UNIVERSITY OF TWENTE.

PHILIPS
sense and simplicity

# Minimizing the overall size of a vacuum cleaner


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# Title Page

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# Preface

This report is the result of a research on the options for minimizing overall vacuum cleaner size for Philips. The research was done as a final assignment in the bachelor curriculum of the study Industrial Design Engineering at the University of Twente. The research was executed at Philips, which gave me the opportunity to learn about the work ethos in a big company, to work in an international setting and to take a look behind the scenes of one of the worlds' biggest electric consumer product producing companies.

'As Industrial Designers, you will be taught to lead multidisciplinary project teams that are involved in product development. You will be able to talk about the content with all the involved disciplines and translate and share this information with the people from other involved disciplines', is a commonly heard statement. In the research, I have tried to include a lot of specialists to make this broad assignment as valuable as possible and to test my abilities as Industrial Designer.

I want to thank Maarten Bonnema, my scientific supervisor, and Paul van Wolferen, my supervisor at Philips, for the time and effort they put into this project. The talks I had with you, Maarten, always gave me new insights on the project and cleared my view on the assignment. Paul, you gave me a really good opportunity to see Philips in a lot of different aspects. You explained how the company works and gave me freedom in my assignment and on the Philips work floor. This made me really enjoy my time in Drachten.
If it were not for Freddie Moes, I would have had a really hard time keeping the research lively and consistent. We shared a lot of lunches and brainstorm sessions together and your creativity and ability to shift focus on a subject inspires me.

Other colleagues that cannot be left unmentioned:
Erik Teeuw for showing me the business sides of the Philips-employer relationship.
Pritesh Patel for the discussions we had and of course the fun activities you took me to in Drachten and Groningen.

And I want to thank Sunil, Kelly, Erica, Olivier and Vidyadhar for giving me the chance to learn about their cultures and taking my mind off the work in the evening. We had a lot of fun guys!

Next to the people involved in the process, I would like to thank my family and friends. Special thanks to my parents for giving me the opportunity to study and unconditional support in my activities. Also my aunt Elly should be mentioned for helping me out with the housing problem in the beginning of the assignment and Rick, Melvin, Kajsa, Ivo, Freek, Sander, Irina, Tim and Jan-Jaap for keeping my social life so very interesting and fun.
Last, but not least, I want to thank Joan for helping me correct the English in this report.

I hope you will enjoy reading my report.

Leon van Dijk

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# Summary

Recent Philips consumer research showed that big, bulky canister vacuum cleaners negatively influence consumer satisfaction. Consumers stated that they had a hard time cleaning between two objects, that big canister vacuum cleaners move clumsily and that such a vacuum cleaner is too heavy to lift when cleaning the stairs. Therefore Philips wanted to research the possibilities of developing a small canister vacuum cleaner, without decreasing the performance level that had been reached. The Philips 'Performer' vacuum cleaner was chosen as the competitor model.

The research started with an inventory of the available information on size within Philips. Because Philips is a big international organization, the assumption was made that all necessary information to perform this research would be available. A lot of the information indeed was present, however the effect of decreasing overall vacuum cleaner size on consumer satisfaction was missing. Therefore, apart from an internal research into the requirements for the Philips departments, a consumer satisfaction research also had to be done.

To gather all the right information within Philips, specialists involved in the vacuum cleaner development process were interviewed. As a preparation to these interviews, colleagues were informed about the project and its goals through a Value Proposition House and two use scenarios. After the interviews, the acquired requirements were bundled in the requirement management program DOORS. In this program the requirements were elaborated on stakeholder, system and component level. After processing the results, it became clear that there were few detailed requirements for the development of a small vacuum. It was clear, however, that decreasing the size of certain components has a negative influence on the performance. For example the air tubes; there is no minimum width for the tubes, but a change in tube diameter causes performance loss.

While gathering the information at the Philips departments, a consumer research was prepared. The goal of the investigation was to determine the effect of size, weight and the size-weight combination (independent variables) on consumer satisfaction (dependant variable). To test these effects, three vacuum cleaner dummies, with different sizes and changeable weights, were made. Participants were asked to perform three operations with the dummies and give the model a score. The result of the research was that consumer satisfaction is the biggest at approximately 12 $dm^3$. Results on weight, and therefore as also on size-weight combinations, were invalid due to a wide spread in consumer satisfaction scores and a small difference in average scores.

The possibilities of decreasing overall vacuum cleaner size were explored by first determining the key drivers of a vacuum cleaner. These were then used together with system and component information to determine the key components of a vacuum cleaner. Hereafter ideas were generated, using the innovation methods TRIZ, the Theory of Inventive Problem Solving, and SIT, Systematic Inventive Thinking, to decrease overall vacuum cleaner size. Then together with the component specialist, a component roadmap was made for the next five years.
As a result of the research into the possibilities of decreasing size, it is recommended to change the motor type to a brushless motor and to also research alternative ways of winding the electric cord. The last potential opportunity, compressing the collected dust, would also save a lot of space, however, research into alternative ways of emptying the dust bucket should be done first.

To visualize the results, two vacuum cleaner concepts were developed. The first concept was a vacuum cleaner with approximately the determined optimal volume, using only currently available components that theoretically could perform as well as the Philips 'Performer'. The second concept was a vacuum cleaner that could be developed within five years if the proposed research would be done. Because the expectation is that consumers prefer the slim upright vacuum cleaners above the canister vacuum cleaners, the second concept is a stick concept. Both concepts are reviewed using the key drivers to show the improvement of the new concepts.

# Samenvatting

Recente consumenten onderzoeken van Philips lieten zien dat een grote slede stofzuiger de tevredenheid van consumenten negatief beïnvloed. Consumenten gaven aan beperkt te worden in hun mogelijkheid om tussen twee object schoon te maken, dat grote slede stofzuigers lomp zijn in hun verplaatsing en dat deze stofzuigers erg zwaar zijn voor het schoonmaken van de trap. Om deze redenen wilde Philips de mogelijkheden onderzocht hebben om een kleine slede stofzuiger, met de prestaties van een grote stofzuiger, te ontwikkelen. De Philips 'Performer' stofzuiger was gekozen als referentiemodel.

Het onderzoek begon met een inventarisatie naar alle beschikbare informatie over grootte binnen Philips. Omdat Philips een grote internationale organisatie is, was het uitgangspunt voor de opdracht dat alle benodigde informatie voor dit onderzoek beschikbaar was binnen het bedrijf. Voor een groot deel klopte dit, echter informatie over het effect van de verkleining van de stofzuiger grootte op consument tevredenheid miste. Hierdoor is er, naast een onderzoek binnen Philips naar de eisen voor het verkleinen van een stofzuiger, een consumenten onderzoek gedaan.

Om binnen Philips de juiste informatie bij elkaar te krijgen en te bundelen, zijn er interviews gehouden met specialisten van elke betrokken afdeling in het stofzuiger ontwikkel proces. Ter voorbereiding op deze interviews zijn collega's geïnformeerd over het project en haar doelen middels een Value Proposition House en twee gebruik scenario's. De verkregen eisen zijn hierna overzichtelijk gebundeld in het requirement management programma DOORS. In dit programma zijn de eisen op stakeholder, systeem en component niveau uiteen gezet. Na het verwerken van de eisen bleek dat er weinig harde eisen zijn. Desondanks was het duidelijk dat het verkleinen van sommige componenten een negatief effect had op de prestatie. Bijvoorbeeld bij vernauwing van de luchtwegen; technisch gezien kan dit gerealiseerd worden, maar een verandering van de diameter veroorzaakt prestatieverlies.

Tegelijkertijd met het verzamelen van de informatie binnen de Philips afdelingen is er een consumenten onderzoek voorbereid. Het doel van het onderzoek was om het effect van grootte, gewicht en grootte-gewicht combinaties (onafhankelijke variabelen) op consument tevredenheid (afhankelijk variabele) te bepalen. Om deze effecten te testen zijn er drie dummy stofzuigers gemaakt. Participanten werden gevraagd om een aantal gebruikshandelingen uit te voeren met de dummies en het model een cijfer te geven. De uitkomst van het onderzoek was dat de consument tevredenheid het grootst is bij een volume van ongeveer 12 $dm^3$. Resultaten over het gewicht, en daardoor ook over grootte-gewicht combinaties, waren niet valide bevonden door een grote spreiding van de gegeven cijfers en hele kleine verschillen in de gemiddelde cijfers.

De mogelijkheden tot verkleining waren onderzocht door eerst de key drivers van een stofzuiger te bepalen. Deze werden vervolgens gebruikt om, samen met de systeem en component informatie, de belangrijkste componenten van een stofzuiger te bepalen. Vervolgens zijn er met behulp van de innovatie methoden TRIZ, de theorie van het inventief probleem oplossen, en SIT, systematisch inventief denken, ideeën gegenereerd om een stofzuiger te verkleinen. Hierna is er samen met de component specialisten een component roadmap voor de komende vijf jaar gemaakt.
Als resultaat van dit onderzoek naar de mogelijkheden om een stofzuiger te verkleinen wordt het aangeraden om van motortype te veranderen naar een motor zonder koolstof borstels. Tevens moet er onderzoek gedaan worden naar alternatieve mechanismen om het snoer op te winden. Ook zou er ruimte gespaard worden als het opgevangen stof gecomprimeerd zou worden, maar het wordt aangeraden eerst een onderzoek te doen naar verschillende manier van stof weggooien.

Om deze resultaten te visualiseren zijn er twee stofzuiger concepten ontwikkeld. Het eerste concept is een stofzuiger met ongeveer het bepaalde minimale volume die, met gebruik van huidige componenten, theoretisch een net zo goede prestatie kan halen als de Philips 'Performer'. Het tweede concept is een stofzuiger die over vijf jaar ontwikkeld zou kunnen worden, door nu de voorgestelde onderzoeken te doen en ontwikkeling te stimuleren. Omdat er de verwachting is dat de slede stofzuiger minder geliefd is dan een goed werkende bezemsteel, is dit een steel concept. Beide concepten zijn tot slot getoetst aan de key drivers zodat de verbeteringen ten opzichte van huidige modellen overzichtelijk wordt weergegeven.

# 1. Introduction

## 1.1 Company

The foundations of Philips were laid in 1891 when Anton and Gerard Philips established Philips & Co. in Eindhoven, the Netherlands. The company began manufacturing carbon-filament lamps and, by the turn of the century, had become one of the largest producers in Europe. By 1910, with 2,000 employees, Philips was the largest single employer in The Netherlands.
Nowadays Philips is a diversified Health and Well-being company, focused on improving people's lives through timely innovations. As a world leader in healthcare, lifestyle and lighting, Philips integrates technology and design into people centered solutions, based on fundamental customer insights and the brand promise of "sense and simplicity". (www.philips.com)

## 1.2 Problem

Recent market research showed Philips that big / bulky vacuum cleaners are disliked by consumers in Europe. Often consumers pointed out that big vacuum cleaner decrease their flexibility to clean between objects, move clumsily, are often heavy when cleaning the stairs and that storing a big vacuum cleaner is inconvenient. Using this consumer insight, Philips wants to increase consumer satisfaction and meet the consumer demands on size. Therefore Philips wants to know the possibilities of reducing the size of vacuum cleaners for the European market, without decreasing the performance and durability.

## 1.3 Objective

*The goal of this research is to define options for minimizing the overall size of a vacuum cleaner for the European market, without compromising in performance or durability.*

## 1.4 Scope

The focus of the research was "Normal" canister-type vacuum cleaners that use the existing key components like Philips canister-type vacuum cleaners do.

