While a visibly full dirt container may give a sense of achievement, the look of a machine quickly deteriorates with use. The sense of disgust engendered by dirt may ultimately have a role in disposal decisions. The current design language used to signify technical advancement and capability involves convoluted shapes, which harbour dirt, as well as thin, fragile moulded plastic details: both invite rapid physical deterioration and such design also risks quickly becoming stylistically obsolete. However, lack of longevity did not seem to be a major problem to users, many of whom appear satisfied with their vacuum cleaner's life-span.

Finally, the scoping stage revealed five promising areas to intervene for vacuum cleaner longevity:

- Ageing Gracefully - improving the functional and aesthetic ageing characteristics, to minimise depreciation and maximise user attachment.
- Optimal Construction - facilitating repair and optimising resource use through modularity and/or lightweight components.
- Information Provision - communicating clear information, via the product, about its performance and condition, before purchasing and while in use.
- Enjoyable Experience - re-evaluating the vacuum cleaner and its context through the provision of an effortless experience in achieving clean floors.
- Servicing Systems - exploring opportunities for trade-in, repair and resale by developing skills and networks between professionals and amateurs.

Report structure

The research was undertaken in a series of work packages. Work undertaken at the scoping stage (WP2) underpinned the next two work packages, the survey (Data Questionnaire - WP3) and concept development (Co-creating Solutions - WP4), findings from which were published in an Interim Report. Subsequent work packages developed the product concepts and their specific features (Action based pilot interventions - WP5) and refined these concepts for use in a toolkit (Action refinement - WP6). Other work packages addressed project management (WP1) and the delivery of reports (WP7). Table 1 summarises the methods used for each work package.

Table 1. Structure of report, by section, work package and methods used.

Section (WP)	Method
1 (WP2)	Literature review, stakeholder and consumer interviews, product teardown
2 (WP3)	Online survey
3 (WP4)	Design and Co-creation (user/manufacture) workshops
4 (WP5)	Focus group
5 (WP6)	User workshop, online survey and stakeholder interviews

This report includes a summary of the Scoping Report (above), updated material from the Interim Report, and findings from subsequent work packages.

Section 2 describes the development of the questionnaire that comprised WP3 and presents survey results. The survey of vacuum cleaner users investigated the trends and variables identified in WP2, in order to assess the level of interest in the proposed concepts. Responses from different socio-economic groups indicated attitudes to cleanliness, purchase, use, maintenance and disposal of vacuum cleaners and revealed challenges to changing users' attitudes and behaviour.

Section 3 presents the development of possible design interventions for behavioural change under the five *themes*, aimed at improving the maintenance and longevity of vacuum cleaners by fostering the active engagement of users and manufacturers (WP4). The work package developed and explored five *product concepts* corresponding to the five initial themes. The ideas drew on both usability and commercial perspectives, benefiting from the collaboration of users and industry representatives.

Section 4 presents findings from WP5, in which vacuum cleaner users' responses to the design interventions (i.e. product concepts) derived from WP4 were assessed. The aim was to inform future development of the concepts concerning the appearance, usability and maintenance of vacuum cleaners, the owner's relationship with the manufacturer, and the product's environmental impact. Participants from earlier phases of the research took part in a focus group discussion, providing an opportunity to further review consumer habits, attitudes and behaviours.

Section 5 describes the development and the results from WP6, in which the product concepts were refined into *components* of a 'toolkit' of possible design interventions to engage industry stakeholders and encourage sustainable user behaviour. The toolkit, in the form of guidance cards, was presented to and discussed with participants involved in previous phases of the research, and the product concepts and specific design *features* were assessed through an online survey, followed by stakeholder interviews.

Conclusions and recommendations from the research are in Section 6. The research methods and tools are provided or described in greater detail in Appendices.

2. SURVEY

An online consumer survey (WP3) was undertaken in August 2014, following a scoping exercise, and addressed two objectives:

- To investigate whether the attitudes and behaviour towards vacuum cleaner repair, maintenance and disposal that were identified are representative of the UK population.
- To gain preliminary responses to the five themes and proposed product concepts.

Questionnaire development, delivery and data analysis were supported by sub-contractors JRA Research. The sample was drawn from a national online consumer panel representative of the UK population that is regularly used by the sub-contractors. Panel responses were sought until 500 respondents who owned a vacuum cleaner and were solely, or jointly, responsible for its maintenance and upkeep had satisfactorily completed the questionnaire; this comfortably exceeds the number required for a confidence interval of $\pm 5\%$ in 95% of cases. The final sample of 507 was broadly representative of the UK population in terms of age (27% aged 17-35; 39% aged 36-55, 34% aged over 55), gender (45% male; 55% female) and social grade (27% AB; 43% C1C2; 30% DE).

As the data were normally distributed and standard deviations known, data were subjected to z tests to compare sample percentages from the population and t tests to compare derived mean scores in order to identify whether there were significant differences between sub-groups based on demographic variables or attitudes and behaviour towards cleaning (Section 2.2).

2.1 Survey contents and structure

The questionnaire asked respondents about their vacuum cleaner(s), their attitudes to cleanliness, maintenance, damage, purchase and disposal, and their reaction to the five themes (see Appendix 1 for the full questionnaire). They were expected to complete the survey within 15 minutes, recommended by JRA as a reasonable time for maintaining their attention.

Screening questions determined whether respondents were eligible to take part in the study and addressed:

- Ownership (only owners of vacuum cleaners were allowed to answer the questionnaire).
- Demographic data, i.e. age, gender, income.
- Attitudes towards the environment, e.g. 'I'd like to do a bit/a lot more to help the environment.'
- Responsibility for use, purchase, maintenance and disposal of the vacuum cleaner, e.g. solely, jointly and/or mainly responsible.
- Six sets of questions in the survey addressed:
 - The product(s) owned - their number, type, brand and length of ownership.
 - Attitudes to vacuuming and the importance of cleanliness, indicated by frequency of use, where the machine is stored and engagement with cleaning.
 - Attitudes to regular and exceptional maintenance or servicing (including emptying, changing/cleaning filters, changing the belt) and to information and servicing.
 - Attitudes towards signs of damage or malfunction.
 - Disposal of previous vacuum cleaners.
 - Attitudes when purchasing a new vacuum cleaner.

2.2 Key findings

The survey was aimed at respondents who owned a vacuum cleaner and were solely, or jointly, responsible for its maintenance and upkeep. Most respondents (89%) had previously owned other vacuum cleaners, although nearly a quarter (23%) of those aged 17-35 had not.

The survey investigated general attitudes towards the environment by asking respondents which of three statements described how they feel about their current lifestyle and the environment. Nearly a quarter (23%) indicated that they wanted to do 'a lot more' to help the environment, around a third (35%) would like to do 'a bit more' to help the environment, while 40% were 'happy with what I do at the moment.'

2.2.1 *Attitudes to dirt and cleanliness*

A majority of respondents were the main user of the vacuum cleaner (64%), while just under a quarter (23%) shared this responsibility. In other cases a partner or spouse (10%) or another adult (2%) was the main user. Around three-quarters of respondents either use their vacuum cleaner 2 to 5 times a week (41%) or once a week (33%).¹ At the extremes, 13% vacuum once or more a day, while 4% vacuum only once a month or less often. The other 10% vacuum 2 or 3 times a month. Overall, females reported vacuuming slightly more frequently than males; 58% of females vacuum more than once a week, compared with 49% of men.

Cleanliness in the home is a 'high priority' for nearly a third of respondents (31%), while the majority (59%) rate it as a 'medium priority' and 10% a 'low priority'. This aligns with research by MINTEL (2013), which concluded that most people take pride in maintaining a clean home. The priority put on home cleanliness relates to frequency of vacuum cleaning and, to some extent, to attitude to the environment; respondents willing to do 'a lot more' to help the environment were significantly more likely to strongly agree that 'it's really important to me that I keep the floors in my home spotlessly clean to ensure the well-being of my family/household' than those willing to do 'a bit more', or 'happy with what I do' (39% cf. 15% and 17% respectively, $p < 0.01$).

The majority of respondents agree (46%) or strongly agree (21%) that keeping floors 'spotlessly clean' in their home is important to ensure the wellbeing of their family/household, which is also consistent with findings from MINTEL (2013). Only 8% either disagree or disagree strongly. Cleaning the house is usually an activity carried out by household members; only a small minority (4%) currently pay someone else to help clean their house. However, around a third of respondents (35%) would like to employ a cleaner but do not for various reasons, suggesting that many do not regard cleaning the house as enjoyable or engaging.

The set of questions on attitudes to vacuuming and the importance of cleanliness made it possible to assign almost all respondents (96%) to one of four groups based on their attitudes and behaviour (

¹ Findings on frequency of vacuuming are fairly consistent with other studies, although respondents reported using their vacuum cleaner slightly more frequently. According to a 2013 survey by Electrolux addressing vacuuming attitudes on a global scale, a third of the population will vacuum 2 to 5 times per week, while 16% will vacuum once or more a day. According to MINTEL (2012), around three in ten homes in the UK are vacuumed two or three times a week and a similar proportion four or more times.

Table 2), applying descriptors identified by Vaussard et al. (2014)²:

- Spartan cleaners (12%)
- Minimal cleaners (34%)
- Caring cleaners (40%)
- Manic cleaners (10%).

² See Scoping Report for more details. The diagram of the clustering process is in Appendix 2.

Table 2. Cleaner type, based on behaviour and attitudes to cleanliness.

Cleaner type	Vacuum cleaning and attitudes to cleanliness
Spartan	Vacuum less than once a week and consider cleanliness of their house a medium or low priority.
Minimal	Vacuum once a week or, if less often, consider cleanliness of their house a high priority.
Caring	Vacuum 2-5 times a week and consider cleanliness of their house a high or medium priority.
Manic	Vacuum daily and prefer to do it themselves rather than employ a cleaner.

A Spartan cleaner, for example, barely notices dirt and does very little about it (Vaussard et al. 2014); thus in our categorisation she or he vacuums infrequently and rates cleanliness as a low priority. Spartan cleaners do not seem to enjoy vacuum cleaning and half of them reported that they would like to employ someone to help clean the house. At the other extreme are Manic cleaners, who clean almost obsessively and spend considerable time tidying up (Vaussard et al. 2014). In our categorisation Manic cleaners vacuum once or more a day and rate cleanliness of their house as a high priority. About 9 out of 10 Manic cleaners (cf. 3 out of 10 Spartan cleaners) agree or strongly agree that keeping floors spotlessly clean is important.

There are demographic influences upon the cleaner types. A significantly higher proportion of males are Spartan cleaners (16%) compared with females (8%) ($p < 0.05$). Likewise, a significantly higher proportion of females are Caring cleaners (43%) or Manic cleaners (12%) compared with males (37% and 8%, respectively) ($p < 0.05$). Age is not closely associated with cleaner type except that people aged 46-55³ are significantly more likely to be Manic cleaners (29%) than Caring cleaners (17%) ($p < 0.01$). No relationship was found between social grade and cleaner type.

Linking use of vacuum cleaners to attitudes towards cleanliness through the cleaner types provided some useful insights; the findings reported below highlight the attitudes to vacuuming of different types of cleaners.

2.2.2 Ownership

The majority of respondents (69%) own one vacuum cleaner, but a substantial percentage (27%) own two, and a small minority (4%) own three or more.

Many respondents indicated that they have sole (51%) or shared (13%) responsibility when purchasing the vacuum cleaner. They own a variety of types of machine, notably bag-less uprights (47%) and cylinders with bags (20%). The majority (70%) own bag-less models.⁴ Most uprights are bag-less, whereas cylinders are fairly evenly divided between bagged and bag-less. The most common brand among respondents was Dyson (34%), followed by VAX (17%), Hoover (10%) and Numatic (7%).⁵

Almost half the respondents (45%) have a main vacuum cleaner that is under 2 years old, while that of a third (32%) is 2-5 years old; only 22% have a main vacuum cleaner that is over 5 years old.⁶ Manic cleaners replace their vacuum cleaners more frequently: 70% own one under 2 years old and only 10% own one over 5 years old (none own one older than 10 years). At the other end of the spectrum, Spartan cleaners keep their vacuum cleaner for longer: 34% own one older than 5 years and 14% own one older than 10 years. Caring and Minimal cleaners tend to be between the two extremes. The more intense use of their machine by Manic cleaners may shorten their machine's life-span in comparison with those of Spartan cleaners.

³ Age groups were subdivided for this question.

⁴ This data is consistent with other studies (Electrolux 2013; MINTEL 2010).

⁵ Dyson, Vax and Hoover are in the top 4 brands according to MINTEL (2010).

⁶ The life-span of vacuum cleaners according to the survey appear even shorter than findings from MINTEL (2013), according to which in 2012 a similar proportion of respondents (44%) had replaced their vacuum cleaner during the past 3 (cf. 2) years.

A majority of respondents keep their vacuum cleaner out of sight, storing it in a cupboard (62%), hidden elsewhere (16%), or put in a utility room, garage or storage room (2%); the remainder (20%) leave it on view. This suggests that a vacuum cleaner is widely considered an object to be kept out of sight, which might contribute to its disposability. 40% of Manic cleaners have their vacuum cleaner on view (compared with between 15% and 21% for other cleaner types), possibly to keep it in easy reach for daily use and perhaps communicating that they value a machine that helps them to accomplish a task that matters a lot to them.