## 1.5 Approach

The start of the research, gathering the necessary information and requirements for a miniaturized vacuum cleaner, is described in chapter two. This started with an inventory of the available information on size at Philips. After reading the available reports, all involved stakeholders in the development of a vacuum cleaner in the Philips floorcare value stream were identified. Requirements were acquired from the stakeholders through interviews in which the stakeholder got insight in the project from a Value Proposition House and two scenarios. One stakeholder, the end user, needed a different method of approach to get the right requirements. A consumer research into user satisfaction, in which vacuum cleaner operations with dummies had to be performed, was done to obtain the consumer requirements on the minimal size of a vacuum cleaner. All the requirements were processed in DOORS, the requirement management program that Philips uses.
In Chapter three the innovation and roadmap steps are elaborated. First key drivers were derived from the Philips requirements, component information and data from (previous) experiments. Hereafter key components that influence size and shape were determined and road mapped for the next five years. The key drivers were also used as input for the innovation methods. To define future opportunities, TRIZ, a Russian innovation method, and SIT, a simplification of TRIZ, were used. Brainstorm sessions to gather innovation ideas were held and together with Paul van Wolferen, vacuum cleaner specialist, the ideas were rated on their feasibility.
In chapter four the concepts that were developed as a closure of the project, are described. The first concept was a high performing vacuum cleaner that was optimized in overall size and only consists of currently available vacuum cleaner components, that Philips already uses. The second concept was a future concept for 2015 where ideas from the innovation tools were used and the vision of Philips on vacuum cleaning is recognizable. Both concepts were prototyped to have tangible end results.

# 2. Requirements development

At the start of this project the assumption was made that Philips, a multinational with more than fifty years of experience in the development of vacuum cleaners, would have a lot of information about the technical and consumer aspects of a vacuum cleaner available within the company. Philips indeed had a lot of information on vacuum cleaning available, detailed consumer information was missing. Although Philips has propagated being a consumer centered organization for the past few years, it had been a technology driven company for most of the time that they were involved in vacuum cleaner development. To make this change in the way of working in Philips Consumer Lifestyle, the ergonomics department was transformed into the Application Research Centre (ARC). Where as the ergonomics department was a passive department that was mostly focused on not making a bad appliance, the ARC is a pro-active department that collects data on consumer preferences, satisfaction and the overall use of products. Because this change in the way of working occurred recently, there was a lot of knowledge and information on vacuum cleaner systems and components size, but information on the influence of vacuum cleaner size on customer satisfaction was lacking. Therefore next to gathering requirements for a miniaturized vacuum cleaner in the Philips departments, requirements for a miniaturized vacuum cleaner also had to be acquired from consumers.

## 2.1 Previous research

Figure 2.1: Gemini and Performer

Before the search for the necessary information started, two vacuum cleaners, the Philips 'Performer' and 'Gemini' (Figure 2.1), were disassembled to gain insight in the components and architecture of current canister vacuum cleaners. The components found are listed below and showed in Figure 2.2. A list with pictures to visualize components can be found in appendix A.

**Canister**
Dust management system (DMS)
Housing (incl. motorpot and air channels)
Printed Circuit Board (PCB)
Control interface
Motor inlet filter
Motor
Exhaust Filter
Cord winder
Wheels

**Accessories**
Hose
Tube
Nozzle

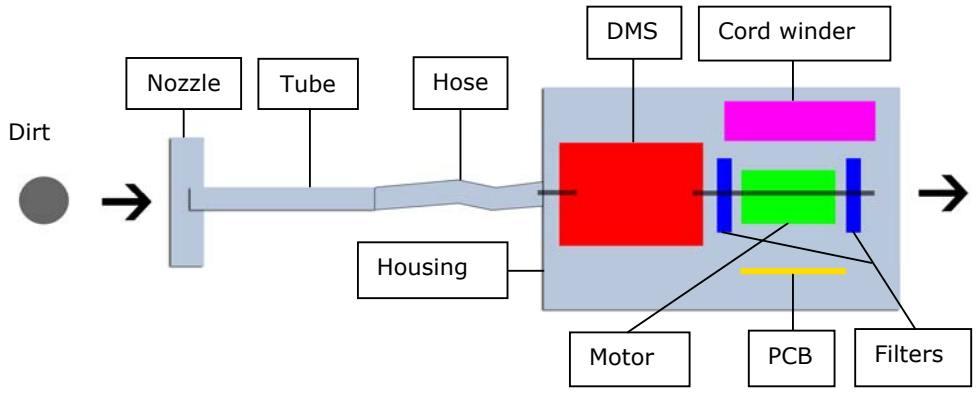


Figure 2.2: Generic vacuum cleaner

To get a better understanding of what the assignment 'miniaturization of a vacuum cleaners' included, previous Philips researches were read. Most reports were size related, but did not have size as main focus.
[Van Raalte & van der Wijst, 2001] gave a better understanding of the cleaning process. The report describes what dust and dirt is, what it consists of and explains the circle of Sinner. Several reports like [Gibert and Arends, 2001; Dindas,2008] about modules and platforms in vacuum cleaners, gave more insight into necessary vacuum cleaner components and how they affected the overall size. [Van Wolferen, 2006, 2007] showed how competitor vacuum cleaner producers constructed their vacuum cleaners. Small vacuum cleaners, high efficiency vacuum cleaners, all different vacuum cleaner models with different properties. The high efficiency report [Zjiroecha, 2009] elaborated the basic principles of efficiency loss in a vacuum cleaner.
Several concept labs and turbo factories, types of Philips consumer researches, gave insight into the Philips consumer segments and their preferences. All the knowledge that has been collected through these researches is bundled in the floorcare consumer bible [Grol, 2007]. This document turned out to be a very helpful document because based on all the consumer information in this document a substantiated choice of consumer segment could be made. Although the consumer bible features a lot of consumer information, much more then this project required, information on the effect of size on consumers preference was not included. Therefore next to collecting requirements from the Philips departments involved, requirements from end users also had to be acquired.

## Mind map stakeholders model

A mind map was made to get a clear view of the stakeholders in vacuum cleaner development. It was composed top down, which means that from the main set of requirements for a miniaturized vacuum cleaner, stakeholders involved in the vacuum cleaner development were determined. Passive stakeholders like distributors or resellers would, most probably, also have had requirements, but these stakeholders were not included in the research (and mind map) to keep the size of the project limited. This choice was made in consultation with Philips. The map includes representatives for each stakeholder to direct the communication for requirements. The representatives were chosen in collaboration with Paul van Wolferen. A full-scale mind map can be found in Appendix B.

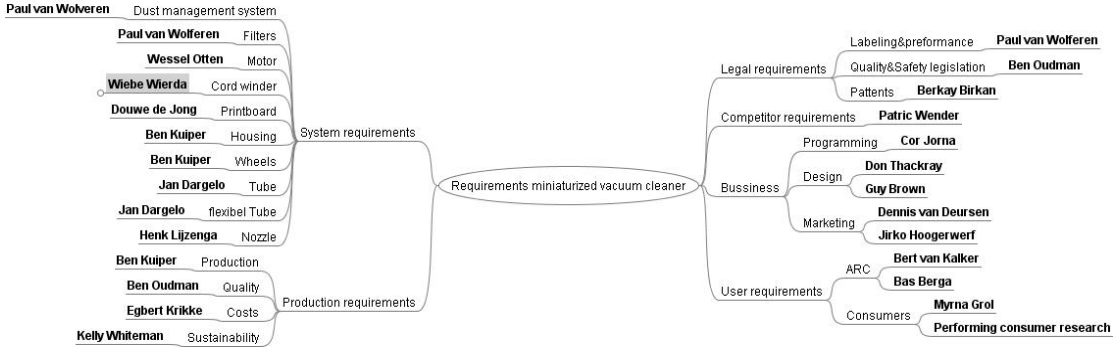

Figure 2.3: Mind map

## 2.2 Acquiring requirements from involved Philips departments

Using the stakeholders mind map, the way of collecting the necessary information could be determined. Beside the available information from previous research, information from various Philips departments and from consumer research had to be gathered. Combined, this set of information could be used as a basis for determining current limitations, future opportunities and concept development.

### Gathering information from involved Philips departments

To give the representatives (colleagues) of the Philips departments a quick, but adequate insight in the miniaturization project, a Value Proposition House (VPH) and two operation scenario's were made. These documents describe the benefits and context of using a miniaturized vacuum cleaner entirely and compact. Involving colleagues in the project in this way enabled their ability to imagine possible results so that they could justify their requirements more specifically. The VPH and Scenarios can be found in appendix C.
At first it was attempted to collect the requirements through digital communication, but it quickly turned out that this way of working did not produce the right kind of requirements. Therefore it was decided to interview the representative of every department to collect the right requirements.

A side effect of making a VPH and the scenario's was that to write the documents it was necessary to have a very clear view of the target group. As it turned out that this was not the case, the target group was further explored using the information from the floorcare consumer bible and discussions with colleagues from the Application Research Centre.

### Processing gathered information

When all requirements from Philips departments had been collected, they were arranged in DOORS, a requirement management program that is used within Philips. Using DOORS, requirements can be written in separate documents and those documents can be assigned to a specified group of people. The requirements in the different documents can then be linked together. An evaluation of working with this program can be found in [6. Evaluation].

For this project, requirements were arranged in three documents, on three different levels:

- Stakeholder requirements
- System requirements
- Component requirements

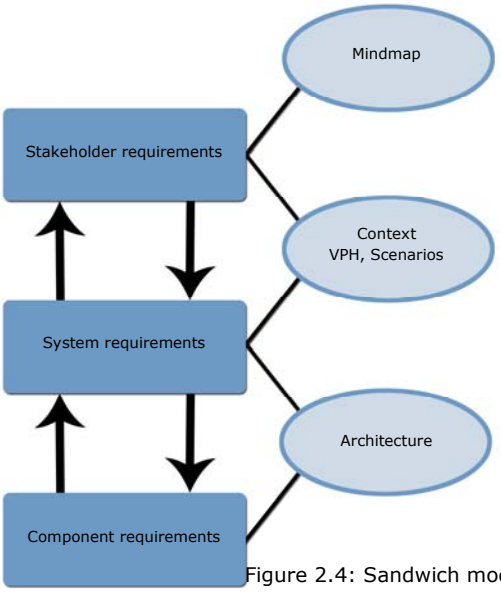

Figure 2.4: Sandwich model

These levels were determined together with Patric Wender, requirement engineer at Philips. He explained the model in Figure 2.4 as the sandwich model and other different levels of requirements were discussed. The result of the discussion was that more general and more detailed requirement levels were outside the scope of this assignment.

Stakeholder requirements were the most general requirements for this project. The end user, the production department and quality department were the only parties that had requirements on the stakeholder level. Requirements from the business departments (Design, Marketing and Programming) would also have fit well in this set of requirements. However, it was chosen to not include the only Marketing requirement *'reduce size with <70%'* in this project, because consumer research results contradict this requirement. The Marketing requirement could be used as starting point in miniaturization projects until other, more specifically applicable requirements contradicted this requirement. The only requirement from the Design department *'a miniaturized vacuum*

*cleaners must look as much as a broomstick as possible'* did not fit in the document because the scope was limited to canister vacuum cleaners. Programming did not have direct requirements in this phase of a project.

The stakeholder requirements interact with the system requirements and both interact with the context of use. These requirements are detailed on the system, but describe limited information on component. Except for requirements from the business, labeling and patents departments, all stakeholders from the project have requirements on system level. The lack of business requirements is explained in the paragraph above. Requirements from the labeling department were equal to the competitor requirements and not yet that detailed (because labeling is still in progress), therefore they were left out. Together with the patent department there has been a search for patents that would restrict the development of a miniaturized vacuum cleaner, using the adjusted Philips database. This search had no explicit results.

The system requirements interact with the component requirements and both interact with the system architecture. As the scope of the assignment was 'normal' canister vacuum cleaners, the main (component) architecture was already determined. The end user, the quality department and divers component departments were the only parties who had component requirements.

The full requirements documents can be found in appendix D.

The critical factor from the involved Philips departments in developing a miniaturized vacuum cleaner was determined by the necessary components and their size limitations. These size limitations determine together what minimal vacuum cleaner volume was technically feasible. If the components would not fit the minimal accepted volume by consumers, the minimal vacuum cleaner size would be determined by the sum of the minimal components sizes. The component size limitations are discussed in the paragraph 'component size limitations' below.

Next to the critical factor, the competitor requirements were found to be very important for the system requirements. Because the Philip 'Performer' is the competitor for this project, the miniaturized vacuum cleaner must be able to achieve a very high dust pick up, have a handle to be lifted and the user must be able to control the suction power of the appliance.

**Component size limitations**

Although all components had requirements that were to be met when decreasing the size of a high performing vacuum cleaner, not all requirements include a minimum size. There were only a small amount of requirements found that limit the size of a component. This did not mean that the size could be decreased without consequence, but the size could be decreased. The consequences are listed in the efficiency principles.

*Vacuum cleaner accessories requirements:*

The nozzle must have a minimal width of 270 mm.
The nozzle must have a minimal height equal to the tube width.
The tube must be variable in working height from maximal 600 mm to 1080 mm.
The tube must have a handle of 32 mm diameter.
The hose must have a minimal length of 1700 mm.

All connection interfaces between nozzle, tube, hose and canister must fit the standards already used.

*Vacuum cleaner canister requirements:*

The motor has a minimal cylindrical space in the appliance of 120 diameter * 100 dept (1.1 $dm^3$).
The dust management system must have a volume of at least 1.5 $dm^3$.
The exhaust filter must keep the same volume (0.45 $dm^3$), but can differ in dimensions.
The cord winder should have a minimal volume of 0.015 dm3 for the cord (9 meter) and a total cylindrical space of 1.5 $dm^3$.
A PCB must fit in for power control. The size is quite flexible and almost negligible.

## 2.3 Consumer research

As Philips claims to be a consumer-centered company, consumers are an active, leading stakeholder in the development of current vacuum cleaners. No previous Philips researches focused on the effect of minimizing vacuum cleaner size on consumer satisfaction. Therefore a consumer research into the effect of minimizing vacuum cleaner size on consumer satisfaction had to be done.

### Preparing and performing the consumer research

After discussing several research methods to achieve the goal, *"test the effect of minimizing vacuum cleaner size on consumer satisfaction"*, with colleagues from the Application Research Centre (ARC) department, it was decided to perform a consumer research with dummies of different sizes. This method was chosen because size perception is best when people are able to see, touch and use a 3D model. The effects of size, the independent variable, on consumer satisfaction, the dependent variable could be tested by performing specifically chosen handlings with the dummies.

Figure 2.5: Vacuum cleaner dummies

Next to the different sizes, it was decided to include the weight of the dummies as an independent variable in the research. The variable weight was included because this was an interesting, unexplored field for the ARC and because there could be a size-weight influence (third independent variable) on the consumer satisfaction.

Once the research method was chosen, dummies had to be made. Because there were no guidelines for the dimensions of a (miniaturized) vacuum cleaner, and therefore neither for the dummies, a research was done into the dimensions used for various vacuum cleaner canisters (appendix E). The resulting insight into the used dimensions for vacuum cleaners, was used as a starting point for the development of the dummies. Because of this, the dimensions of the middle model are the same dimensions as the Philips 'Gemini', a Philips vacuum cleaner that is currently on the market. Once the dimensions were chosen, only simple adjustments to the shape were made, to make the dummies look like vacuum cleaners. After the models were made they were painted grey to reduce the effect of color on the perception of the sizes as grey is a fairly neutral color. The result is shown in Figure 2.5.

Once all the dummies were finished, consumers were invited through EyeQuestion. EyeQuestion is an application that Philips uses to prepare and process sensory and consumer research. In collaboration with colleagues from the ARC, consumers who fitted the Philips Happy Home segment profile and were between 25 and 55 years old, were filtered from the database and invited to come to the home lab at the Philips site in Drachten. The invitation included two questions about the participants' current vacuum cleaning situation, about the cleaning surface and the currently used vacuum cleaner, to be able to compare this information with the results of the research.

The consumer research was done in the home lab, which is especially equipped for consumer testing, consist of a hall, living room, kitchen and a discussion room and has the possibility to record the research on audio and video. The living room and the hall were used to test three operations on the vacuum cleaner to determine the consumer satisfaction:

- Cleaning a hard floor
- Cleaning a carpeted floor
- Cleaning the stairs

These actions were chosen, because they are the most common and require interaction with the canister. Therefore they have a big influence on consumer satisfaction.

A second, subordinate, goal of the consumer research was to gain more insight on the importance of size versus other vacuum cleaner properties. To achieve this goal, two trade-off questionnaires were held among the participants. In the first questionnaire, respondents had to trade off different properties of a vacuum cleaner against each other. In the second questionnaire different operations had to be traded off against each other.

Results of the consumer research are described in the next paragraph. For the whole consumer plan, see the appendix F – consumer research plan. To watch the consumer research contact Jan Kohl, test coordinator at the ARC of Philips Drachten, for the DVD's.


Figure 2.6: Performing the consumer research

## Processing results from the consumer research

To reach the goals, fifteen consumers tested nine vacuum cleaner dummies with different sizes and/or weights. After the doing the test exercises with a dummy, participants were asked to rate dummy, on a scale of one (low) to ten (high), based on their overall satisfaction. The average scores are shown in Figure 2.7.

With the score results the optimal (minimal) volume of a vacuum cleaner was calculated together with Marc Schuld, a senior consultant in quantitative methods from CQM. First the assumption was made that the scores represent points in a linear model and therefore the consumer satisfaction could continuous be calculated by using the linear regression model (ANOVA). The consumer satisfaction can then be described in the formulas:

$Y_v$ = Score of the dummy (consumer satisfaction) on weight

$V$ = volume

$Y_v = \alpha_0 + \alpha_1 * V + \alpha_2 * V^2$

The outcome is that **the optimal, minimal volume of a vacuum cleaner is approximately 12,1 dm$^3$**. This volume has a score of 7,45 and results have a fit of 39%. This fit is not very high, but the specialist indicated that this fit was high enough for valid results.

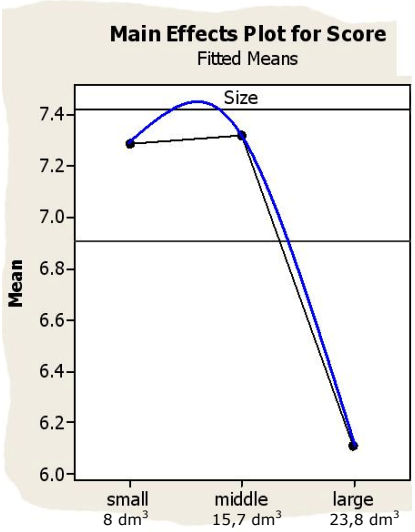

Figure 2.7: Scores of the dummies

With the score results the optimal (minimal) weight of a vacuum cleaner could also be calculated. However, the scores from the test had a very wide spread (low fit) and the average scores of the different weights did not differ much, this caused an invalid outcome. The reason that the scores were invalid could have been caused by two factors. The first, most likely, factor is that the difference in weights that were used in the consumer test was too small. Therefore the differences in weight were not noticeable and consumers did not base their score on weight. The second factor could be that weight is not important for consumers, but this contradicts the results from the trade off questionnaire.

Because the weight results were not valid, the effect of a different size-weight combinations was invalid as well. Although it has to be remarked, that there is an effect noticeable.

| **Properties** |
|---|
| Good usability |
| Good performance |
| Good storability |
| Environmentally friendly |
| Light weight |
| Small size |

Table 2.1: Ranked properties

| **Handling** |
|---|
| Vacuum clean floor |
| Control suction power |
| Vacuum clean stairs |
| Take/store vacuum cleaner |
| Empty dust storage |
| (Dis) assemble vacuum cleaner |

Table 2.2: Ranked handlings

Next to the interaction tests with dummies, participants were asked to fill out two trade-off questionnaires and some open questions to gain insight into the most important properties and actions in vacuum cleaning. The results (Table 2.1) showed that from all included vacuum cleaner properties, a small size was the least important. In the operations trade off, operations where size played an important role, were also not that important (Table 2.1).

The open questions gave more insight on other vacuum cleaning aspects. For example all respondents answered that they find changing the cord to another plug within the same room a dissatisfactory and half of the respondents claimed to be willing to pay 50 euro extra for a miniaturized high performing vacuum cleaner. When asked what the ideal vacuum cleaner would be, only one respondent answered "a robot vacuum cleaner".

The overall conclusion from the consumer research is that miniaturization is subordinate to other properties of a vacuum cleaner. This is in line with the requirement from the Philips departments to only minimize when performance, operation and usability are not decreased. All the results of the consumer research are shown in appendix F – consumer research results.

# 3. Future opportunities for Philips floorcare

To determine future opportunities, first the key components that influence size and shape were determined using the acquired component information and the key drivers. Then ideas were generated to improve a vacuum cleaner. Minimizing the overall size was always the main focus of these brainstorms, but other ideas were also listed. The ideas were rated on their feasibility together with Paul van Wolferen. In collaboration with the components specialists, a component roadmap was made. Based on all these steps, the most potential future opportunities were pointed out.

## 3.1 Vacuum cleaner key drivers

Seven key drivers for vacuum cleaning were derived from the available Philips consumer information. These key drivers were used for determining the key components in the rest of the idea process and concept development.

*Key drivers (randomly ranked):*

1) Dust pickup (DPU)
2) Dust storage capacity (DSC)
3) Cleaning range
4) Weight
5) Convenience of use
6) Storage Convenience
7) Size

## 3.2 Key components that influence size and shape

The components that have the biggest influence on the final shape and size were determined from the collected requirements and key drivers of a vacuum cleaner. In a vacuum cleaner, three components have the biggest influence on size and shape and they are listed below. The first listed component has the most influence and the third listed component the least.

### 1. The motor

There is a wide selection of available vacuum motors and their influence on size and shape differs per motor type. However, the motors that Philips uses in her vacuum cleaners are most important to the size and shape of the vacuum cleaner.
Current vacuum cleaner systems use a motor that is able to produce a high vacuum and a fast airstream. The efficiency of the used vacuum cleaner motors, approximately 46%, results in the need for a high input power. This high input power requires the use of a cord (winder). Furthermore, Philips uses motors that work with carbon brushes. This causes a need for an exhaust filter and an airtight air channel to this filter. The shape of a motor is also predetermined and there has to be enough space in the vacuum cleaner to reduce the noise the motor produces. All this together makes the motor a big component with a big influence on size and shape of a vacuum cleaner.