2.2.3 *Attitudes to maintenance*

Maintenance was identified in the scoping phase as crucial to the longevity of a vacuum cleaner. The survey investigated attitudes to regular and exceptional maintenance such as emptying dust, changing filters and undertaking repairs.

Emptying dust

Just under half (45%) of respondents empty their vacuum cleaner when they 'think it's full'. Others do so when the machine *indicates* that it is full, when it 'does not suck properly', or 'after almost every use' in smaller, comparable proportions (around 15% in each case). Significantly more Manic cleaners (24%) than Spartan cleaners (3%) do so 'as soon as the machine indicates that it is full' ($p < 0.01$), whereas Spartan cleaners (25%) are significantly more inclined than Caring cleaners (12%) to wait until 'it does not suck properly' ($p < 0.05$).

Maintaining filters

About a third of respondents (32%) change or clean their filters in the machine when they 'think it needs it' and 15% according to manufacturer's instructions, while around a fifth (18%) wait until it 'does not suction properly' before carrying out this task. However, 13% do not clean their filters or do not know if their vacuum cleaner has them (a much higher proportion, 29%, in the case of Spartan cleaners). Cleaning or replacing filters is regarded by manufacturers (i.e. in instruction manuals) and by repairers as a fundamental task for keeping vacuum cleaners in good working order (thus prolonging their life-spans). This highlights a low level of knowledge about the fundamental components of a vacuum cleaner and its basic maintenance requirements.

Other maintenance tasks

Questioned about other maintenance tasks, the most common was checking that the vacuum cleaner brush head is free from hair or dirt (62%), especially by those vacuuming more than once a week. Over half of respondents (55%) remove dust from around the casing, but only 28% check the electrical cable. For most tasks more Manic and Caring cleaners reported carrying out maintenance than Spartan and Minimal cleaners. Significantly more Caring cleaners checked the brush head than Spartan or Minimal cleaners (71% cf. 51% and 57% respectively, $p < 0.01$). One in six respondents (16%) do not carry out any of the listed maintenance tasks; significantly more in the case of Spartan cleaners than Caring or Manic cleaners (31% cf. 10% and 8% respectively, $p < 0.05$). Respondents willing to do 'a bit more' for the environment were significantly less likely to indicate that they do not carry out the maintenance tasks than those 'happy with what I do' (9% cf. 21% respectively, $p < 0.01$).

The likelihood of contact with dirt when undertaking these tasks does not, on its own, explain the lack of interest in maintenance tasks. Most respondents indicated that either 'I regard some contact with dirt as inevitable' (43%) or 'I don't mind getting my hands dirty' (41%). Only 13% 'try very hard to avoid contact with dirt'; these are more likely to be female (16%), Manic cleaners (18%) or under 35 years old (24%).

Expected responses to failure

In the event of a loss of suction or the machine not switching on, most respondents would seek to repair their vacuum cleaner themselves or get it repaired by someone else. In the event of loss of suction, for example, owners would consider undertaking the repair themselves if the fault was minor (27%) and definitely do so if they had the necessary information and parts (26%); nearly a quarter (23%) would consider getting the vacuum cleaner repaired by someone else. Similar proportions were recorded in the event of machines

not switching on. Vacuum cleaners are not considered worth repairing by 14% of respondents if they lose suction and 11% if they do not switch on.

Other factors can influence attitudes to repair in such circumstances. Owners of cylinder models are significantly more likely than owners of upright models to consider vacuums not worth repairing if they lose suction (20% cf. 10%, $p<0.01$) or do not switch on (16% cf. 7%, $p<0.01$).

Gender significantly affects responses to disrepair. Males are significantly more likely than females to 'definitely try to repair' their machine if it does not switch on (32% cf. 19%, $p<0.01$) or loses suction (33% cf. 21%, $p<0.01$), assuming they have access to the necessary information and parts. By contrast, females are significantly more likely than males to consider having their vacuum 'repaired by someone else' if it does not switch on (31% cf. 19%, $p<0.01$) (though not in the case of it losing suction). Moreover, females are significantly more likely to consider themselves 'not responsible for repairing the vacuum' if it does not switch on (8% cf. 2%, $p<0.01$) or loses suction (8% cf. 3%, $p<0.05$).

Age, too, significantly affects people's responses. Fewer young people would 'definitely' try to repair a machine which stopped sucking effectively, assuming they had the necessary information and parts: only 12% of 17-35 year olds, compared with 32% of those aged 36-55 and 30% of those aged 56 and over. This may imply a lack of confidence among the young in their ability to undertake such a task. A similar picture emerged in the case of a machine that does not switch on, although in this case a significantly larger proportion of 17-35 year olds would consider having it repaired by someone else (33%) than those aged 56 and over (19%) ($p<0.05$).

Repair experiences

As indicated above, most respondents would consider repairing their vacuum cleaner or getting it repaired. Yet only 18% have had their current vacuum cleaner repaired, which suggests that the repair option is rarely taken. The gap between the stated attitude and performed action could be due to barriers preventing the execution of the repair option in the case of failure or loss of efficiency, such as the product's design, levels of service, inconvenience and cost (Defra, 2011).

The survey found that repairs are significantly more likely not to have been undertaken on currently owned cylinder models (88%) than upright models (78%) ($p<0.01$), suggesting that the former may be more reliable. Overall, 10% of respondents had personally repaired their vacuum cleaner, while others had their machine repaired by a family member (3%), specialist repair shop (2%), manufacturer (2%) or retailer (1%). Repair work by respondents was significantly more likely to have been undertaken by males than females (14% cf. 6%, $p<0.01$).

Sources of information

Respondents search for information on the maintenance and repair of vacuum cleaners in various ways, but by far the most popular method is to use the instructions that come with the product: 74% have done so at least once (47% frequently or occasionally, 27% once). Just 26% have never used this method (cf. over 70% for other information sources). Respondents have also used the manufacturer's website (29%) or searched the internet for advice (22%); in both of these cases the proportions were higher for the 17-35 age group than those aged 56 or over. Respondents also asked friends or family members (26%) or a specialist or retailer (14%).

Servicing

The option of having a vacuum cleaner serviced is not very popular: only 22% of respondents would consider having their vacuum cleaner serviced annually (even if cost effective and convenient), and a very small proportion (3%) would consider renting or leasing a vacuum cleaner (even if this included regular servicing). Nearly half (49%) think that vacuum cleaners are well made these days and do not need servicing.

However, nearly a third of Manic (32%) and Caring (30%) cleaners would consider an annual service if it was cost effective and convenient, significantly more than Spartan (10%) and Minimal (15%) cleaners ($p < 0.05$), and the same was true for people wanting to do a 'lot more' (31%) or a 'bit more' (25%) for the environment compared with those 'happy with what I do' (16%) ($p < 0.05$). An annual servicing option is significantly more likely to be considered by those who bought a vacuum cleaner recently (28% if within 3 years cf. 16% if over 3 years ago, $p < 0.05$). Spartan and Minimal cleaners appear less inclined towards servicing: around a quarter responded that they 'don't think that vacuums are well made these days but servicing is not a realistic option', around double the proportion for Manic and Caring cleaners.

2.2.4 *Attitudes to wear and damage*

An initial hypothesis was that the ageing of vacuum cleaners through general wear and tear could be a trigger for faster replacement. However, only 10% of respondents reported dissatisfaction when their machine gets marked or chipped. Nearly half (47%) prefer it to look new but 'tolerate' visible signs of wear, while 43% 'do not care' if it shows signs of wear.

Manic (60%) and Caring (59%) cleaners are significantly more likely to 'prefer my vacuum to look new but tolerate visible signs of wear' than Spartan and Minimal cleaners (both 34%, $p < 0.05$) and, consistent with this, significantly more Spartan (54%) and Minimal (55%) cleaners 'do not care if the vacuum shows visible signs of wear' than Manic (30%) and Caring (33%) cleaners ($p < 0.05$). Unsurprisingly, tolerance of signs of wear increases with the age of the vacuum cleaner and age of the owner. More than half (54%) of owners of a vacuum cleaner older than 5 years do not care about visible signs of wear, against 40% of those owning one aged 1 year or less. Similarly, 50% of respondents aged 56 years or over do not care about signs of wear, against 33% of those aged 17-35.

Tolerance of visible signs of wear is reflected in the way that vacuum cleaners are used. Around three quarters of respondents (73%) 'take care when vacuuming but accept that marks on the machine are inevitable with regular use' and one in five (20%) 'vacuum quickly to get the job done even if it risks causing marks on the machine', while only a small proportion of respondents (7%) vacuum 'very carefully to minimise the risk of causing marks on the machine'. Spartan cleaners (37%) are significantly more likely to 'vacuum quickly to get the job done' than Minimal (23%), Caring (12%) or Manic cleaners (14%) ($p < 0.05$). Likewise, those who vacuum less than once a week are significantly more likely to 'vacuum quickly to get the job done' (37%) than those who vacuum 2-5 times each week (14%) or once or more each day (13%) ($p < 0.01$).

In the case of a possible fault in the form of an unusual noise or smell, while 70% of respondents would 'investigate immediately', 20% 'do not worry' as long as the vacuum cleaner is sucking dirt effectively and 9% as long as it works. People aged 17-35 are significantly less likely to 'investigate immediately' than those aged 36-55 or aged 56 or older (53%, cf. 73% and 81% respectively, $p < 0.01$).

Reasons for replacement

The most common reasons for respondents ceasing to use their previous vacuum cleaner are because it 'didn't work efficiently' (44%) or 'didn't work at all' (34%). Around one in six respondents (16%) replaced their vacuum cleaner because they 'wanted a new one' despite their existing one still working. Small proportions indicated that they replaced their vacuum cleaner because they received a new one as a gift (5%), moved house (2%), or for other reasons.

Disposal

When disposing of their old vacuum cleaner, 39% of respondents took it to a civic amenity site and 18% put it in a bin or skip (especially younger owners). Owners aged 17-35 were significantly less likely to take it to a civic amenity site than those aged 36-55 or 56 and over (22% cf. 39% and 49% respectively, $p < 0.01$). Owners aged 56 and over were significantly less likely to put it in a bin or skip than those aged 17-35 or 36-55 (7% cf. 29% and 22%

respectively, $p < 0.01$). 14% of respondents gave it away and the same proportion still had it at home. A small proportion (5%) indicated that the machine was collected by the retailer.

2.2.5 Attitudes to purchase

The priorities of respondents when purchasing a new vacuum cleaner are:

- price (87% rating it as either important or very important)
- expected life-span (80%)
- weight (75%)
- length of the guarantee (63%)
- range of features (64%)
- brand (47%)
- appearance 40%.

Respondents in social grades D and E were significantly more likely to consider price as 'very important' than those in social grades A and B (67% cf. 47% $p < 0.05$).

Female respondents were significantly more likely to consider weight as 'very important' than males (49% cf. 26% $p < 0.01$) and, likewise, users aged 56 or over more so than those aged 17-35 (46% cf. 30%, $p < 0.01$).

Manic (46%) and Caring (35%) cleaners were significantly more likely than Spartan (17%) and Minimal (24%) cleaners to consider the length of guarantee to be 'very important' ($p < 0.05$), while Caring cleaners were significantly more likely than Spartan and Minimal cleaners to consider the machine's expected life-span to be 'very important' (53%, cf. 31% and 39%, respectively, $p < 0.01$). People who want to do 'a lot more' for the environment were significantly more likely to consider life-span 'very important' than those who want to do 'a bit more' or are 'happy with what I do' (58% cf. 39% and 42%, $p < 0.01$).

Respondents were given a hypothetical scenario of purchasing a 'totally new type of vacuum cleaner' and asked to rank five types reflecting the five themes, in two sets of options. Their preferences appeared to favour *Optimal Construction*, *Information Provision* and *Enjoyable Experience* over *Ageing Gracefully* and *Servicing Systems* (see Appendix 3 for detailed descriptions and rankings).

2.3 Implications

The survey results describe attitudes and behaviours towards use, maintenance, damage, servicing and repair of vacuum cleaners in the UK with a higher level of detail than previous research. In so doing they contributed to a better understanding of users and supported the development of future products/services. The results revealed key challenges that the development of the product concepts would face in subsequent work packages:

- Creating the perception of the vacuum cleaner as a pleasant object that warrants effort: Vacuum cleaners are generally stored hidden from view. Few respondents indicated that they dislike it if their vacuum gets marked or chipped, suggesting that they perceive it as an object to keep hidden and one which is readily disposable. Some replace their vacuum merely because they want a new one, suggesting that a vacuum is perceived as a disposable object that does not warrant time, money and effort.
- Creating the perception of vacuuming as an enjoyable task: Many people do not regard cleaning the house as an enjoyable (or even engaging) task, with nearly 40% of respondents wishing that someone else would clean their house.
- Motivating constant and effective maintenance: Maintenance tasks (e.g. emptying the dirt container and changing filters) are carried out less often than recommended by manufacturers, although they are essential for a machine to be longer-lasting and effective while in use.