### 2. The cord winder

A cord winder is a necessary component in a vacuum cleaner to achieve a certain performance level. Batteries of the same size as the cord winder do not have the required capacity for good cleaning and are much more expensive. Therefore without a cord winder the performance of a vacuum cleaner would decrease significantly.
The cord winder is a very standardized component. The only variables in this component are the overall size due to different cord lengths (small difference) and the width/diameter ratio. Furthermore, a cord winder does not use its volume efficiently, because the winding volume has to be approximately 1.7 times the cord volume due to the lack of a cord guiding system. Additionally current cord winders must to be placed vertically in order to work correctly. These properties make the cord winder a very inflexible, big component that has a big influence on the size and shape of a vacuum cleaner.

### 3. The dust management system

Consumers want a good, constant dust pickup and find it a chore to empty their vacuum cleaner. To reduce emptying a vacuum cleaner as much as possible and therewith achieve a good user comfort, the dust storage capacity should be as big as possible. Because current dust storage

systems do not compress dust into a small volume, a big dust storage capacity requires a big volume. So the required / determined storage capacity has a big influence on the volume. However, the shape of the dust storage is flexible and designed in house at Philips. This means the influence on the total size and shape of a vacuum cleaner could be reduced by shaping the dust storage custom (smart) for each vacuum cleaner.
Because the dust filtering systems do not filter out all the dust, motor inlet filters are required to guarantee a certain product lifetime. This again causes a lot of extra necessary volume.

### 3.3 Used innovation methods

To generate ideas for improving vacuum cleaners (in size), tools from two methods were used. The first used method is called TRIZ, the acronym for ***T****eoriya* ***R****esheniya* ***I****zobretatelskikh* ***Z****adatch* meaning "The Theory of Inventive Problem Solving". TRIZ features a set of tools that can be used in all kinds of innovation processes. TRIZ was founded in 1969 by Gerrit Altshuller and is based on the analysis of innovations in 40 000 patents. Two tools from this method were used. First a S-Jump curve was made to get a clear view of the evolution of the vacuum cleaner. After this the '40 principles' and 'evolution analysis' tools were used to generate ideas.
Next to the tools used from the TRIZ methodology, a tool from the SIT methodology was used. Filkovsky, Horowitz and Goldenberg introduced SIT, short for Systematic Inventive Thinking, in the early 1990's with the goal of simplifying TRIZ. SIT starts its process with the product or service that is offered and elements directly available in the environment. With this closed world principle, new product ideas will be formed based on the current product. From the SIT method the subtraction tool was used.
The use of TRIZ en SIT is elaborated in the next two paragraphs.

## TRIZ

To get a clear view of the evolution of the dry cleaning process, a S-Jump curve, that can be found in appendix G, was made. This curve orders all innovations from the broomstick up to the canister vacuum cleaners used nowadays. Hereafter the '40 inventive principles matrix' was used. The tool consists of a matrix that is filled with 40 abstract engineering parameters. Innovative ideas were formed when changing a parameter caused a negative effect on another parameter. In the matrix abstract solutions were proposed from which engineering solutions could be created. An example:

Two vacuum cleaner properties, overall size and dust storage capacity, conflicted with one another when decreasing the overall size. These properties were converted to the parameters 'size of moving object' and 'amount of substance' in the 40 principles matrix and the result suggested:

Inventive principle 29. The use of gasses and liquids
Inventive principle 30. The use of thin films and flexible shells
Inventive principle 7. Nestling

When all conflicts were determined, brainstorm sessions about innovative solutions took place using these suggestion. These sessions resulted in a list of ideas for improvements and/or new products that can be found in appendix H.

The second tool, the 'Evolution analysis' tool, was used to define up to what stage the product parameters were evolved compared to their maximal evolutionary potential. An example:

The volume of a vacuum cleaner was shaped in three dimensions. This property was abstracted to the term 3D complex shape. The shape of an object can evolve in the following stages:

| **Abstracted property** | **Example (from the used book)** | **Score** |
|---|---|---|
| Plane | Flat and slim gas tank in a car | 1 |
| Box | Box-shaped gas tank in a car | 2,5 |
| Cylinder | Cylinder shaped gas tank in a car | 5 |
| Spherical shape | Spherical-shaped gas tank | 7,5 |
| 3D complex shape | Complexly-shaped gas tank to fully match and fit the surrounding geometry | 10 |

Table 3.1: Stages of Volume evolution (Souchkov V.V.: 2009; xTRIZ)

The stage up to which the parameter was evolved was given a score. Scores of all parameters were plotted on a radar plot. In this type of plot chances to improve the product are clearly visualized. Per parameter that was not evolved to its maximal evolutionary potential, a brainstorm was held about how to achieve an higher evolution of the parameter in order to improve the product. The scores of all parameters are plotted in Figure 3.1. An explanation of the score per parameter is to be found in Appendix H.

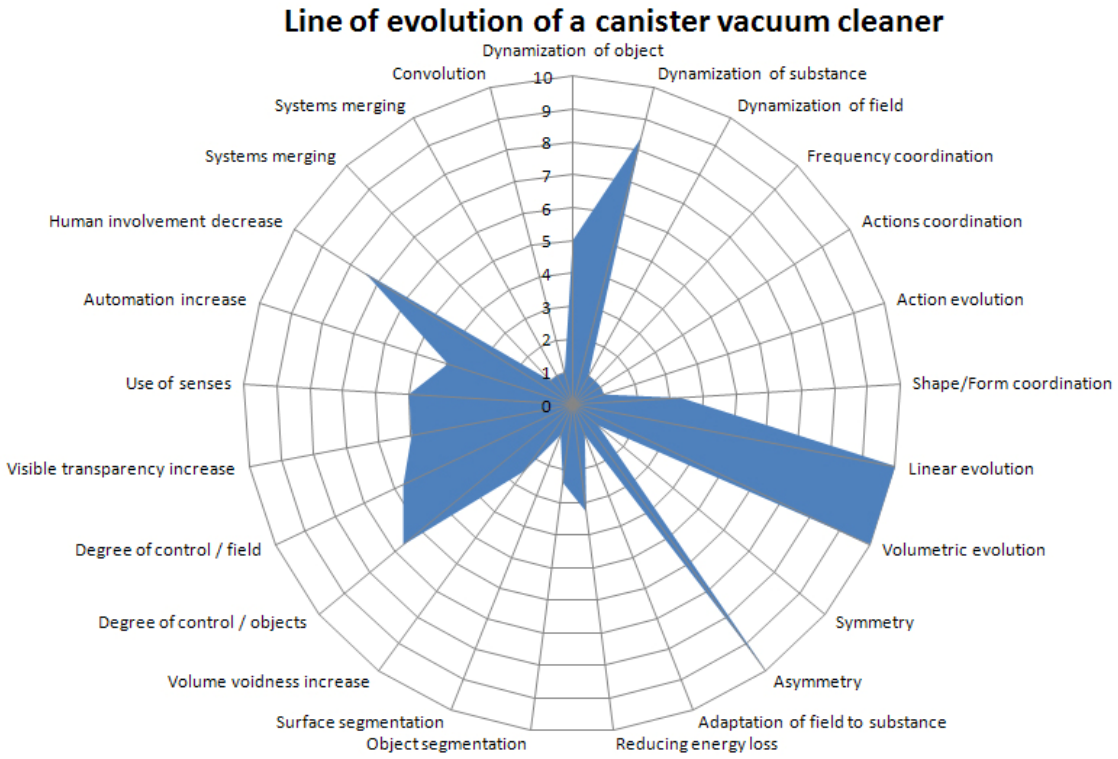


Figure 3.1: Evolution Plot canister vacuum cleaner

## SIT

From the SIT methodology one of the five thinking tools, that form the base of the methodology, was used: the subtraction tool. With this tool essential components were taken away from the component (one at a time) and benefits for the subtracted version were found. For example:
The chosen product was a vacuum cleaner. One of the critical components, the motor, was taken away. Ideas were formed about how the product could work if other components fulfill the function of the motor. This would save a component and therefore reduce size. The ideas are included in the idea list. Pictures of the SIT session, that was held with Freddie Moes, can be found in appendix I.

## 3.4 Ideas

Although the focus of the brainstorm sessions had always been reducing the overall size of a vacuum cleaner, all ideas to improve a vacuum cleaner were noted. This was done because it would be a waste to throw away ideas that might be of use to Philips but did not fit in the scope of the project. The ideas for decreasing the size of a vacuum cleaner are listed in Table 3.2, with their feasibility. The full list of ideas can be found in appendix J.

| Idea | Feasibility |
|---|---|
| Make the whole vacuum cleaner flexible in size | |
| Motor with filtering system in it | |
| Motor with dust storage in it | |
| Use a rotating brush to stir up / collect dust | |
| Put several filters with different porosity behind each other instead of a dust separation system | |
| Use an inflatable dust storage | |
| Separate different types of dust to reduce storage volume | |
| Introduce a special hair filter | |
| Develop an extendable hose | |
| Collect dust in a small one-time-use cup that you have to throw away after use every time | |
| Make a plug entrance and sell cords & winders separately | |
| Adapt the shape on the most functionally used shape | |
| Use a brushless motor to lose the hepa filter for carbon particles | |
| Use a motor that only produces an airflow, no vacuum | |
| Increase the broadness of the winding space for the cord winder | |
| Change the motor type into a motor with a flexible body | |

Table 3.2: Ideas to decrease overall size

## 3.5 Component roadmap

In collaboration with the components specialists from the engineering department (mind map), a component roadmap was made for the next five years. The basis for this roadmap was formed by the interviews where the development of components was discussed. The ideas that were generated in the brainstorm sessions were also discussed in these interviews and based on the discussion included or excluded. The roadmap of the key components can be found in Table 3.3. The full component roadmap is available in appendix K.

| Component | Alternatives | 2010 | 2012 | 2015 |
|---|---|---|---|---|
| Motor | Currently used (global 2) | Diameter ± 120 mm, Height ± 100 mm, 1800 W input power, 800 – 900 grams, 48% efficiency | Same size and weight, 1200 W input power and 50% efficiency | Same size and weight, 750 W input power and 52% efficiency |
| | Brushless motors | Same as the brush motors, though more expensive | Same as the brush motors, a bit more expensive | Same as the brush motors |
| | Axial flux (flat) motor | Diameter ≤ 100 mm, Height ≤ 30 mm, 50 W input power, Low weight, At least same efficiency | | All the same but 750 W input power |
| Cord winder | Currently used (vertical) | Diameter ± 160 mm, Width ± 60 mm | A bit smaller size available | More flexible sizes to implement |
| | Horizontal cord winder | Not yet that far developed | Good working prototype | An option for using it in a vacuum cleaner |
| | New cord winder configuration | Start development | Functional prototype | Working system |
| Dust management system | Bag | Standard interface, minimal 1,5 L loose dust in a bag | Same as in 2010 | Less used (maybe even a phase out) or better, more efficient materials used |
| | Bag less | Different types of bag less filtering, requires a motor inlet filter | More effective filtering | No motor inlet filter required |
| | Compressed dust system | Start development | Functional prototype | Working mechanism |

Table 3.3: Component roadmap of the key components

Table 3.3 shows that the traditional key components will only increase in efficiency and, except for the motor, will also increase in flexibility. Size does not really decrease when current components are optimized. It requires alternative, yet to be developed components to achieve a real decrease in size. For instance the dust management system could be decreased a little bit in size due to more effective filtering and therefore the option to leave out the motor inlet filter, but a real size decrease can be achieved when the stored dust requires less volume.