- Communicating information effectively: Maintenance tasks are mainly triggered by personal perceptions (perhaps flawed) and habits rather than a manufacturer's instructions, or signals indicated by the machine. Too few respondents check the range of sources of information about appropriate maintenance and repair.
- Encouraging the servicing and repairing option: Many respondents replaced their previous vacuum cleaner because it did not work at all, but some did so because it was not working efficiently, suggesting that it may not have been beyond repair. Few owners have had their vacuum cleaners repaired and most show little interest in regular servicing, although such action could prolong product life-spans.

Overcoming these barriers is particularly challenging because they are associated with low value being attributed to vacuum cleaners, which means that they are perceived as not worthy of being looked after and having resources invested in them to extend their life-span. At the same time, cleanliness at home has a medium or high priority for most people, reflected in the habit of vacuum cleaning once or more each week.

Given the crucial role that vacuum cleaners play in cleanliness and the apparent potential for greater satisfaction from their use, identifying these barriers and challenges is an important step towards changing attitudes and behaviours towards vacuum cleaning. Finally, potential success in behaviour change will demand understanding how the product concepts under development address the specific attitudes to cleanliness, maintenance and repair that were observed in the different cleaner groups.

3. CO-CREATING SOLUTIONS

The next stage of the research was to explore novel product concepts for less impactful vacuum cleaners, aiming at longer life-spans. The concepts were based on the five themes previously identified (WP2), drawing upon survey findings on attitudes and behaviour towards vacuum cleaners and potential barriers to change (WP3). The process involved co-creation methods, '*creativity that is shared by two or more people*' (Sanders and Stappers, 2008), using insights from users and manufacturers (WP4, WP6).

Five final year students on the Product Design programme at Nottingham Trent University were recruited to explore product concepts based on the five themes:

- Ageing Gracefully
- Optimal Construction
- Information Provision
- Enjoyable Experience
- Servicing Systems.

Drawing upon insights from the earlier research (WP2, WP3) their main task was to 'sketch' models and scenarios for testing at the concept development stage (WP5), based on a range of possible strategies:

- Environmental redesign of existing systems (e.g. a new component or tool).
- Designing new products and services (e.g. a new type of vacuum cleaner).
- Designing new production–consumption systems (e.g. a new repair service).
- Creating new scenarios for sustainable lifestyles (e.g. a new perception of maintenance) (Vezzoli and Manzini, 2008).

The students were recruited on the basis of the quality of an initial project proposal presentation and their contribution to a group discussion on how to address the issues identified. The successful students each received one of the five themes as a brief and was asked to address it by developing an associated product concept under the supervision of academic staff. The students were encouraged to draw upon life cycle thinking, be creative and not feel constrained by current business models which focus on maximising the sales throughput of new machines. Recent research has highlighted a need for alternative business models in order to increase product life-spans (Bocken and Short, 2015) and proposed that business model development and design strategies will need to be aligned within the context of a circular economy (Bocken et al., 2016),

Each brief presented different challenges. For example, the student exploring the Optimal Construction theme quickly established the idea of using fewer material types and aiming to create a vacuum cleaner for which certain parts would be longer lasting, whereas high-wear components would be short-lived but recycled. He also suggested that a maintenance-free vacuum cleaner would be highly appropriate for his targeted users, Spartan cleaners. One of the main features that he investigated was the design of sealed dust containers that users could send back to the manufacturer when full, for reuse or recycling. A second student, working on the Ageing Gracefully brief, found getting started a little more challenging. The theme concerns psychological influences upon users and it was necessary from the outset to identify psychological barriers to acceptability of vacuum cleaners that would 'age gracefully'. The on-street consumer interviews had indicated that visual 'wear and tear' would have little effect on disposal decisions and survey respondents indicated that they would tolerate marks or chips, but it was uncertain whether, in practice, dirtiness or scratches might encourage disposal at a subconscious level.

The briefs were implemented by involving users and a manufacturer of vacuum cleaners in the creative process of developing and refining product concepts. Two workshops were

conducted, one with users and another with the project's partner manufacturer, VAX, to gather feedback from the design students' preliminary proposals and as concept design sessions to broaden the set of possible solutions.

3.1 User workshop

The user workshop was designed to collect feedback on the five themes and associated concepts, co-create ideas for each theme, and gain additional information on consumer attitudes towards vacuum cleaners and cleaning.⁷

3.1.1 *Logistics and method*

Thirty users of vacuum cleaners were recruited from the on-street and in-home interviews, and a few additional participants were recruited through JRA in order to ensure an appropriate range of cleaner types. An incentive of £25 was offered to attend a two hour co-creation session held at NTU in November 2014.

Upon arrival, participants were asked to complete a short questionnaire in order to create teams of six participants, each containing a range of cleaner types. Each team addressed one of the five themes (e.g. Ageing Gracefully) at a different table. The arrangements of the tables in the venue allowed participants to see what other teams were doing and provide feedback on ideas in a subsequent plenary session.

The workshop was designed to reflect on new ideas and insights concerning vacuum cleaners and cleaning using participants' personal experiences. A participatory approach was pursued to exploit the potential innovation brought by users, following co-creation techniques (Sanders and Stappers, 2008), involving users as experts (Millard et al., 2009), prompting discussion among participants, and providing visual stimuli (e.g. film clips) and materials for modelling (e.g. Plasticine) to facilitate the expression and generation of ideas.

Each team was asked to complete two tasks, the method of which is outlined below (see Appendix 4 for full schedule). These were facilitated and assisted by NTU researchers and students. A camera on each table recorded the development of the tasks.⁸

3.1.2 *Most frustrating and most enjoyable vacuum cleaner*

The first task served as an ice breaker, stimulating conversation before a second, more demanding, task, and enabling more information about vacuum cleaners and cleaning to be collected from users. Working as a team, participants were asked to describe their most frustrating and most enjoyable vacuum cleaners. The task was designed to be quick and to allow participants to reflect upon their personal experience. Each team was provided with simple outlines of an iconic upright and cylinder vacuum cleaner and encouraged to work together to annotate and adapt the drawings (Figure 1). The five themes were briefly introduced, although participants were asked not to focus on these at this point in the proceedings.

Participants indicated that they considered vacuum cleaning most enjoyable when operating a machine that is easily manoeuvred (e.g. lightweight and cordless), user-friendly (e.g. easy to take apart), adaptable (e.g. including accessories), requiring low maintenance (e.g. easy to empty and repair), powerful (e.g. high suction performance) and appealing (e.g. smooth aesthetic and sensible price).

Participants felt that vacuuming was most frustrating when the machine was difficult to manoeuvre (e.g. heavy, wobbly and unstable), not user-friendly (e.g. noisy and difficult to store), required complex maintenance tasks (e.g. emptying from the bottom and disentangling hair from the brushes), lacking in suction power, visually bulky, and liable to attract dust and scratches. The features of the most enjoyable and most frustrating vacuum cleaners are summarised in Table 3.

⁷ During the process, potential participants for future activities were identified.

⁸ Participants were informed that the workshop was recorded and arrangements made for those who did not wish to be filmed.

Table 3. Summary of 'Most Frustrating' and 'Most Enjoyable' features of a vacuum cleaner.

Most frustrating vacuum cleaner	Most enjoyable vacuum cleaner
Manoeuvrability	
Bad mobility	Ball wheels
Heavy	Easy to move
Unstable and wobbly	Cordless
Loose cable	Fits in corners
Excessively long hose	Lightweight
Short cord	Long cable
Small wheels	
Hard to drag around	
Rigid hose	
Square wheels	
User-friendliness	
Difficult to store	Easy to store
Small capacity	Large capacity
Difficult to assemble	Easy to take apart
Hidden features and parts	Clear (see-through) plastic
Noisy	
Scares children and small animals	
Adaptability	
Too many tools	Lots of nozzles
Loose parts liable to be misplaced	Interchangeable tools
	Multi-application tools
	Compact but extendable
	Removable 'Dustbuster'
Maintenance	
Empty from bottom	Easy to empty
Paper bags	Compresses dust into bales
Not repairable	Easy to repair
No replaceable parts	
Repaired and held together with sticky tape	
Dust and hair gets caught in brushes	
Performance	
Lack of power	Powerful
Poor suction	Satisfaction through excellent suction
No suction	
Appearance and Price	
Bulky	Smooth aesthetic
Catches dirt in edges	Strong, smooth material
	Thin, slim line body
	'Sensible' price

3.1.3 Co-creation for a 'persona'

The second task aimed at collaboratively generating product concepts for the themes addressed by each of the teams. Fictional personas (Nielsen, 2010) were developed and used for each theme (see Figure 2 for an example and Appendix 5 for all five personas). The personas were generated from target users that the students had identified and with reference to the survey findings in order to be linked to the relevant theme.

Each team watched a two minute video in which the personas introduced themselves, described issues relating to the theme and summarised the frustrations they felt towards their old vacuum cleaner; they then introduced their (hypothetical) new vacuum cleaner. Talking about the persona's vacuuming habits encouraged participants to reflect upon and comment on their own, personal, experiences (Figure 3).



Figure 2. Persona card displayed in the user workshop.

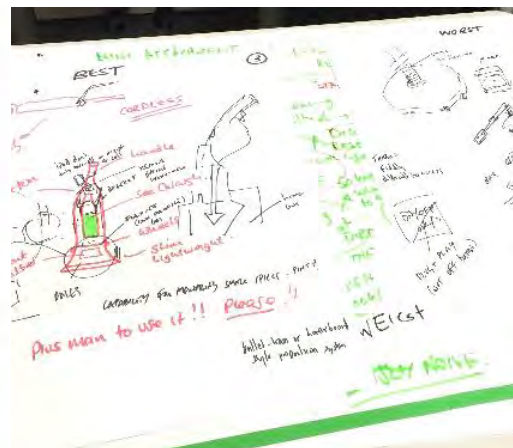


Figure 1. Sketches of the Most Frustrating and Most Enjoyable vacuum cleaners.



Figure 3. Participants at the user workshop.

For the theme Optimal Construction, for example, the persona was based around a character described on a poster as follows:

'Seth Price is a 22 year old, part-time bar worker living in Shoreditch, London. He's described as a bit of a party animal by his friends and finds chores a bit of a drain. He is currently in a relationship with his girlfriend Anna, who he's been seeing for four months. He shares a semi-detached house with five other like-minded individuals.'

His attitudes, habits, frustrations and desirable new vacuum cleaner were described in the video as follows:

'Seth vacuums on average once a month or less, where the common driver for that is his girlfriend staying over or parents visiting. He knew very little about his previous vacuum and how to maintain it, and was constantly pestered by his dad to empty it and clean the filters.'

'He was drawn to his new, cheaper alternative as it promised zero maintenance, requiring some basic disassembly when the vacuum reaches the end of its life and needs to be recycled. Overall, Seth is very happy with it, as it works every time and doesn't need emptying or any other nonsense with the filters.'

The personas proved particularly useful when co-creating with participants; they allowed participants to relate their personal experiences to those of the persona, and therefore to share their most interesting experiences with confidence. Generating ideas that related to the set of criteria that the persona had outlined meant that the co-creation process was aligned to each theme, rather than to the personal preferences of participants.

3.1.4 Key findings

Similarities existed between all teams in describing the most frustrating and most enjoyable vacuum cleaners. This was especially true of the former: users complained about vacuum cleaners that were unstable, heavy, noisy or smelly, had small capacity, short cords, stiff hoses or an excessive number of tools. By contrast the most enjoyable vacuum cleaners were lightweight, powerful and with a large capacity, and cordless models were considered attractive. Ideas from each team were drawn as illustrations by a professional cartoonist to show and compare the outputs in a clear and simple form (Figure 4).

At the end of the workshop a representative for each team presented an overview of the concepts that they had generated or developed (see Appendix 6 for images of the outputs). For instance, for the theme Optimal Construction the concept was a vacuum cleaner that could easily be upgraded by the user over time according to new needs arising from changed life circumstances, such as having new people in the house (e.g. a spouse or babies) or new pets. In this case, the proposal was for a vacuum cleaner with a bigger container that could be fitted by the user through a snap fitting; its components would be modular so that they could be configured according to use and storage.

In summary, the workshop helped to identify or confirm key elements of vacuuming from the user's perspective that need to be considered in developing the product concepts. Subsequent progress made on each is described below (Section 4).

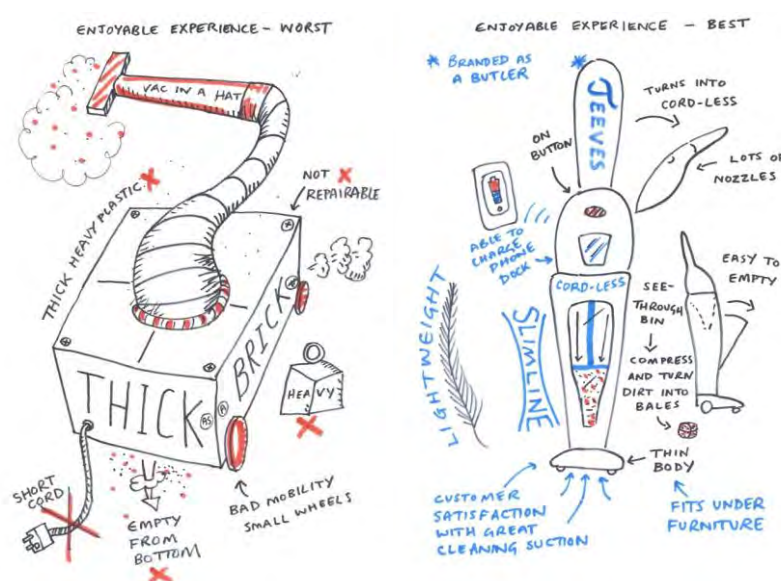


Figure 4. Examples from user workshop of features of Most Frustrating (left) and Most Enjoyable (right) vacuum cleaners (Enjoyable Experience team).

3.2 Manufacturer workshop

A workshop was held with the industry partner, VAX, in order to collect feedback on the five themes from a manufacturer's perspective, assess technological feasibility and market potential of concepts, and establish areas for future development.

The project proposal had included a second co-creation workshop involving different stakeholders (e.g. manufacturers and repairers). Due to their lack of availability at that stage in the project, however, the workshop was run solely with VAX using a revised format: a semi-structured discussion between the research team and industry partner. The discussion explored the outlook for research and development and provided insights into areas that VAX believed were promising.

The workshop was held in December 2014 at VAX's head office in Birmingham. Five representatives of the company were present: the Head of Product Development, Business Development Manager, Head of Reverse Logistics, and representatives from the Insights and Intellectual Property teams. Three researchers from NTU led the discussion. The project was introduced and the personas and illustrations generated in the user workshop were then presented and discussed.

The concepts from the Optimal Construction and Information Provision themes were considered especially promising by the company, as they fit its core strategies. In the case of Optimal Construction, for example, recent product development by the company aims to reduce material usage and create lightweight products. In the case of Information Provision, the company representatives thought that if this served as a means of identifying which sub-assembly required replacement, then their repair process could be made easier: its products are designed to be disassembled into a number of key assemblies so that a faulty part can be identified over the phone by a VAX technician and a replacement be sent out, which can be fitted easily by the client. More generally, the workshop generated useful insights about the technological feasibility and market potential for each theme (Table 4)

The discussion with VAX offered an opportunity to address the emergence of cordless vacuum cleaners and their implications for longevity and environmental impacts. Lightweight, easy to use and cordless products are seen by the company as part of a growing market, with the share of cordless products expected to reach 50% within a few years. VAX anticipate providing a diverse range of vacuum cleaners and see a growth in multiple ownership as a market opportunity. However, the sale of cordless vacuum cleaners may increase environmental impacts because of their use of scarce materials (e.g. lithium batteries) and difficulties relating to end-of-life batteries. Significantly, cordless vacuum cleaners are not covered by recent European legislation addressing vacuum cleaner component longevity (European Commission, 2013).

3.3 Implications of findings

The themes identified were addressed and expanded through a design perspective that took into account usability, appeal and sustainability requirements. The user and manufacturer workshops were essential in validating and exploring the themes (as distinct from developing new ones) and creating the product concepts. The workshop with users contributed to refinement of the concepts such that they should better fit the needs and interests of users. The workshop with the manufacturer provided insights into their strengths, weaknesses, technological feasibility and market potential.

Using a co-creation method presented the challenge of overcoming difficulties when expressing ideas to people without a design background and elaborating such ideas collectively. There was valuable discussion in the user workshop which generated useful ideas and opinions for the research team. However, the participants did not co-create any additional concepts, as had been hoped, and proved somewhat reluctant to use the modelling materials provided. Nonetheless, the workshop allowed for an initial exploration of tangible product

concepts that, following further development, were further assessed by users in an iterative process.

The workshops enabled investigation of the commercial and environmental opportunities provided by each of the themes (Table 5). Like the survey they highlighted interest in lighter-weight cordless vacuum cleaners. These are likely to form an increasing share of the market but raise a concern that inadequate battery longevity may result in shorter life-spans for the whole unit.

Table 4. Technological feasibility and market potential for each theme, as discussed at the manufacturer workshop.

Ageing Gracefully	Longevity and performance-based attributes must be met with a strong business case to ensure commercial viability. The product offer from brands such as Oreck (a company owned by VAX's parent company Techtronic Industries Company Limited, or TTI) demonstrates the potential commercial feasibility.
Optimal Construction	A product which combines functionality with the convenience of disposability and responsible recyclability may make an interesting commercial proposition. There is a market for maintenance free, disposable products: for example, some builders buy a Henry vacuum cleaner and dispose of it at the end of a job.
Information Provision	As maintenance and simple fault-finding by users is generally poor, communication methods that can address this are desirable, not least to reduce return rates. There is significant potential for a next generation 'internet of things' in creating customer loyalty and improved product experience.
Enjoyable Experience	VAX seek to incorporate attributes into products that make vacuuming a more positive experience: hence their latest cordless product. There may be potential in developing themes such as fragrance or on-show docking. Worries about health and hygiene influence purchasing decisions, and product concepts that avoid exposure to dirt and improve air quality in the home are worth development.
Servicing Systems	The vacuum product offer is increasingly based on providing a complete package: VAX offer products with different length guarantees, 2 years and 6 years. There may be market opportunities for developing an integrated product service system, especially at the higher end of the market.

Table 5. Commercial and environmental potential of the product concepts.

Theme	Commercial Potential	Environmental Potential
Ageing Gracefully	<ul style="list-style-type: none"> ▪ Premium product. ▪ Brand loyalty. ▪ Servicing and consumables. 	<ul style="list-style-type: none"> ▪ More durable machines. ▪ Carefully considered materials that age with dignity reduces disposal tendency due to 'worn out' appearance. ▪ Removing dust-collecting contours makes cleaning the vacuum cleaner easier, making it less liable to be discarded due to perceived dirtiness.
Optimal Construction	<ul style="list-style-type: none"> ▪ Increased sale of consumables. ▪ Brand loyalty. 	<ul style="list-style-type: none"> ▪ Longer lasting main body components. ▪ Reduced embodied energy due to less use of metals and plastic. ▪ Increased recyclability through reduction in material variations and reduced design complexity. ▪ Reduced maintenance requirement.
Information Provision	<ul style="list-style-type: none"> ▪ Brand loyalty. ▪ Reduction in returns. ▪ Increased sale of filters and consumables. 	<ul style="list-style-type: none"> ▪ Longevity through regular and effective maintenance in response to information on the machine's operating efficiency and the location of maintenance-intensive parts.
Enjoyable Experience	<ul style="list-style-type: none"> ▪ Premium product. ▪ Brand loyalty. ▪ Increased sale of consumables. 	<ul style="list-style-type: none"> ▪ Increased product life through a stronger user-product attachment created by provision of an effortless experience through lightweight materials and manoeuvrability, which increases enjoyment while vacuuming. ▪ Use of high quality materials and a simple form allows the vacuum to be kept on show, perhaps even a talking point between user and visitors, creating user-product attachment.
Servicing Systems	<ul style="list-style-type: none"> ▪ Premium product supplied as part of a product service system. ▪ Re-sale of vacuum cleaner multiple times. ▪ Wide range of servicing options. 	<ul style="list-style-type: none"> ▪ Product longevity through a service system that provides for regular servicing throughout the contract. ▪ Longer lasting components through reuse and remanufacture. ▪ Optimised system of collection, remanufacturing and resale when user reaches end of the contract.

4. DEVELOPMENT OF CONCEPTS

The five product concepts were further developed (and, where appropriate, expanded) by the research team, taking account of findings from the user and manufacturer workshops (WP4). They were explored through an action-based intervention in which the product concepts were subject to a pilot test with prospective users (WP5) and subsequent iterative refinement (WP6, in the next section). The aims of this phase of the research were to:

- Review consumer habits, attitudes and behaviour relating to the five product concepts and reflect upon the original and any emergent themes.
- Assess and collect feedback on prototype models for each product concept in order to inform their future development.
- Identify project trajectories for implementation of each of the product concepts.

Fifteen participants from earlier phases of the research were recruited as prospective users for a focus group discussion. The focus group was took the form of two tasks: a concept ‘sales pitch’ by design students and an open discussion among the participants. First, students presented a ‘sales pitch’ of their concepts, outlining features and benefits, and using models, visuals, videos and material samples. Participants then took part in a structured discussion about the five concepts, addressing questions asked under the headings Appearance, Usability, Maintenance, Relationships and Environment. The discussion was video recorded to ensure correct attribution.⁹

4.1 Focus group

The focus group enabled understanding of possible user reactions to the five concepts, both at a general and concept-specific level (Table 6; a detailed description of responses is in Appendix 7).

Participants did not appear very aware of the environmental impact of vacuum cleaners and were more readily engaged in discussion of product performance than appearance. This may reflect a perception that vacuum cleaners are working machines and aesthetics appears less relevant.

The ideal vacuum cleaner appearance was ‘small, sleek and light’, minimal in style, with smooth surfaces and ‘not clunky’. Removing the likelihood of the user coming into contact with dirt was seen as especially positive.

Service model options were not considered particularly appealing, although responses became more positive when ideas of an improved product offer were explored. Disinterest in the servicing option appeared linked to suspicion towards increased communication with manufacturers. Strategies in this direction would evidently need to radically change the perception of interaction with manufacturers.

In considering features across all of the five concepts the focus group highlighted a distinction between *purchase priorities* and *use priorities*. Purchase priorities include features that improve product appeal and longevity; they are potential selling points to consumers. Use priorities are features that become most apparent when engaged with by users when operating the vacuum cleaner.

⁹ Contrary to what was originally envisaged, use of N-Vivo software for data analysis was not necessary.

Table 6. Reactions of focus group participants to product concepts.

Ageing Gracefully	Neutral reaction. Not seen as revolutionary but perhaps worth integrating into other proposals.
Optimal Construction	Mixed reaction. May suit niche market. Reduced contact with dirt was deemed positive for allergy sufferers.
Information Provision	Positive reaction, particularly to 'information handle' concept. Less positive reaction to 'VAX Cloud' due to privacy concerns. Educational 'out of box' assembly was liked, but disassembly was not.
Enjoyable Experience	Positive reaction, particularly towards parcelling of dirt, although concerns expressed about cost.
Servicing Systems	Mixed, if not negative, reaction. Most suited to luxury products. Company distrust, with concern about unwanted phone calls. Viable if product provided is a known, high quality brand.

4.2 Revised concepts

The outcomes of this first pilot exercise were useful for refinement of the five concepts developed by the students, the updated versions of which are summarised below (detailed descriptions are in Appendix 8).

4.2.1 Ageing Gracefully

A consumer base already exists for expensive, robust, attractive and high performance products. The aim is to expand this through a product which ages well, retaining 'as new' sensorial (e.g. visual, noise smell) qualities over a longer lifetime, and which offers a high level of performance.

This product concept was approached through consideration of both functional and aesthetic ageing. Functional ageing was addressed by tackling a problem identified with vacuum cleaner motors: high temperatures reached by motors through blocked or clogged filters can cause premature failure and exacerbate emission of unpleasant smells. This proposal is to change the airflow within the machine to keep the motor cool.

The concept also investigated materials that 'age with dignity', considering brushed metals, leathers and woods that might be appropriate as alternatives to plastics. Visual stimuli that change over time, such as colours, textures or details, may encourage the user to carry out simple maintenance tasks. The concept was developed into a prototype motor housing that used an aluminium shell and heat-dissipating fins, resulting in an exhaust temperature significantly lower than with existing machines. These were incorporated into a timeless aesthetic with a robust outer finish (Figure 5).

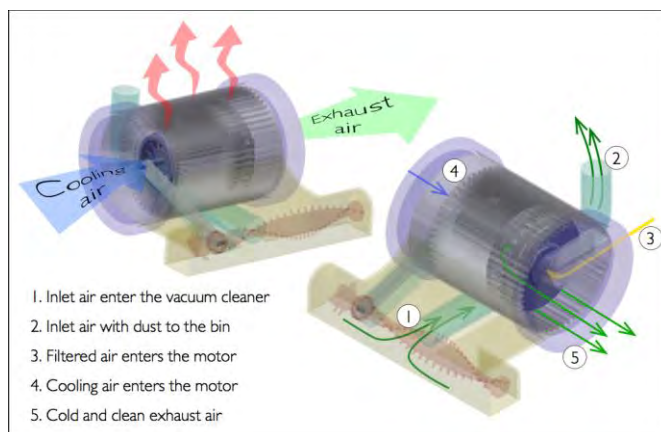


Figure 5. Development of Ageing Gracefully theme.

4.2.2 *Optimal Construction*

Noting the negative attitude of many survey respondents towards maintenance, the second concept developed a product that could be maintenance-free. High wear components of the vacuum cleaner were made to be easily recyclable and the other components longer lasting, in order to reduce the overall impact of end-of-life disposal while taking account of current market dynamics. The vacuum cleaner has a simple construction and minimal components, grouped into two according to their potential life-span.