## 3.6 Most potential opportunities

The future opportunities in Philips floorcare were focused on product improvement opportunities for miniaturizing vacuum cleaners. However, next to the opportunities based on the research, a document has also been written about the opportunities for the process in the Philips floorcare department, based on the work floor experience. The process proposals can be found in appendix L. The product improvement opportunities are elaborated in the next paragraphs.

The most potential opportunities for Philips to minimize vacuum cleaners can be found in the extensive research into (alternative) key components and new vacuum cleaner designs. The cleaning level of Philips vacuum cleaners has improved over the years and the current cleaning level is very good. However, these improvements were all based on using the same type of components and small changes in the design of the same product configuration. A wider, more free choice of the key components changes the system requirements and creates the opportunity to come up with designing solutions to create a compact system or even a different product. The impact of developing new and/or using different key components will be demonstrated for each key component.


Figure 3.2: Axial flux motor

It is recommended to start with a change of the motor type. For example: by using brushless motors, the exhaust filter and airtight channels would become superfluous. This creates the opportunity to make different, smart designs that decrease the overall vacuum cleaner size. Combining a brushless motor with an active nozzle would have even more impact as there is less vacuum needed and the choice of motor types increases.

Research into alternative working mechanisms to decrease the size of the motor while keeping the efficiency constant would have an extra impact because the size of the motor is quite big in relation to the overall size. The upcoming axial flux motor for vacuum cleaners is therefore a very interesting development for minimized vacuum cleaners.

The inflexibility of the traditional cord winder has to be broken to expand the design freedom while keeping a high performance. The vacuum cleaning requires so much power that a cord winder must still be included in the vacuum cleaner. A translation to more flexible, compacter solutions must be made. For example, if the cord can be wrapped around the motor pot, the cord winder and the motor related components can be integrated, which can save a lot of space.

Especially when developing towards a whole new product configuration, flexibility in storing the cord, without decreasing user comfort is a necessity.

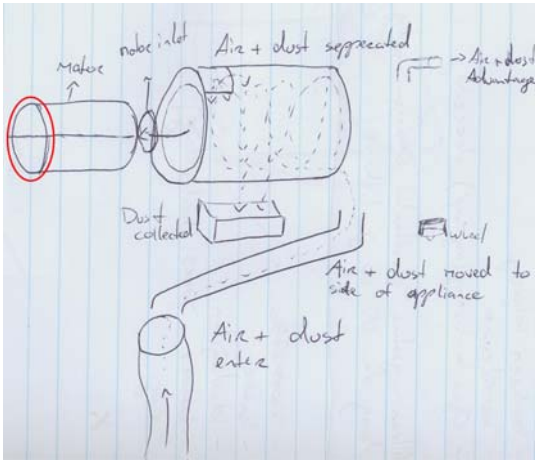

Figure 3.3: Sketch of integrating components options

Making the dust storage more compact would be a good development, but is not a necessity yet. First a consumer research into the different options for emptying dust storage must give an outcome that can be used as starting point for developing a more compact dust storage. For example: keep a big dust can, starting to use a cup system, a compacted system, or a combined system with the garbage bin.

An extensive research into alternative system designs and product configurations, when size can get < 12 $dm^3$, is a good way to stay ahead of the competition in other vacuum cleaner properties. The more space a design has left over after putting in the necessary components, the more other vacuum cleaner properties (e.g. muffling of the motor for sound reduction) can improve. Next to this benefit, other product configurations to increase user convenience, like a slim upright solution, would become easier to realize and consumers have a big preference for these configurations according to the ARC department.

It is important to keep in mind that Philips is a cost driven organization. Products must be produced as cheaply as possible and therefore costs are a very important argument in making component choices. However using more expensive components does not automatically result in a more expensive system. If, for example, a brushless motor would be used, the costs for the motor would double from eight euro to sixteen euro. Therefore this option appears to be very unattractive, but because an exhaust filter (approximately five euro) becomes superfluous, less material would be used, transportation costs would be less and the construction for the filter could be left out, the costs could end up being (almost) similar.

Figure 3.4: Back of the conventional concept

# 4. Miniaturized concepts

As a closure of the assignment two vacuum cleaner concepts were developed that have as main purpose to visualize the conclusions of the research into the options for minimizing overall vacuum cleaner size. In consultation with Philips it was decided to develop a concept using only conventional components and a future concept for the year 2015.

## 4.1 Conventional concept

The conventional concept had to consists of already used components in Philips vacuum cleaners, which meant that most of the components were determined before the concept development started, showed in table 4.1. To meet the minimized volume, the components had to be arranged in an architecture that fitted this volume, with a theoretical plausibility that performance could be similar to the performance of the Philips 'Performer'.

| Component | Model | Comment |
|---|---|---|
| Motor | Domel 463.3.401 | Same as Performer |
| Cord Winder | Athos Cord winder | Same as Performer |
| Dust Management System | Custom design | Separator from Panther project |
| Motor inlet filter | Hepa custom size | |
| Exhaust filter | Hepa regular size | Required due to motor |
| PCB | Same components | Not included in design due to flexible size |
| Wheels | Custom design | Same wheel configuration as Performer |
| Housing | Custom design | Based on archetype used in the consumer research |

Table 4.1: Conventional concept component list

### Development

The development of the conventional concept started with the creation of a box that had a volume of 12,1 $dm^3$ and the archetype that was used in the consumer research, Figure 4.1. Also raw component shapes were made, based on the known component sizes and/or minimal requirements from the various Philips departments. Before different architectures could be made up it was tried to fit all components in the volume.

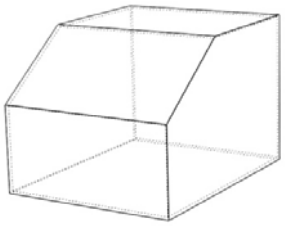

Figure 4.1: Sketch box

Once it was clear that the components fitted different architectures were thought and tried. In a review, with Philips, of these different architectures it was chosen to use the architecture of Figure 4.2. The most notable difference of this architecture compared to the other architectures is that the motor was put in the front of the vacuum cleaner. The motor was put there because putting the motor in the back of the appliance would in any case cause a very short exhaust channel, leaving little options for sound reduction as a consequence.

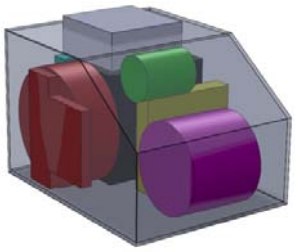

Figure 4.2: Architecture

After choosing the architecture, sketches were made to roughly design the housing of the vacuum cleaner in Figure 4.3. Due to limited time a definite shape was chosen from the sketches and put into Solid Works. Here again the raw components, arranged in the architecture, were tried to fit in the shape. To fit all the detailed components in the model, additional components like the air channel and motor pot had to be designed.

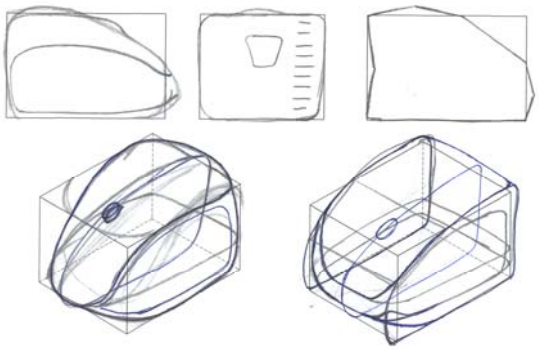

Figure 4.3: Sketches

Once it was clear that all components fitted, the translation to printable files for the prototype was made (Figure 4.4). When the files (components) were translated, it was chosen to make the prototype completely able to be (dis)assembled often, so future students can use the model to learn about the components and architecture more easy.

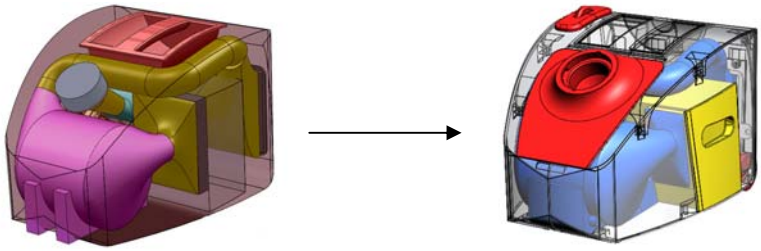

Figure 4.4: Prototype translation

## Features and Specifications

Because a lot of the used components are also used in the Philips 'Performer' and the basic efficiency principles were taken into account, the theoretical performance of the conventional concept can be similar to the performance of the Philips 'Performer'.

*Features*

+ Good dust separation
+ Optimal minimized size
+ Big Handle
0 Weight distribution (Figure 4.5)
- Take out the dust bin on the side
- Effectiveness of the dust storage
- The hose connection must be up before the dust bin can be removed

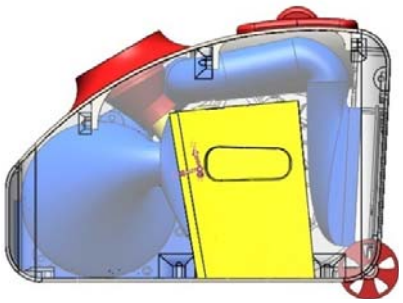

Figure 4.5: Centre of mass

*Specifications*

| | |
|---|---|
| L*B*H: | 318 * 255 * 210 mm |
| Volume: | 12,8 $dm^3$ |
| Mass: | 3712 gram |
| (input) Power: | 2000 W |
| Loudness: | ≤ 76 db |
| Dust capacity: | 2,1 $dm^3$ |
| Cost price: | 45 euro |

Figure 4.6: Renders conventional concept

## 4.2 Future concept

Developing the future concept created the possibility to use the feasible ideas and component roadmap. In deliberation with Philips it was decided to make an upright vacuum cleaner concept. This was chosen because the Philips ARC and Design department had a strong preference towards such a concept and the most recommended opportunities could be clearly visualized.

### Choice of ideas for concepts

*Include a handheld in appliance*

When a high performing vacuum cleaner and a handheld can be combined in one concept, it would safe homes a lot of storage space as it requires one appliance less. And it is a handy feature to be able to clean e.g. the table, while cleaning the floor.

*Make the vacuum cleaner consist of several subparts*

This idea was used to include a handheld and to make it possible to store the appliance more flexible.

*Use a rotating brush so the nozzle stirs up dust & Use of an axial flux motor*

Combining a brushless flat motor and a rotating brush in the nozzle, results in the possibility to achieve a high DPU within a small appliance size using less energy.

*Increase the broadness of the winding space for the cord winder*

By changing the whole working mechanism of a cord winder, the size could be made more flexible. The cord winder included in the model is a mechanism that guides the cord in one direction.

*Use a compressed dust volume system*

There are numerous possibilities to reduce the size of stored dust. A future research to this new component has to turn out what possibility would work best.

### Development

| Component | Model | Comment |
|---|---|---|
| Motor | Axial flux motor | Research to increasing performance |
| Cord Winder | Custom design | One of the possibilities |
| Dust Management System | Custom design | Separator from Panther project<br>The compression system is yet to be researched |
| Motor inlet filter | -- | Not included. Necessity depends on the DMS |
| Exhaust filter | -- | Not required due to motor |
| PCB | Same components | Not included in design due to flexible size |
| Wheels | -- | Included in the Nozzle |
| Housing | Custom design | Sketched around the necessary components |

Table 4.2 Conventional concept component list

The development of the future concept started with making the raw component shapes and composing them in an upright architecture. Because there was limited time there were only a few architectures made and directly one chosen.