The first group, where the majority of material and embodied energy reside, comprises the handle, body and power unit (i.e. battery and motor) and would be designed to be kept by the user for a substantial period. The second group, comprising the head, filter and dust container, which are parts that require maintenance, would instead be replaced whenever required. Materials used in this latter group, the disposable parts, would be carefully chosen to maximise recyclability.

The dust container is a single unit positioned on the head which when full can either be emptied or removed, recycled and replaced, removing human contact with dirt. The prototype was developed to explore the functional positioning and removal of the container. The result was an uncomplicated machine which facilitated easy replacement of parts (Figure 6).

4.2.3 *Information Provision*

This theme explores user interaction with the product and, specifically, ways in which the product can communicate how it is performing and assist in fault-finding. Information provision starts from the moment the product is unpacked and, in this proposal, continues with the communication of product status, including informing the manufacturer through the Internet.

The concept proposes that during the unpacking process the user will assemble key parts (e.g. filters, motor housing, dust bin, hose and brushes) as this will educate them as to the location of maintenance hotspots, enabling them to carry out any necessary maintenance tasks quickly and effectively.

A second element is the provision of information regarding the vacuum cleaner's efficiency in operation. Two airflow sensors are used to detect whether or not it is working correctly. If the machine is providing the right level of performance, a display mechanism on the handle glows green. If the handle turns orange, the user is being warned that the machine is not operating at a right level of efficiency, inviting them to clean the filters or empty the bin. If it turns red, the filters are badly clogged and if the red flashes, the machine is blocked and will be damaged if it continues to be used, warning the user to remove the blockage immediately (Figure 7).

4.2.4 *Enjoyable Experience*

Increasing the user's emotional attachment to a product can increase its longevity. In the case of a vacuum cleaner this attachment can be created through ease of use such that cleaning carpets and other flooring becomes an effortless experience.

This concept is a vacuum cleaner that light, nimble and easy to manoeuvre. The latter would be achieved by locating most of the technical parts at the bottom of the machine, providing a low centre of gravity. The user would be free to vacuum without becoming frustrated with cables because the machine would use cordless, using rechargeable batteries with a simple charging method.

The vacuum would be manufactured from high quality brushed metal and include wooden detail, implying somewhat higher material costs. The choice of material is intended to increase appeal and perceived value, promoting emotional attachment and facilitating a more positive perception of vacuum cleaners, such that owners might feel more willing to leave them on view when not in use. To reduce the negative perceptions in use, the dirt collected is parcelled in biodegradable film so that emptying the container involves no contact with it (Figure 8). The biodegradable nature of the film prevents an additional waste-related problem, but the vacuumed dirt in the parcels may nonetheless include plastic particles from nylon or

polypropylene carpets or general dirt and will not itself be wholly biodegradable and will need to be disposed of appropriately.

4.2.5 *Servicing Systems*

Leasing vacuum cleaners could be more environmentally sustainable than ownership because, in theory, such a business model could provide a commercial incentive to increase both product longevity and use-intensity. However, the survey illustrated that only a very small proportion of users are currently interested in servicing options such as leasing.

In this concept the vacuum cleaner was redesigned to facilitate remanufacture, based on the design of the Henry vacuum cleaner manufactured by Numatic; this involves facilitating quick assembly and disassembly through a reduced number of fittings and repositioning the switchgear. The vacuum cleaner has additional, large bump strips around the perimeter to reduce damage and a pivoting base to reduce the risk of toppling. The body is made from aluminium, which can be reformed and re-brushed, and the top is coated in a silicon moulding which can easily be removed and replaced.

This product service system would suit commercial or managed applications, but could be adapted to retail scenarios: this would involve a closer relationship between user and manufacturer. Maintenance would be provided directly by a 'click and collect' scheme directly from the manufacturer, ensuring that products are regularly and professionally maintained. At the end of the lease period, the manufacturer would collect the vacuum cleaner and replace it with a remanufactured unit, which would look and perform as new (Figure 9).



Figure 6. Development of Optimal Construction theme illustrating recyclable dirt container.



Figure 7. Development of Information Provision theme illustrating glowing handle.



Figure 8. Development of Enjoyable Experience theme illustrating emotive finishes.



Figure 9. Development of Servicing Systems theme illustrating removable silicon coating.

5. TOOLKIT AND CONCEPT REFINEMENT

5.1 Toolkit development

Analysis of the research findings and exploration of the five concepts highlighted potential areas for design interventions to increase vacuum cleaner life-spans. These were developed and collated as components of a toolkit with the aim of enabling designers, manufacturers, policy makers, repairers and consumers each to play a role (WP6).

The research team evaluated the possible impact that each feature (i.e. prospective toolkit component) could generate, especially in terms of changing attitudes, practices and behaviours surrounding purchase, use and disposal. Initially the 24 most promising components were included in a draft toolkit, some derived from the five product concepts developed by the design students and others from the interviews, focus group and workshops. Subsequently additional information was included, after their refinement (Section 5.3).

The toolkit was developed in the form of a collection of cards (Figure 10), each of which has, on one side, an outline of the component, with an evocative picture, and symbols indicating:

- the actor with primary responsibility for implementation (i.e. user, manufacturer, policy maker)
- the cleaner group, or groups, that might find the component most attractive
- whether there was especially strong user interest.

The reverse side of the card is divided by a vertical line into positive and negative: benefits of the component and disadvantages or obstacles. Following final revision, the cards will be available, separately from this report, in 'A toolkit for increasing vacuum cleaner life-spans.'

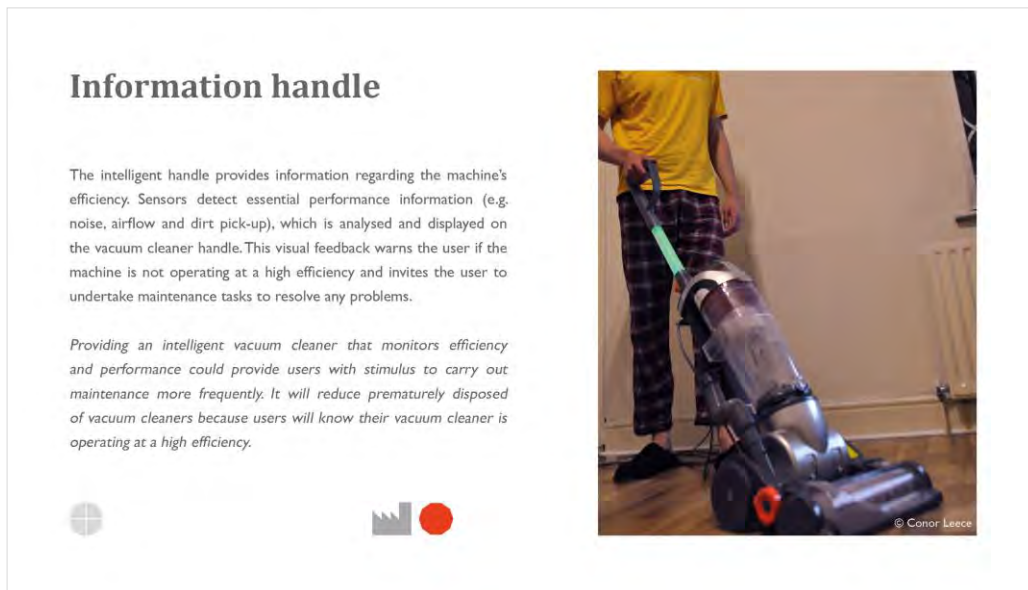


Figure 10. Information handle, an example of the front of a card.

5.2 Concept refinement

The second action-based activity collected feedback on the draft toolkit components, together with information on users' purchase and use priorities. It was structured into three activities:

- A further user workshop
- A second national online consumer survey
- A series of stakeholder interviews.

5.2.1 *User workshop*

A two-hour workshop was held in June 2015, the aims of which were to:

- Present the toolkit to users in order for them to evaluate the components
- Understand which components might influence consumers when considering vacuum cleaner purchase
- Identify the preferred combination of toolkit components
- Rank the toolkit components according to the level of interest.

Seven individuals who had been involved in previous research tasks participated. Prior to the workshop, they were asked to complete and return a draft version of the online survey; this provided feedback on draft questions.

During the workshop, participants received descriptions of 18 toolkit components (i.e. vacuum cleaner features) out of the original 24 and were shown images relating to each; the residual six were excluded because responsibility was judged to lie with industry and policy makers rather than users.

The concepts were organised as four vacuum cleaner ‘packs’, named ‘Information’, ‘Senses’, ‘Emotion’ and ‘Convenience’ (although emphasis in the discussion was placed on the individual features rather than each pack as a whole). Participants were asked to express their level of interest in each of the features, indicate whether they might make them want to keep the vacuum cleaner for longer, and discuss positive and negative aspects.

They provided positive feedback on several features. In particular:

- Longevity labelling was considered a ‘brilliant’ idea and although it may not necessarily lead them to keep the vacuum cleaner for longer it could prove successful as a selling point.
- Colour coded maintenance parts were considered attractive as they would make maintenance and repair tasks easier.
- The Information handle could help users to keep the machine for longer but may require them to trust manufacturers.
- Dirt parcelling is an attractive feature that is very rare in existing models.
- Repair workshops were considered a useful opportunity to learn.
- Certain features led participants to raise concerns:
- Internet-enabled diagnostics require a smart phone and might not be appropriate for all users.
- Emitting a fragrance might hide smells that signify damage (e.g. burning, melting).
- In-home servicing led to scepticism due to the potential cost.
- Servicing was questioned in relation to a stigma surrounding second hand parts.

A full description of participants’ responses for each component can be found in Appendix 9. As an action-based activity, participants were encouraged to suggest ways to implement each component, including technical features or marketing strategies. Thus, for example, some suggested that they would only engage with the *Educational Assembly* concept if it was extremely simple, did not involve any nuts, bolts or screws, and only took 5-15 minutes to carry out. Others argued that screws are sometimes better than ‘push fit’ mechanisms as they are simple to remove and avoid the risk of accidentally snapping push fit parts.

5.2.2 User survey

Following the user workshop, a second national online user survey was conducted, to assess the appropriateness of the proposed toolkit components (see Appendix 10 for the survey questionnaire).¹⁰ Prior to the survey the vacuum cleaner features were revised and reconfigured from the original list on the basis of comments received during the user workshop, and grouped together in the four packs (Table 7). Each was represented by an image annotated with a description of the features (Figure 11, below). Questions were asked about each feature in turn. As well as gathering responses to each of the features, the survey aimed to:

- Evaluate whether each of the features would encourage them to keep their vacuum cleaner for longer.
- Evaluate whether respondents would be prepared to pay more money for a vacuum cleaner based on each pack.
- Establish whether different payment plans, associated with product quality and servicing options, might affect their choices.

Table 7. Packs and their features after development through the focus group and user workshop.

Pack	Information	Senses	Emotion	Convenience
Feature	Information handle	Timeless and classic	Leave vacuum cleaner on display	Simple replacement of worn parts
	Internet enabled diagnostics	Cool running motor	Clean air function	Recyclable bin container
	Colour coded maintenance parts	Anti-scratch and anti-static materials	Customisable covers or casings	Longevity labelling
	Educational assembly	Durable service parts	Dirt parcelling	Replaceable motor unit
	Online maintenance	Quick fixes	In-home servicing	Easy disassembly

There were 552 respondents to the survey. The demographic breakdown of the sample - gender (51% male, 49% female) and age (30% aged 17-35, 33% aged 36-55 and 38% aged over 55) - was similar to that of the first survey (WP3) and results are therefore comparable. As with the first survey, data were subjected to z tests to compare sample percentages from the population and t tests to compare derived mean scores in order to identify whether there were significant differences between sub-groups.

Although no significant gender differences were identified with regard to responsibility for purchasing a new machine, male respondents were significant more often solely responsible than females for maintenance (67% cf. 48%, $p < 0.01$) and disposal (69% cf. 48%, $p < 0.01$). Nearly a sixth of respondents (15%) vacuum once or more a day, a half (50%) 2 to 5 times a week, a quarter (25%) once a week and around one in ten (11%) 2 to 3 times a month or less often. Only 5% currently pay someone to help clean their house. Nearly a third (31%) would like to employ a cleaner but do not for various reasons; these are significantly more likely to be female than male (38% cf. 24%, $p < 0.01$) and less likely to be aged 66 or over (23%) than aged 17-35 or 36-45 (35% in each case, $p < 0.05$).

Using the same criteria as in the first survey (frequency of vacuum cleaning, priority of cleanliness in the home, and willingness to employ someone to help clean the house),

¹⁰ The survey data was coded by subcontractor JRA prior to analysis.

respondents were clustered into the cleaner type groups.¹¹ Results were broadly similar, although this survey revealed more Caring cleaners and fewer Spartan and Minimal cleaners.

- 9% Spartan cleaners
- 26% Minimal cleaners
- 53% Caring cleaners
- 10% Manic cleaners.

No significant relationships were found between cleaner types and gender or age group.