Around these components a rough shape was sketched in Figure 4.7 and put as a shell in Solid Works. Because the shape was sketched around the components it was not necessary to try to fit the components in the shell.

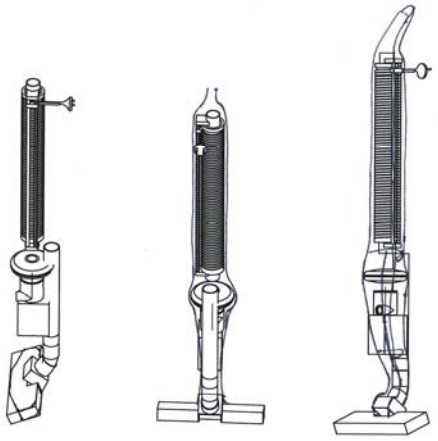

Figure 4.7: Sketches future concept

After all parts were made in Solid Works the translation to printable parts started immediately. Because the concept had to be developed in a very limited time span, but was still very well thought true, it was chosen to develop one of the innovations, the new cord winder, into a semi working part. This way it could be shown that the ideas were not just a guess, but a very well estimated chance of being able to develop components to producible parts in the next five years. The rest of the model only consists of the shell, because most of the components are not available yet.

## Features and specifications

Cleaning with an upright (stick) vacuum cleaner is a totally different experience of cleaning the floor. All the interaction between the user, the appliance and the environment is within eyesight. This causes a lot more control over the vacuum cleaner

*Features*
+ Modular components
+ Transformable to a handheld
+ Low energy
+ Very easy to use and store
0 Dust storage is at the bottom of the appliance
- Still a bit bulky

Figure 4.8: Centre of mass

*Specifications Vacuum cleaner mode*

| | |
|---|---|
| L*B*H: | 120 * 120 * 1093 mm |
| Volume: | 6,0 $dm^3$ |
| Mass: | ≈4100 g |
| (input) Power: | 800 W |
| Loudness: | ≤76 dB |
| Dust capacity: | ≥2,1 $dm^3$ compressed |
| Cost price: | -- euro |

Figure 4.9: Future concept vacuum cleaner mode

*Specifications Handheld mode*

| | |
|---|---|
| L*B*H: | 120 * 120 * 597 mm |
| Volume: | 3,4 $dm^3$ |
| Mass: | ≈1800 g |
| (input) Power: | To be determined |
| Loudness: | ≤76 dB |
| Dust capacity: | ≥2,1 $dm^3$ |

Figure 4.10: Future concept handheld mode

## 4.3 Concepts review

In Table 4.3 the concepts are reviewed, using the KPI's that were determined in the project. The results show that improvement in vacuum cleaning can both be achieved by minimizing the current vacuum cleaner architectures and developing towards an upright concept, with each their own impact on the consumer satisfaction.

| KPI \ Models | Philips Performer | Philips Gemini | Conventional concept | Future concept |
|---|---|---|---|---|
| **Dust pick up** | 1 | -1 | 1 | (1) |
| **Dust storage** | 1 | -1 | 0 | (1) |
| **Cleaning range** | 1 | -1 | 1 | (1) |
| **Use convenience** | 0 | 1 | 1 | (1) |
| **Storage convenience** | 0 | 1 | 1 | (1) |
| **Size** | 0 | 1 | 1 | (1) |
| **Weight** | -1 | 0 | 0 | (1) |
| **Total** | 2 | 0 | 5 | 7 |

Table 4.3: Concept review

Figure 4.11: Performer, Gemini and the concepts

# 5. Conclusions and Recommendations

Defining a minimal size for vacuum cleaners can be done. That size is 12,1 $dm^3$ in this research, were the consumer satisfaction on size is leading in this outcome. However, it must be taken into account that this outcome is only valid for a certain archetype. When Philips finds the outcome of this research relevant enough to include it in their own development, two types of research are proposed.
A bigger research into the relation between overall size, size perception and options for using archetypes can be done. The other type of research would be a consumer test to get insight the effect of different model sizes on consumer satisfaction after the archetype is determined, as done in this research.

A small size is preferred by consumers, but only if the performance and convenience of use is at least as good as in bigger sized vacuum cleaners. If these aspects decrease to make a smaller appliance, consumers will not even consider buying the appliance. Therefore it is recommended that a design choice to decrease size might never have the consequence that performance or user convenience decreases to a level under the level of competitor (bigger) appliances.

With current technology, Philips can develop vacuum cleaners that have a very small overall size. This does not mean that components are small enough and Philips can shift focus to other aspects, but currently it is (currently) possible to make a high performing vacuum cleaner in the current optimal minimized size. To be able to compete with competitors it is necessary to keep decreasing component size and create more options for component selection.

It is possible for Philips floorcare to have a new, well performing floor cleaning product, like a slim upright concept, on the market over five years. However, the research to alternative key components has to start this year. To be able to realize such concepts and small canister vacuum cleaners with better properties then the conventional concept, Philips has to be more flexible with the components that can be used. Because Philips purchases a lot of the key components, future product development must be shared with the producers of these components.

A research into 'storing the vacuum cleaner' as main research subject would be an important and good addition to the research into the effect of size on consumer satisfaction. Because 'storing the vacuum cleaner' is very extensive subject, it is not recommended to include it in a research with another main focus.

# 6. Evaluation

*Evaluation of gathering requirements in Philips*

The stakeholder mind map with the contact persons for each part was used a lot and it was a very helpful document. People from every department were met when making the mind map and therefore there was no threshold to contact these people further in the project.

Making a VPH and the scenarios before interviewing specialists for their input was very useful and provided new insight in the project, next to the purpose of explaining the project to involved colleagues. When these documents were made, it was forced to think more about the goals of the research like: 'Why a small vacuum cleaner? Who would be interested in such a vacuum cleaner? And what benefits must the appliance have then?'. Before the information gathering could start the whole assignment, especially the end goals, had to be clear.

Gathering the information within Philips was harder than expected. All colleagues were very busy and did not take that much time for this assignment. At first it was tried to collect the requirement from involved Philips departments through digital communication, but it soon was clear that it was not a good approach. Either the respondents gave no answer or an incorrect/insufficient answer. For that reason it was decided to interview all involved people to get the results that were useful although a lot more time then estimated had to be spent.

*Evaluation of the consumer research*

Preparing, executing and processing a consumer research was very fun and informative, but also hard. Keeping all factors as constant as possible during the tests was difficult, especially because it was tried to comfort the respondents at the same time. Some of the correspondents had a hard time to imagine the dummies as working vacuum cleaners and therefore the effort they put into testing the dummies varied. This was difficult manipulate and it could have caused the result to be different then when the research was done with working vacuum cleaners.

During one of the tests, all three dummies broke the bottom plate. This was caused by a construction error in the dummies. Because it was the first time that the researcher did a real consumer test and made dummies for this, it was not noticed during the development.

Thinking up this research did open the opportunity to learn a lot about the preparation and execution of a consumer research. Though it was found strange that there was no start up help at the execution of the research as it did represent Philips as a company.

During the test it became clear that for purchasing a product, trust is a big factor. Consumers related power and dust capacity direct to overall size and make the decision whether to buy it or not on their own perception if it would be pleasant to vacuum clean with the appliance. This outcome is not a quantified and therefore not included in the research, however it would be interesting to research this mental aspect further.

This type of consumer research delivers good results when the archetype of a vacuum cleaner is clear, but the size of the design is still changeable. However, when the optimal volume of a vacuum cleaner in general has to be determined, another, bigger approach would give better results. The reason for this difference is that size perception is very dependent on the archetype of a vacuum cleaner.

*Evaluation of information processing*

The gathered requirements from involved parties were processed with the requirement management program DOORS. This program was found to be very useful in setting up a clear requirement set for systems with a lot of requirements and a lot of involved people, were specific information can be assigned to specific users.

However if there are not that many people involved, the program is not very pleasant to use. The reason is exactly opposite to why it is pleasant to use with many people. The amount of requirements and involved people in this project was low enough to keep a more clear overview if there could be worked from one document.

What is also important to keep in mind when making requirement documents is the type of business that is performed. The difference in developing software or complete combat management systems is very big and both developments demand a totally different requirement

management. In software development more vague guidelines can lead to a good first version, from which updates can be made endlessly. In the development of combat management systems, products must be right in once, because the product itself is so expensive or important that a product cannot fail. So the choice will always be made based on product costs, importance and extra development time.
In Philips about three to five prototypes can be made, depending on the innovation level, before everything has to be ready for production. This has the consequence that requirements has to be determined quite detailed up to component level, but not every bolt has to be specified before the development begins.

*Evaluation of determining future opportunities*
Although using the Funkey architecting method could have been a good method to come up with solutions, the choice to use know methods turned out really good. Because the Funkey method was unknown to the researcher and no examples were made preliminary to the assignmet at Philips to get to understand the method better, using it did not work out. When the purpose of using the Funkey method, producing innovative ideas, became subordinate to using the method correctly, the innovation method had to be switched.
Making the component roadmap en checking the idea feasibility with a vacuum cleaner specialist really increased the value of the produced ideas for Philips and helped in the concept development were a high development speed could be achieved.
Determining the most potential opportunities from the acquired information and generated ideas was found very hard. The next project it is recommended to determine certain criteria (e.g. the key drivers) to which the ideas will be rated. This way of working provides a more substantiated choice for the most potential opportunities.

*Evaluation of the concepts*
When developing the concepts, a lot of choices had to be made within a very limited time span. Therefore not all choices in the end result can be fully substantiated, but most of the choices are really well thought through.
The choice to make two concepts in the limited time span was made, because the future concept would visualize the future opportunities in floor vacuum cleaning. A tangible vision on future Philips floorcare is missed during the execution of the assignment and was therefore found very important to include this in the research. Looking back on the concept development in this project; designing and substantiating the concepts would have been better if their either was more time planned for concept development or the choice was made to make only one concept. Nevertheless the concepts do arouse the interest in Philips and therewith fulfill their purpose very well.

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PHILIPS
sense and simplicity

# Appendices

## Minimizing the overall size of a vacuum cleaner

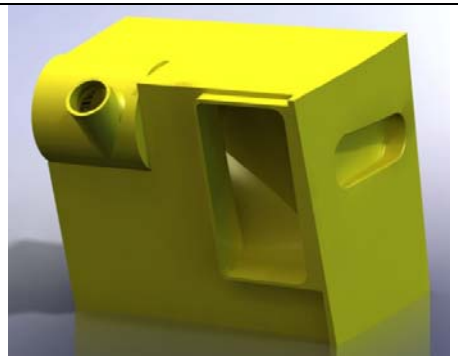
Date 15-02-2010

Author Leon van Dijk

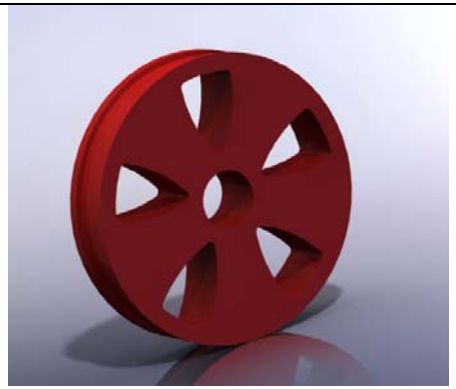
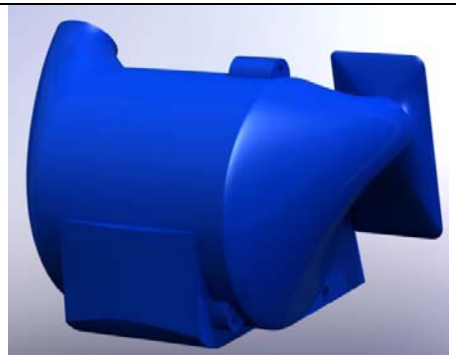
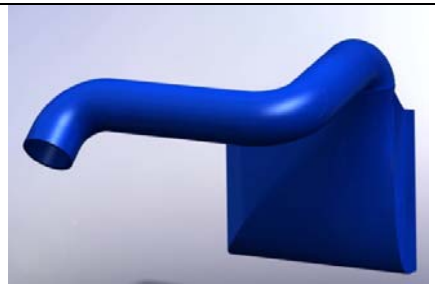
# Table of content

# Appendix A – Component List

| Component | Render |
|---|---|
| Motor |  |
| Cord winder |  |

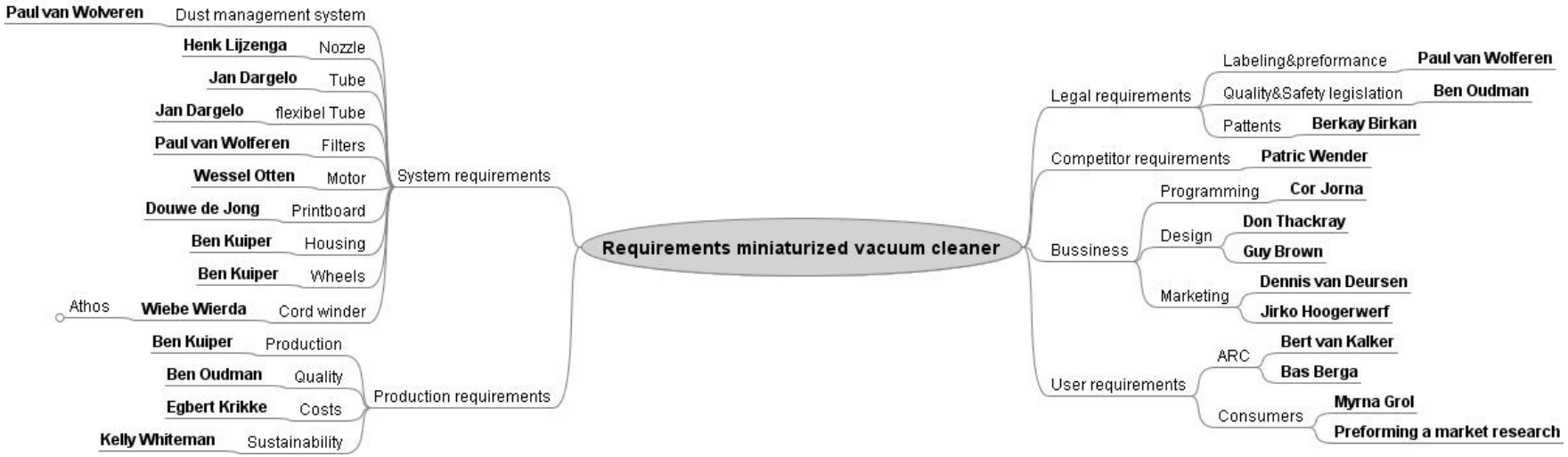
| | |
|---|---|
| Dust Management System |  |
| Motor inlet filter |  |

| | |
|---|---|
| Motor exhaust filter |  |
| PCB |  |
| Housing |  |

| | |
|---|---|
| Wheels |  |
| Motorpot |  |
| Exhaust tube |  |

| | |
|---|---|
| On/off switch |  |

# Appendix B – Mind map



# Appendix C - VPH

| Miniaturization of vacuum cleaners | | |
|---|---|---|
| **Target who is proclaiming the consumer insight**<br><br>"Happy Homers."Adults (mainly woman) aged 25 - 55 whom have family life and a healthy lifestyle as their main concerns. Most of these people work or are housewife. They live in the city where space is very scarce. Due to the busy family life and the urge to provide a healthy environment for the family they use their vacuum cleaner (almost) every day and find results of floor cleaning highly important.<br>Although these people have an enjoyment in floor cleaning they find it a very physical job. | **Consumer Insight**<br><br>For such a frequent and intense user as I am, a current vacuum cleaner with a typical high performance is inconvenient, because it is too big and heavy and I don't have enough space to store such a device. A small cleaning device would fit me better but I don't want to compromise on cleaning performance, to provide a healthy environment for my family.<br>I wish there was something that is convenient in handling and easy to store, without compromising on cleaning performance. | **Competitive environment**<br><br>Compact size vacuum cleaners<br>- Japanese small vacuum cleaners<br>- Dyson baby<br>Easy to grab and store solutions<br>- Swiffer<br>- Handheld vacuum cleaner<br>Low weight solutions<br>- Swiffer<br>- Japanese small vacuum cleaners<br>Ergonomic concepts<br>- Swiffer<br>Smart designs<br>- Ecoclean |
| **Benefits**<br><br>• I can maneuver the vacuum cleaner with the utmost ease causing a decrease in the physical load of vacuum cleaning.<br><br>• Because the vacuum cleaner needs very little storage space, I am able to store my vacuum cleaner out of sight.<br><br>• The typical high performance of the vacuum cleaner ensures me that I provide a healthy environment for my family. | **Reasons to believe**<br><br>• The new Philips vacuum cleaner is very easy to use and store as a result of an intuitive design langue based on a research to the optimal size and weight for a vacuum cleaner.<br><br>• The vacuum cleaner can remain a typical high cleaning performance and decrease in size because innovation of components made the vacuum cleaner more efficient. | **Discriminator**<br><br>**Only with the new Philips vacuum cleaner I can clean my house firmly with the utmost ease and store it out of sight due to its optimal size and weight!** |

# Appendix C - Scenario Maneuverability

## A normal weekday in the city life of Miriam

After a morning of work, Miriam, a 35 year old married mother of two kids, takes care of the kids and prepares the household for family usage in the afternoon. The family lives in a small house in Utrecht. Miriam lunches with her kids, Daan (5) and Emma (7), every day before they go back to school.

Between lunch and picking up the kids after school Miriam arranges all household related activities to enjoy her time with the family. She wants to provide a nice and clean environment for family usage. So cleaning has to be done frequent and firmly.

Since she has bought the new Philips vacuum cleaner she can maneuver very easy through the small spaces! Due to its small size the vacuum cleaner is easy to maneuver on the ground between the furniture and toys of the kids. Even when it is not convenient to clean with the canister on the ground, Miriam is able to pick up the canister with the utmost ease because of its light weight.

After vacuum cleaning Miriam feels refreshed and the house is cleaned firmly with ease. She now has all her energy to enjoy the family life in her healthy environment.

The new Philips vacuum cleaner is optimal in size and weight, with the cleaning performance of a traditional high performing vacuum cleaner. Therefore it is very easy to use and a timesaver when it comes to cleaning difficult places!

Where cleaning with traditional vacuum cleaners is a physical hard job, the new Philips vacuum cleaner is useable without troubling situations. The size and weight optimalization solves getting in awkward positions to get the house firmly cleaned!

# Appendix C - Scenario Storability

## A normal weekend day in the city life of Miriam

Every Saturday morning Miriam, a 35 year old married mother of two kids, gets the overall weekly groceries in the city center. Because Ben (her husband) and Miriam are getting friends over for dinner, she has to get more than normal.

They live in a small house in Utrecht together with their kids Daan (5) and Emma (7). Because their space is scarce, all groceries have to be stored in one stock cabinet together with some cleaning products.

Luckily Miriam just bought the new Philips vacuum cleaner. This vacuum cleaner is very easy to store and takes very little space due to its size. The optimized weight enables Miriam to pick the vacuum cleaner up very easily. This expands the possibilities to store the appliance off the floor. She can first pack the cabinet with groceries and then figure out where to put the vacuum cleaner later!

The new vacuum cleaner makes Miriam feel comfortable when friends come over because she can store her vacuum cleaner out of sight for the first time. She thinks that their home represents her family is and having a vacuum cleaner within eye sight isn't part of that.

With just a couple of simple handlings the new Philips vacuum cleaner is transformed from the stock cabinet into a high performing cleaning device on the floor. Now she can clean before their friends are coming.

The house can be enjoyed without having their vacuum cleaner within eye sight giving Miriam a pleasant and confident feeling.

Where traditional vacuum cleaners claim their space, the new Philips vacuum cleaner is flexible in its storability. The size and weight optimalization solves the problem of having the vacuum cleaner in the living area due to scarce space!

# Appendix D – Stakeholder requirements

| Requirements | Comments | Department | Source |
|---|---|---|---|
| **1 Introduction** | | | |
| This document describes what the stakholders expect of a vacuum cleaning system | | | |
| The requirements describe what the system should comply to are solution free | | | |
| For this project, only the production parties, quality departement and the end user are taken into account in further work | | | |
| **2 Production parties** | | | |
| The production parties shall be able to produce the parts of the vacuum cleaning system | | Production | Ben Kuiper |
| The production parties shall be able to assemble the parts of a vacuum cleaning system quick enough to be capable of mass production | | Production | Ben Kuiper |
| The production parties shall be able to ensure the quality of the parts of a vacuum cleaning system to european legislation and Philips standards | | Production | Ben Kuiper |
| **3 Quality department** | | | |
| The quality department must be able to test the vacuum cleaning system on complying to the applicable european legislation | | Quality | Pierre van Tartwijk |
| The quality department must be able to test the final vacuum cleaning system based on STIWA and SLG test, without demolishing the product | | Quality | Erik Engels |
| **4 Distributor** | | | |
| **5 Sales organizations** | | | |
| **6 End user** | | | |
| The end user shall be able to prepare the vacuum cleaning system for usage, for the first time, as quick as competiting vacuum cleaning systems | | ARC | Bert van Kalker |
| The end user shall be able to vacuum clean the interior of a house with the vacuum cleaning system as firmly as cleaning with a competiting vacuum cleaning system | | ARC | Bert van Kalker |
| The end user shall be able to vacuum clean the interior of a house with the vacuum cleaning system within the same time as cleaning with a competiting vacuum cleaning system | Moeilijk concreet te maken. Nozzle breedte is hier ook nog van toepassing | ARC | Bert van Kalker |
| The end user shall be able to use the vacuum cleaning system without polluting the air | | Engineering | Paul van Wolferen |

| | | | |
|---|---|---|---|
| The end user shall be able to adjust the vacuum cleaning system to their own working height | | ARC | Bert van Kalker |
| The end user shall be able to use the vacuum cleaning system correctly | | ARC | Bert van Kalker |
| The end user shall be able to move the vacuum cleaning system while using the vacuum cleaning system | | ARC | Bert van Kalker |
| The end user shall be able to lift the vacuum cleaning system while vacuum cleaning | | ARC | Bert van Kalker |
| The end user shall be able to vacuum clean a room without changing the plug into another socket | | ARC | Bert van Kalker |
| The end user shall be able to use the vacuum cleaning system for one month without performing maintenance | | ARC | Bert van Kalker |
| The end user shall be able to perform maintenance on the vacuum cleaning system without using tools | | ARC | Bert van Kalker |
| The end user shall be able to perform maintenance on the vacuum cleaning system without physical contact with visible dirty parts | | ARC | Bert van Kalker |
| The end user shall be able to store the vacuum cleaning system out of sight | | ARC | Bert van Kalker |
| **7 Dumping ground** | | | |