A quarter (25%) of respondents had spent £50 to £99 when purchasing their current vacuum cleaner, 29% had spent £100-£199 and 21% had spent £200-£299. Only 5% spent over £300, 8% paid less than £50, and the remainder did not buy it or did not remember how much they had paid. Spartan and Minimal cleaners were significantly more likely to have bought machines costing under £50 than Caring cleaners (14% and 15% respectively, cf. 4% $p < 0.05$).

Most respondents had owned their previous vacuum cleaner for less than 6 years. A small proportion (6%) had owned it for up to 1 year, just under a third (31%) for between 1 and 3 years and another third (32%) for 4 to 6 years. Nearly one in five (19%) had owned it for over 7 years (9% for 7-9 years; 5% for 10-12 years; 5% for over 12 years). One in eight (12%) could not remember how long they had kept it or had not owned one. Spartan cleaners were significantly more likely than Minimal, Caring or Manic cleaners to have owned their vacuum cleaner for over 12 years (16% cf. 4%, 4% 2% respectively, $p < 0.05$).

5.2.3 Analysis by features

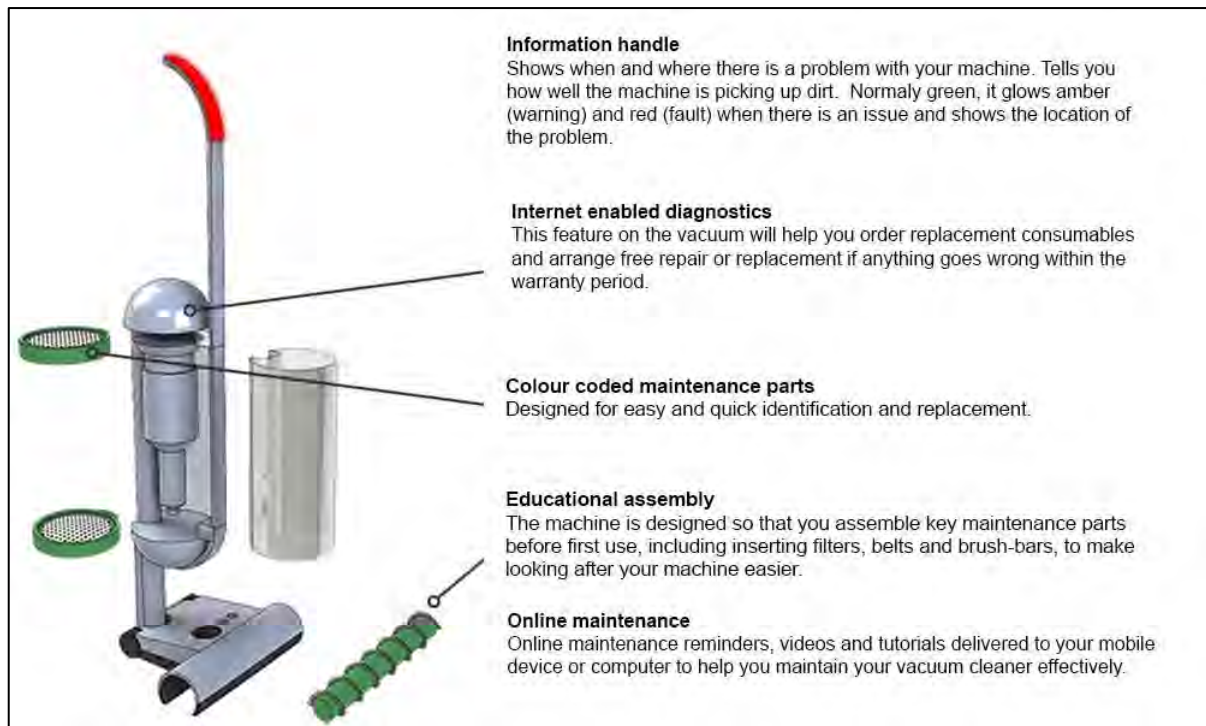
Survey respondents were asked about the extent to which they agreed whether a particular feature 'might make me want to keep this vacuum cleaner for longer' for each pack. The level of the agreement for each feature was averaged, by mean, on a scale from 1 (strongly disagree) to 5 (strongly agree) (Table 8). Overall, the features in the Convenience pack attracted the highest scores (mean 3.72) and Emotion pack the least (3.29).

Table 8. Extent to which features might make respondents want to keep vacuum cleaner for longer (each number represents the mean value scored for each feature on a one to five scale).

Information		Senses		Emotion		Convenience	
Information handle	3.64	Durable service parts	3.90	Dirt parcelling	3.68	Simple replacement of worn parts	3.89
Colour coded maintenance parts	3.53	Quick fixes	3.83	Clean air function	3.65	Easy disassembly	3.78
Internet enabled diagnostics	3.42	Cool running motor	3.68	In-home servicing	3.33	Replaceable motor unit	3.75
Educational assembly	3.36	Anti-scratch and anti-static materials	3.38	Customisable covers or casings	3.01	Reusable and recyclable bin container	3.71
Online maintenance	3.32	Timeless and classic design	3.35	Leave on display	2.80	Longevity labelling	3.49
Mean	3.45	Mean	3.63	Mean	3.29	Mean	3.72

¹¹ A small number of respondents, 15 (3% of the total), could not be assigned to a specific cluster.

INFORMATION PACK



SENSES PACK

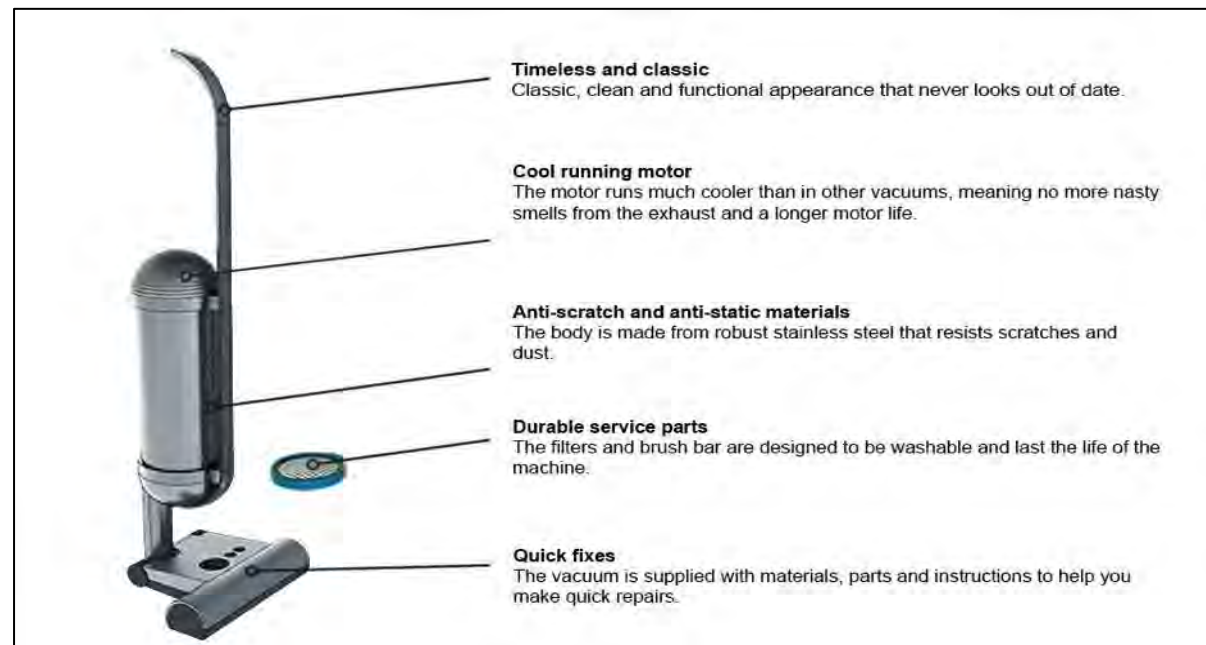
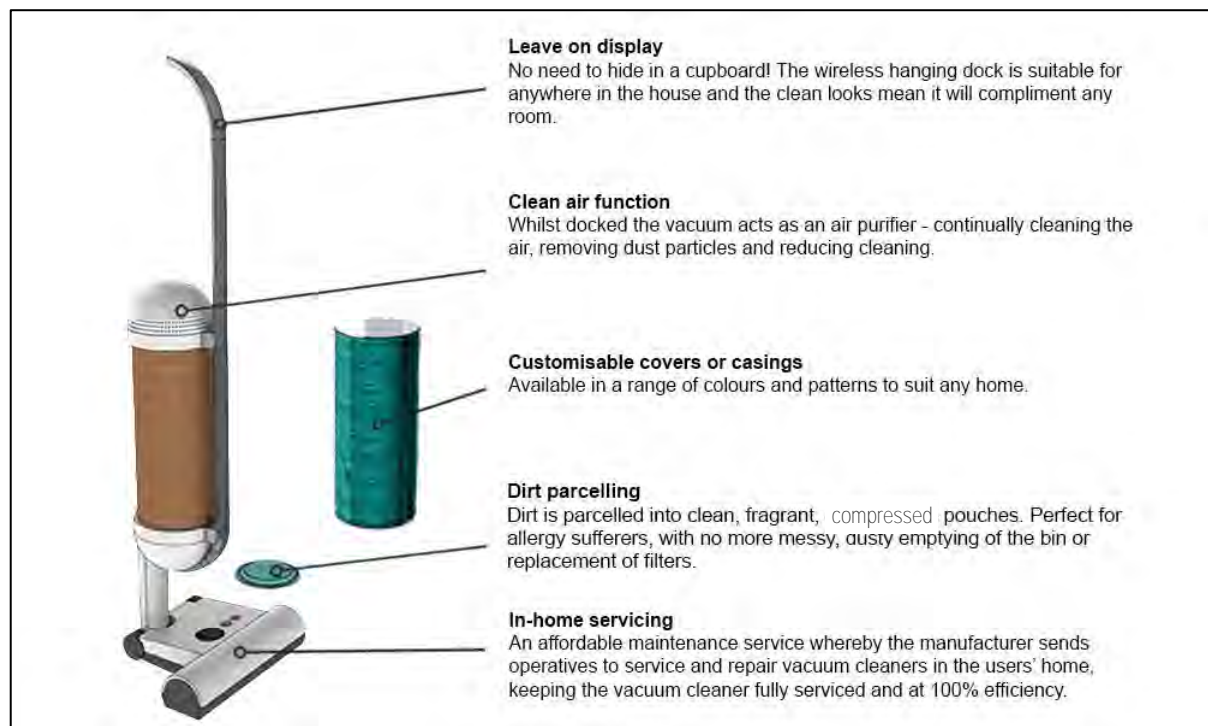


Figure 11. Visual representation of features in the packs used in the survey

EMOTION PACK



CONVENIENCE PACK

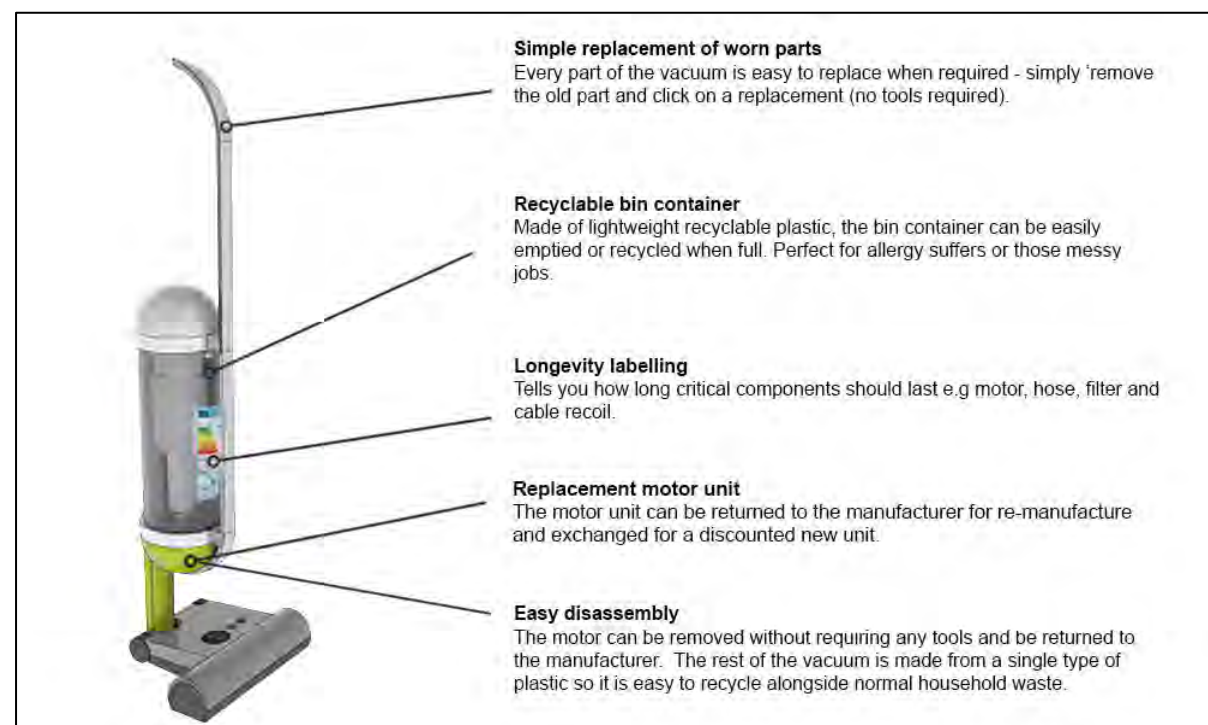


Figure 11 (cont.). Visual representation of features used in the packs used in the survey.

Manic and Caring cleaners generally gave higher scores than Spartan and Minimal cleaners, particularly for the Senses and Convenience packs (for which, in each case, the difference was significant for four of the five features at $p < 0.05$). Respondents aged 17-35 generally gave the highest scores among the different age groups, particularly for the Emotion pack (difference significant for four of the five features at $p < 0.01$, and the fifth at $p < 0.05$) and Information pack (difference significant for three of the five features at $p < 0.01$ and two at $p < 0.05$). There was no significant difference between the scores of males and females.

For the *Senses* and *Emotion* packs, respondents appeared to consider that functional features (*Durable Service Parts* and *Cool running motor* in the former, *Clean air function* and *Dirt parcelling* in the latter) would affect how long they would keep the machine than those relating to fashion and appearance (*Timeless and classic design* and *Anti-scratch and anti-static materials* in the former and *Leave on show* and *Customisable covers or casings* in the latter).

In the following analysis the order of the features for each pack is shown to be consistent with a few exceptions. Variation may be explained by the fact that features might be appealing without necessarily making people want to keep the vacuum cleaner for longer.

Information Pack

Respondents agreed that, for the Information pack, the *Information handle* was the feature considered most likely to 'make me want to keep this vacuum cleaner for longer' (mean scale rating 3.64), followed by *Colour coded maintenance parts* (3.53), *Internet enabled diagnostics* (3.43), *Educational assembly* (3.36) and *Online maintenance* (3.32).

40% of respondents ranked the *Information handle* as the 'most appealing feature' of the Information pack (Table 9); females were significantly more likely to choose this feature than males (45% cf. 36%, $p < 0.05$) and Manic cleaners were less so than Minimal or Caring cleaners (25% cf. 45% and 42% respectively, $p < 0.05$). *Colour coded maintenance parts* was considered appealing by 20%. The other three features were rather less appealing.

Table 9. Feature chosen in Information pack as highest preference, by % respondents.

Information handle	40%
Colour coded maintenance parts	20%
Internet enabled diagnostics	14%
Online maintenance	13%
Educational assembly	12%

Senses pack

For the Senses pack, the *Durable service parts* (3.90) feature was that considered most likely to encourage respondents to want to keep their vacuum cleaner for longer. *Quick fixes* was second (3.83), followed by *Cool running motor* (3.68) and *Anti-scratch and anti-static materials* (3.38). The feature least likely to encourage longevity was *Timeless and classic design* (3.35), perhaps due to concern that such a product might not fit with their home décor.¹²

The feature ranked most appealing by the highest proportion of respondents (41%) was *Durable service parts* (Table 10), although it was significantly less attractive to those aged 17-35 than those aged 46-65 or 66 and over (30% cf. 48% and 47% respectively, $p < 0.01$). At the other extreme, only 9% ranked *Timeless and classic design* and *Anti-scratch and anti-static materials* as their highest preference (though in the latter case the proportion was rather higher among those aged 17-35, at 15%).

¹² Respondents may have wrongly associated this proposal with the image of a vacuum cleaner used as an illustration to explain the concepts, which may not have matched their idea of a *Timeless and classic design*.

Table 10. Feature chosen in Senses pack as highest preference, by % respondents.

Durable service parts	41%
Cool running motor	26%
Quick fixes	15%
Timeless and classic design	9%
Anti-scratch and anti-static materials	9%

Emotion pack

Dirt parcelling (3.68) was the feature in the Emotion pack that respondents considered most likely to make them want to keep a vacuum cleaner for longer, with *Clean air function* second (3.65). In each case, significantly higher scores were given by females than males (3.75 cf. 3.55 for the *Clean air function* and 3.77 cf. 3.60 for *Dirt parcelling*, $p < 0.05$). Next came *In-home servicing* (3.33), followed by *Customisable covers or casings* (3.01). The feature considered least likely to influence longevity was *Leave on display* (2.80), which received the lowest score across all packs.

The feature in the Emotion pack ranked as the most appealing by the highest proportion of respondents was *Clean air function* (43%) (Table 11). The lowest ranked were *Leave on show* and *Customisable covers or casings*, each with only 6%. *Leave on show* was significantly less likely to be considered most appealing by respondents aged 45-65 or 66 and over than those aged 17-35 or 36-45 (2% and 1% cf. 11% and 8% respectively, $p < 0.05$).

Table 11. Feature chosen in Emotion pack as highest preference, by % respondents.

Clean air function	43%
Dirt parcelling	32%
In-home servicing	14%
Leave on show	6%
Customisable covers or casings	6%

Convenience pack

Simple replacement of worn parts was the feature in the Convenience pack most likely to make respondents want to keep a vacuum cleaner for longer (3.89), followed by *Easy disassembly*, *Easily replaceable motor unit* and *Reusable and recyclable bin container*, which received similar scores (3.78, 3.75 and 3.71, respectively). The least favoured feature was *Longevity labelling* (3.49).

Simple replacement of worn parts was ranked as having the highest appeal, with 35% of respondents placing it as their first choice, followed by the *Reusable and recyclable bin container* and *Easily replaceable motor unit* (both 20%) (Table 12). *Longevity labelling* was the lowest ranked, with only 10% of respondents making it their top preference. *Easy disassembly* was top preference for a significantly higher proportion of people aged 66 and over than those aged 17-35 (20% cf. 8%, $p < 0.01$).

Table 12. Feature chosen in Convenience pack as highest preference, by % respondents.

Simple replacement of worn parts	35%
Reusable and recyclable bin container	20%
Easily replaceable motor unit	20%
Easy disassembly	14%
Longevity labelling	10%

Overall willingness to pay

The level of interest towards the four types of pack was assessed through respondents' willingness to pay, i.e. if they were willing to pay anything extra in the hypothetical case of a purchase. Overall, willingness to pay appears relatively low, and similar across all four packs (Table 13).

Table 13. Willingness to pay.

	Information	Senses	Emotion	Convenience
Not interested in any of these features	19%	14%	20%	12%
Attracted by these features but not willing to pay more	35%	37%	32%	38%
Willing to pay a little more (up to £20)	25%	27%	25%	26%
Willing to pay a lot more (£21 to £50)	13%	12%	14%	15%
Willing to pay over £50 more	9%	10%	9%	10%

No more than a quarter of respondents, for any pack, was prepared to pay over £20 more for a vacuum cleaner with the proposed features, with an additional quarter willing to pay up to £20 more. Over one third were attracted to the features but not willing to pay more, and up to a fifth were not interested in any of the features. In the case of the Information pack, those aged 17-35 were significantly more willing to pay a little more than those aged 45-65 or 66 and over (33% cf. 19% and 20% respectively, $p < 0.05$). In the case of the Senses pack, males were significantly more willing than females to pay over £50 more (13% cf. 7%, $p < 0.05$).

The fact that, overall, more than three quarters of respondents were not prepared to pay more than £20 extra for any of the features may be due to unwillingness to pay extra for features that have not yet been fully refined. Open comments suggested that some were under the impression that images used to explain the features were final renderings of a fully resolved product, even though the use of the visual for 'illustrative purposes only' was stressed in the questionnaire. The data should not be considered as definitive, therefore, in gauging the potential commercial viability of the features.

Purchasing options

Finally, respondents were asked whether different payment and maintenance plans might affect their purchase decisions.

Most indicated that they prefer to pay upfront for a vacuum cleaner, choosing either the *Buy Now* option (49%) or *Buy Now, Trade In Later* (22%), while the *Monthly Payment Plan* was preferred by 10%.

The other respondents, around one in five, were willing to consider service-based options: similar proportions chose the *Service Plan* (10%) (fixed monthly payment, highest quality, longest-lasting machine, free annual servicing, 20% discount when purchasing new machine after 10 years) and the *Lifetime Plan* (9%) (fixed monthly payment, highest quality machine, free replacement machine every 3 years, may include remanufactured parts, guaranteed against faults, free annual servicing). Those who opted for the latter were more likely to be Manic cleaners than Spartan or Minimal cleaners (19% cf. 4% and 7% respectively, $p < 0.05$).

The findings suggest that there may be a potential market for service-based business models but a great deal of development and new understanding is required. This was also evident in the user workshop and focus groups, in which participants appeared wary of servicing plans. Increasing trust between users and manufacturers and addressing users' desire for ownership are significant areas requiring attention if change is to occur.

5.2.4 Stakeholder interviews

In the third exercise of this final stage of the research, industry stakeholders were invited to give feedback on the refined product concepts and features – the components of the toolkit – in order to understand their commercial potential and barriers to their implementation. A full table of their responses can be found in Appendix 11.

Four vacuum cleaner manufacturers and one vacuum cleaner repairer were interviewed for approximately one hour, the manufacturers by phone and the repairer face to face. Each was asked to discuss the technical and commercial potential, positives and negatives of each of the concepts and indicate the possibility of that concept increasing vacuum cleaner longevity).

Overall, the concepts were received positively; with one manufacturer commenting on the usefulness of the exercise, enabling them to '*view vacuum cleaners differently.*'

Overall, the information-based concepts were seen to have the greatest potential for increasing vacuum cleaner longevity and some were thought to offer commercial potential, notably the *Information handle*, *Colour coding of maintenance parts*, *Educational assembly*, *Online maintenance* and *Internet enabled diagnostic*. One manufacturer saw a clear benefit in an internet-enabled vacuum cleaner, possibly in conjunction with the information handle feature as a means of moving the market from a product to a service-based system to increase revenue streams whilst reducing environmental impacts, and was interested in pursuing these features further through collaborative funding.

Colour coded maintenance parts and *Educational assembly* were seen as achievable and beneficial, although not offering a direct commercial benefit. Whilst consumers may want a completely maintenance-free product this is not currently achievable (and perhaps not desirable for longevity). The *Educational assembly* feature may assist in increasing maintenance knowledge but there was concern that it could also put consumers off and increase returns if poorly executed; any future application would require a very simple construction of the machine.

All four manufacturers regarded maintaining and building customer relationships as crucial, and reducing 'no fault found' returns as the principal commercially-attractive method of increasing vacuum cleaner longevity. They indicated that further investigation of the interaction between user and product, and of the types of maintenance and activities that users are willing to undertake before they become frustrated would be useful.

Manufacturers noted that vacuum cleaners have become relatively inexpensive and suggested that they were now fashion-led products, which accelerated replacement cycles. There was also agreement that the trend for transparent materials and bag-less machines could result in machines that looked dirty quicker, and that this may be a further factor causing frequent replacement.

Reducing the overall rate of returns was a priority for all of the manufacturers. Two of them strongly believed in the importance of online tutorials in achieving this, and in building brand loyalty. The other two felt that they were under-used and suggested that they could prove damaging to the brand if negative feedback was received through consumer comments. The current returns systems involving third party suppliers to refurbish and resell returned products was seen as effective and had some scope for expansion, particularly for newer models.

Repair and service were seen as rather out-dated concepts by the manufacturers, who emphasised that they lacked convenience for the modern consumer. However, diagnostics kits that help consumers to identify whether their machine is working efficiently or needs filters or other consumables to be replaced were seen to have potential.

The vacuum repairer suggested that the market for repair shops is diminishing and that the principal reason for this - and the associated decrease in product longevity - was a comparative reduction in purchase price. He commented on the general reluctance of consumers to pay more for a longer lasting, high quality product and the convenience of purchasing, which reduced vacuum cleaner life-spans.

The repairer observed that spare parts for new, lower priced, machines were limited and often did not include small components or casing parts (which were prone to breakages). Manufacturers, he said, often phased out spare parts after short periods of time, in some cases after two years. In order to increase the longevity of vacuum cleaners such products needed to be more expensive (perhaps by further integrating the cost burden of disposed machines) and making mandatory the supply of spares; the repairer viewed these factors as more important than any of the components in the toolkit. He was sceptical about new technical features, concerned that this would increase faults and ultimately lead to quicker disposal.

In summary, the manufacturers saw the greatest potential to increase product lifetimes through greater engagement with consumers, potentially through internet connected devices, in order to enable the sale of service items or associated services, which would allow for business development in a saturated market.

5.3 Toolkit refinement

Following the final workshop, second survey and stakeholder interviews, the toolkit was further refined and additional cards were included, making a total number of 28 (Table 14).¹³

The final workshop was particularly important for revealing changes in wording required in order for prospective users to understand each of the proposed components of the toolkit. The survey was particularly useful in providing the opportunity to review which concepts were most likely to appeal to each type of cleaner. The stakeholder interviews revealed which features were likely to be commercially attractive and highlighted some of the negative aspects.

The revised toolkit cards thus included:

- The cleaner types for which specific features are liable to be most attractive.
- The highest ranked features in each pack.
- Positive and negative aspects from a user and industry perspective.

Table 14. Brief description of final toolkit components.

Toolkit component		Brief description
1	Colour coded maintenance parts	Parts requiring maintenance are colour coded making identification easier.
2	Information handle	The machine provides information of its efficiency and indicates location of and problems.
3	Educational assembly	Users assemble the machine prior to first use which familiarises them with parts that require maintenance.
4	Re-manufacture	The machine is designed to be re-manufactured and resold once its previous life has ended.
5	Dirt parcelling	Collected dirt is packaged into dirt parcels. This removes the likelihood of users (particularly allergy sufferers) coming into contact with dirt.
6	Online maintenance	Providing online maintenance tutorials, videos and reminders will help the users understand and maintain their vacuum cleaner effectively.
7	Easy disassembly	Legislation is developed to give manufacturers direct responsibility for vacuum cleaners that are returned to them.
8	Internet enabled diagnostics	Using an internet based platform to store a machines' statistics of the efficiency, performance and maintenance status. Also helps order necessary consumables.
9	Cool running motor	The motor is designed to run at a much lower temperature which reduces bad smells that vacuum cleaners can emit over time.
10	Multifunctional	The vacuum cleaner could include additional functions or purposes, e.g. looking like a sculptural piece or embedded in a piece of.
11	User diagnostics kit	After-market diagnostics kit that helps users establish the machine's efficiency, performance and maintenance status.
12	Quick fixes	The vacuum cleaner is supplied with materials, parts and instructions to help perform quick fixes and repairs.
13	Perception of cleanliness	Trend towards reduced importance placed on cleanliness, meaning the vacuum cleaner is used less.
14	Vacuum cleaner community	Using social media, forums and community participation the vacuum cleaner community grows providing access to repair tutorials and links to vacuum cleaner experts.

¹³ Components 4, 10, 11 and 13-17 were not included in the second survey as they were either considered less applicable to individual users (being influenced more by policy, manufacturers or cultural change) or developed subsequently.

15	Repair workshops	Provide vacuum cleaner repair workshops that educate vacuum cleaner users and allows them to discuss and learn about their vacuum cleaner.
16	In-home servicing	Manufacturers provide an affordable maintenance service whereby they send operatives to service and repair vacuum cleaners in the users home.
17	Materials that age with dignity	Designing with materials that do not become less valued when subject to general wear and tear
18	Simple replacement of worn parts	A vacuum cleaner that is designed to be easily and obviously upgraded and to have broken/worn parts easily replaced.
19	Timeless and classic design	Classic, clean and functional appearance that never looks out of date.
20	Leased from manufacturer	Users lease the vacuum cleaner for contracted periods of time and the machine is returned to the manufacturer at the end of the lease.
21	Longevity labelling	A label that lists the tested lifetime of key components of the vacuum cleaner (including the motor, cable recoil, hoses and casing etc.)
22	Information campaign	Information campaign that provides advice to consumers about how to give a second or extended life to products
23	Clean air function	While not in use the vacuum cleaner acts as an air purifier continually cleaning the air and removing dust particles.
24	Leave on display	The vacuum cleaner is designed to be left on display and not hidden away in a cupboard.
25	Easily replaceable motor unit¹⁴	The user can easily remove the motor unit, return it to the manufacturer for re-manufacture and reinstall a new one.
26	Reusable and recyclable bin	The bin container can be easily emptied or recycled when full which will stop allergy sufferers coming into contact with dirt.
27	Customisable covers or casings	Different covers or casings in a range colours and patterns are available.
28	Durable service parts	The vacuum cleaner's components are designed to last the entire life of the vacuum cleaner.

¹⁴ The concept 'replaceable motor unit' was updated to 'easily replaceable motor unit' to emphasise the simplicity of replacing the machines motor.

6. CONCLUSIONS AND RECOMMENDATIONS

The research for this project has provided unique insights into current attitudes and behaviours towards dirt, damage, servicing and repair of vacuum cleaners in the UK. The primary output, a toolkit, enables easy access to the main findings and is intended to promote practical action to resolve the problem identified: the significant environmental impact of short-lived vacuum cleaners.

The findings were generated through an approach that engaged manufacturers, users and design students, as well as the research team, in seeking commercially attractive propositions. All contributed significantly to the co-design, assessment and refinement of the five product concepts and the 28 toolkit components. A mixed methods approach was used, including interviews, focus groups, workshops and two national surveys, and each contributed towards meeting the objectives as described below.

6.1 Objective 1: Understanding vacuuming

The first objective was to investigate consumer perceptions of dirtiness and brokenness using vacuum cleaners as a case study, including how they define quality, durability, cleanliness, efficiency and performance, and to identify the motivations for replacement and the barriers to good maintenance.

This has been achieved mainly through findings from the on-street interviews (Scoping Report) and, especially, the first survey (Section 3). In-home interviews (Scoping Report), the user workshop (Section 3.1) and focus groups (Sections 4.1, 5.2) contributed to understanding interpretations of product quality and key influences upon users' attitudes and behaviours.

Expected life-span was revealed to be the top purchasing criterion after price (Section 2.2.5); it can be inferred that product longevity is strictly connected to perceived quality. Although cleanliness at home is generally a high or medium priority, attitudes vary, with frequency of vacuum cleaning ranging from once or more per day to less than once a week (Section 2.2.1).

The research suggests that perceived or actual loss of function is often a motivation for disposal, in spite of potentially cost-effective repair (Section 2.2.4). Understanding efficiency and assessing the performance of vacuum cleaners appears to be difficult for users, who were particularly interested in solutions that help them to understand the status of their machines (Sections 2.2, 5.2.3).

6.2 Objective 2: Exploring attitudes and behaviour toward vacuum cleaner life-spans

These methods also enabled achievement of the second objective, to verify the consistency between consumers' perception and the actual status of discarded vacuum cleaners and to classify perceived dirtiness and brokenness in relation to people's attitudes to cleanliness and maintenance.

A majority of survey respondents reported that they replaced their previous vacuum cleaner because it no longer worked or did not work efficiently (Section 2.2.4), although according to secondary literature and our stakeholder interviews a high number of such machines are found to be still in good conditions or easily repairable (Scoping Report). This suggests that there is a gap between consumer perceptions and the actual status of discarded vacuum cleaners.

The findings indicated that perception of dirtiness and general attitudes to cleanliness may influence vacuum cleaner life-spans. It became apparent that the cleaning groups (Spartan, Caring, Minimal, Manic) identified (Section 2.2.1) reflect different opinions regarding quality, durability, efficiency and performance. Different attitudes to purchase, use and maintenance were identified, resulting in variations in product life-spans, with more frequent cleaners replacing the machines more often (Section 2.2.2).

The results of the survey indicated that inefficiency or complete failure to work were the main reasons for replacing vacuum cleaners (Section 2.2.4). Faults may not be irreparable,

however, and disposal rates may well reflect attitudes towards maintenance and repair, especially if vacuum cleaners are not perceived as worthy of effort and attention (Section 2.2.3).

6.3 Objective 3: Planning and trialling design interventions

The third objective was to plan and trial design interventions to improve the maintenance and longevity of vacuum cleaners, fostering the active engagement of consumers and manufacturers.

To this end, five final year Product Design undergraduates were recruited to develop product concepts based on five themes (i.e. Ageing Gracefully, Optimal Construction, Information Provision, Enjoyable Experience, Servicing Systems). Drawing upon their work the research team closely interacted with users (Sections 3.1, 4.1, 5.2.1) and stakeholders (Sections 3.2, 5.2.4) in order to explore the extension of vacuum cleaner longevity. In particular an iterative process of workshops and focus groups was established to co-create the concepts, receive feedback and implement refinements (Sections 4.2 and 5.3). These action-based activities enabled the identification of enjoyable and frustrating aspects when vacuum cleaning (Section 3.1.4) and the collection of responses to the design concepts. In particular:

- Repair and maintenance, as well as servicing, are currently unattractive and more radical interventions are needed to promote product longevity (Section 5.2.3).
- Users appear particularly interested in solutions that help them to understand the status of their machines, e.g. information handle, educational assembly (Sections 2.2, 5.2.3).
- Users may be prepared to address easy tasks if supported with appropriate solutions, e.g. quick fixes, easily replaceable motor unit, online tutorials (Section 5.2.1).
- Market opportunities that may also increase longevity exist in interactive and internet-enabled devices that can maintain the consumer relationship and increase the product service offer (Section 5.2.4).
- A reduction in the price of vacuum cleaners may have contributed to a decrease in their longevity, and policy incentives may be required to increase the market share for more expensive, longer lasting products (Section 5.2.4).

6.4 Objective 4: Recommending change

Finally, the research sought to meet the fourth objective, to make recommendations based on the findings for vacuum cleaners, some of which may have relevance for other products susceptible to dirt.

An easily accessible toolkit was developed with the aim of enabling designers, manufacturers, policy makers, repairers and consumers to make vacuum cleaners last longer. Five main themes and product concepts, with 28 components, were developed and collected (Section 5). These proposed design interventions specifically address vacuum cleaners, but could also be considered in a wider system of parts, products, technologies and actors. As such, they represent transferable knowledge and are applicable to other consumer durables that require maintenance.

Many product design-focussed components of the toolkit (e.g. *Information handle*, *Dirt parcelling* or *Colour coded maintenance parts*) have the potential to be applied to a range of products other than vacuum cleaners. Understanding the reasoning behind the disposal of these products should enable consideration of potential benefits from such design interventions. Likewise, toolkit components focussed on later stages in the lifecycle (e.g. *Re-manufacture*, *Easy disassembly*, *Simple replacement of worn parts*) could be transferred to many other product categories.

The types of products to which the toolkit components may be applicable include:

- Electrical and electronic goods with high levels of embodied greenhouse gas emissions (e.g. televisions, washing machines, laptops).
- Products that typically have short life-spans (e.g. clothing, mobile phones, tablets).
- Products that are liable to trap dirt (e.g. PC keyboards, upholstery, cookers, microwave ovens, flooring).
- Products that require regular maintenance (e.g. garden tools, cars, bicycles, furniture).

The design interventions suggested in this report are more likely to be effective if supported by evidence-based policy frameworks informed by an understanding of the habits and attitudes behind consumer behaviour. For example, developing a repair community around a range of product types could provide users with the skills and information necessary to start undertaking maintenance and repair work that they had not previously considered. Removing the risk of manufacturers being held liable for failed or unsafe repairs might enable them to be more supportive of such work.

One means of enabling companies to change business practices is the Electrical and Electronic Equipment Sustainability Action Plan (*esap*) initiated by WRAP, a collaborative framework for sharing evidence and implementing sector-wide actions aimed at improving business efficiency and sustainability. Key areas in which companies could act are identified by *esap*: managing product durability, minimising product returns, understanding consumer behaviour, utilising innovative business models, and schemes for re-use and waste minimisation (WRAP, 2016). Should they choose to do so, there will be tensions to resolve, such as that between product durability and innovation, and business model development and design strategies will need to be aligned (Bocken et al., 2016).

Meanwhile the European Environmental Bureau (2015) has produced a range of proposals that could support the UK Government's intention that 'products should be designed...with longer lifetimes, repair and reuse in mind' (HM Government 2013: 3). Their introduction would complement a provision in the EU Ecodesign Directive which, if utilised, requires energy-related products to be subject to measures to extend product lifetimes; the measures include minimum guaranteed lifetime, minimum time for availability of spare parts, modularity, upgradeability and reparability (European Commission, 2009). The durability of motors and hoses in vacuum cleaners has already been made subject to this provision: from September 2017 the operational motor lifetime must be greater than or equal to 500 hours and the hose (if any) must still be useable after 40,000 oscillations under strain (European Commission, 2013).

The findings in this report could be taken further in the interest of researchers, industry and policy makers. For example, academic researchers may be interested in interviewing and observing users while purchasing or using vacuum cleaners in order to get more realistic responses and explain attitude-behaviour gaps. Industry representatives may wish to prototype the more promising concepts and hold trials on a wider scale (e.g. in-home trials of the information handle) in the context of developing commercially viable strategies for circular economies. Policy makers may want a systematic assessment of the economic viability and environmental benefits of the various concepts and to collaborate on specific policy interventions (e.g. design standards to facilitate reparability, life-span labels, information campaigns) in order to reduce waste.

6.5 Themes for further research

Finally, the project has drawn attention to more general user-oriented themes that warrant further research:

- The complex interpretations of 'broken', involving a plethora of factors beyond mechanical unreliability that affect whether users are interested in maintaining their vacuum cleaners, and strategies to strengthen the user-product relationship.

- Variation between users in expected standards of cleanliness, and how perceptions of cleanliness relate to attitudes towards vacuum cleaner life-spans and the ease with which parts can be serviced or replaced.
- Users' lack of enjoyment of vacuum cleaners, especially the process of vacuuming, and to what extent the proposed features might increase their enjoyment and attachment to vacuum cleaners.
- Lack of consumer interest in the servicing and repair of vacuum cleaners, to what extent this is based on their experience, and how to provide more attractive options.

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