# Appendix D – System requirements

| Requirements | Comments | Department | Source |
|---|---|---|---|
| **1 Introduction** | | | |
| This document describes the system requirements. | | | |
| The requirements describe what the system does and are solution free. | | | |
| In the document the system is referred as: 'the appliance'. The appliance consist outs of:<br>- A Canister<br>- The nozzle<br>- A connection from the canister to the nozzle<br>- A handle<br>- A connection from the nozzle to the handle | | | |
| **2 Performance requirements** | | | |
| **2.1 Dust Pickup** | | | |
| The appliance shall have a dust pick up of > 99% on a hard floor | | Competitor | |
| The appliance shall have a dust pick up of > 70% on a carpet with haires < 25 mm | | Competitor | |
| The appliance shall have a dust pick up of > 50% on a carpet with haires > 25 mm | | Competitor | |
| **2.2 Efficiency** | | | |
| The appliance shall have a minimal efficiency of 25 % measured from input power to suction power at the hose. | | Competitor | |
| **2.3 Reliability** | | | |
| The appliance shall drop maximal 30% in efficiency when containing dust of 30 times vacuum cleaning | | Quality | Erik Engels |
| **2.4 Sound** | | | |
| The appliance shall produce $\leq$ 78 DB | | Competitor | |
| **3 Appliance Useability requirements** | | | |
| The appliance shall be able to clean in 90 degree corners with an available floor width of 300 mm | | Competitor | |
| The appliance shall not have more separate components then the competitor model | | ARC | Bert van Kalker |
| The appliance shall be able to store dust of 30 times vacuum cleaning | | ARC | Bert van Kalker |

| | | | |
|---|---|---|---|
| The appliance shall have a handle connected to the nozzle which is variable in hight from 850 mm to 1400 mm | | ARC | Bert van Kalker |
| The appliance shall have a stiff connection from the nozzle to the handle which can be adjusted to the preferred height | | ARC | Bert van Kalker |
| The appliance shall be able to be dragged over a floor with a force of $\leq$ 20 Newton for the canister | | Competitor | |
| The appliance shall be able to have the nozzle moved over a floor with a force of $\leq$ 40 Newton | | Competitor | |
| The appliance shall be able to be dragged in any direction while being used on the floor | | ARC | Bert van Kalker |
| The appliance shall have a canister with a handle | | ARC | Bert van Kalker |
| The appliance shall have a canister weight of ... kg | | ARC | Leon van Dijk |
| The appliance shall have a volume of approximately 12 $dm^3$ | | ARC | Leon van Dijk |
| The appliance shall filter out 99,95% of the particles wich are exhausted | | ARC | Bert van Kalker |
| The appliance shall have a reach ability of 12 meter | | Competitor | |
| The appliance shall be able to be opened up to replaceable components without tools | | ARC | Bert van Kalker |
| The appliance shall be able to be moved over a threshold of 25 mm while dragged on the floor | | Quality | Erik Engels |
| The appliance shall have a dust containing system with visible clean contact points | | ARC | Bert van Kalker |
| The appliance shall have a dust filtering system with visible clean contact points | | ARC | Bert van Kalker |
| The appliance shall prevent the end user from contact with the collected dust | | ARC | Bert van Kalker |
| The appliance isn't allowed to fall over when it is placed under a 10 degree angle from any position | | Quality | Erik Engels |
| The appliance shall be able to contain 400 grams of testdust and reach a performance of 70% of the maximum performance | Het enige discussiepunt | Quality | Erik Engels |
| The appliance shall only consist interface parts that can be used correctly by the end users | | ARC | Bert van Kalker |
| The appliance shall consist a dust bag full indicator | Niet direct relevant voor miniaturisatie, maar als het past dan doen | Competitor | |
| The appliance shall be able to be adjusted in suction power by the end user | Niet direct relevant voor miniaturisatie, maar als het past dan doen | Competitor | |

| | | | |
|---|---|---|---|
| **4 Sustainability requirements** | | | |
| **4.1 Energy consumption** | | | |
| The Appliance should consume less then 0,5 Watt in the off mode | | Sustainability | Kelly Whiteman |
| **4.2 Hazardous substances** | | | |
| The appliance shall be polyvinyl chloride and Brominated Flame Retardant free | | Sustainability | Kelly Whiteman |
| The appliance shall be Nickel-Cadmium battery free | | Sustainability | Kelly Whiteman |
| The appliance shall comply to the Philips restricted substances list | | Sustainability | Kelly Whiteman |
| **5 Product quality requirements** | | | |
| **5.1 Reliability** | | | |
| The appliance shall be of a quality that >90% of the sold appliances have a lifetime of >7 years (490 hours) | | Quality | Erik Engels |
| The appliance shall not have irreversible damage in the drop test at Philips | | Quality | Erik Engels |
| **5.2 Legal and compliance requirements** | | | |
| **5.2.1 Compliance** | | | |
| **5.2.1.1 EuP** | | | |
| The appliance shall comply to the 2005/32/EC requirement | | Quality | Pierre van Tartwijk |
| **5.2.1.2 Electronic EMF** | | | |
| The appliance shall comply to the IEC EN 50366 + amd 1 requirement | | Quality | Pierre van Tartwijk |
| **5.2.1.3 Floor Care (Energy Labeling)** | | | |
| The appliance shall comply to the IEC EN 60312 requirement | | Sustainability | Paul van Wolferen |
| **5.2.1.4 Chemical (e.g. Restriction of Hazardous Substances)** | | | |
| The appliance shall comply to the chemical requirement 2002/95/EC | | Quality | Pierre van Tartwijk |
| The appliance shall have a concentration of < 0,1% in the material for: Lead (Pb), Mercury (Hg), Hexavalent Chromium ($Cr^{6+}$), Polybrominated biphenyls (PBB), Polybrominated diphenyls (PBDE) | | Quality | Pierre van Tartwijk |
| The appliance shall have a concentration of < 0,01% in the material for Cadmium (Cd) | | Quality | Pierre van Tartwijk |
| **5.2.1.5 Electronic EMC** | | | |
| The appliance shall comply to the IEC EN 55014-1:2006 requirement | | Quality | Pierre van Tartwijk |
| The appliance shall comply to the IEC EN 55014-2:1997 requirement | | Quality | Pierre van Tartwijk |
| The appliance shall comply to the IEC EN 61000-3-2:2006 requirement | | Quality | Pierre van Tartwijk |
| The appliance shall comply to the IEC EN 61000-3-3:1995 + amd1 + amd2 requirement | | Quality | Pierre van Tartwijk |

| | | | |
|---|---|---|---|
| The appliance shall comply to the 2004/108/EC requirement | | Quality | Pierre van Tartwijk |
| **5.2.2 Batteries** | | | |
| The appliance shall comply to the 2006/06/EC (WE) battery requirement | | Quality | Pierre van Tartwijk |
| **5.2.3 Safety** | | | |
| The appliance shall comply to the IEC 60335-2-2 ed. 5 incl. amd 1 + am 2 requirement | | Quality | Pierre van Tartwijk |
| The appliance shall comply to the IEC 60335-1 ed. 4 incl. amd 1 + am 2 requirement | | Quality | Pierre van Tartwijk |
| **6 Production requirements** | | | |
| The appliance shall be designed to be assembled according to the accumulation principle | | Production | Ben Kuiper |

# Appendix D – Component requirements

| Leon van Dijk | Comments | Department | Source |
|---|---|---|---|
| **1 Introduction** | | | |
| This document consist the components of a miniaturized vacuum cleaning system | | | |
| **2 Nozzle** | | | |
| The nozzle must have a minimal width of 270 mm | ARC doesn't have a hard requirement on this number, but it is most used. | ARC | Bert van Kalker |
| The nozzle is allowed to have a minimal height of <diameter connection part tube> | Because of a 'cleaning under furniture' test the tube is required to go under the furniture | Engineering | Henk Lijzenga |
| The nozzle must have a connection part to the tube with an inside diameter of 32 mm | | | Standard interface |
| The nozzle must have a minimal dept of 23 mm | The opening of the nozzle is leading in the depth of the nozzle | Engineering | Henk Lijzenga |
| The nozzle must have an opening with a minimal dept of 15 mm | | Engineering | Paul van Wolferen |
| **3 Tube** | | | |
| The tube must have a variable streched lenght of $\geq$ 980 and $\leq$ 1080 mm | The challenge is to decline the length when retracted | ARC | Bert van Kalker |
| The tube must have a minimal length of $\leq$ 600 mm | | ARC | Bert van Kalker |
| The tube must have a connection part to the hose with an inside diameter of 32 mm | This is actually a requirement from the sales department | Engineering | Paul van Wolferen |
| The tube must have a connection part to the nozzle with an outside diameter of 32 mm | | | Standard interface |
| The tube is made of aluminum or plastic | | Engineering | Ben Kuiper |
| The tube has a mechanism to adjust the height to the preferred height | | ARC | Bert van Kalker |

| | | | |
|---|---|---|---|
| **4 Handle** | | | |
| The handle must have a diameter of 32 mm | | ARC | Bert van Kalker |
| The handle must have a length of 90 mm | | ARC | Bert van Kalker |
| The handle must have ergonomic finger grips | | ARC | Bert van Kalker |
| **5 Hose** | | | |
| The hose must have a minimal lenght of 1700 mm between the hose connection and the handle | When choosing for a different configuration (stretched hose), this can be changed | ARC | Bert van Kalker |
| The hose must have a connection part to the canister with an outside diameter of 47 mm | | | Standard interface |
| The hose must have a connection part to the tube with an outside diameter of 32 mm | | | Standard interface |
| **6 Dust management system** | | | |
| **6.1 Bag** | | | |
| The bag must have a volume of 1,5$dm^3$ | For a change rate of twelve times a year | Engineering | Paul van Wolferen |
| The bag must be made of a synthetic material | For good performance | Engineering | Paul van Wolferen |
| The bag must have a visible clean user interface | | ARC | Bert van Kalker |
| The bag must be able to be closed when thrown away | | ARC | Bert van Kalker |
| **6.2 Bagless** | | | |
| The bagless system must have a volume of at least 1,5$dm^3$ | With the separation it is a bit bigger than the dust bucket | Engineering | Paul van Wolferen |
| The dust bucket must have a volume of at least 1 $dm^3$ | From the research of Bas Berga | Engineering | Paul van Wolferen |
| The bagless system must have a visible clean user interface | | ARC | Bert van Kalker |
| The bagless system must be able to allow the end user to control the dust flow when emptying | To not be covered in flared up dust | ARC | Bert van Kalker |
| **7 Filters** | | | |
| The motor inlet filter must have a volume of <L*B*H> | The volume depends on the amount of needed filtration | Engineering | Paul van Wolferen |

| | | | |
|---|---|---|---|
| The exhaust filter must have a volume of 0,45 $dm^3$<br>(currently = 150*121*25 mm) | That is based to a hepa 13 filter, dimensions can be changed (volume nog). Also permanent filters might become interesting | Engineering | Paul van Wolferen |
| The filters must have a visible clean contact point | | ARC | Bert van Kalker |
| **8 Motor** | | | |
| The motor shall have a performance equal to, or better then the Global 2 motor in the competitor model | | Engineering | Wessel Otten |
| The motor will have a diameter of <120 mm | Not fixed, but most used now | Engineering | Wessel Otten |
| The motor will have a length of <100 mm | Not fixed, but most used now | Engineering | Wessel Otten |
| The motor will have a minimal weight of 0,8 kg | | Engineering | Wessel Otten |
| **9 Cord Winder** | | | |
| The cord winder shall contain 9 meter cord | | Engineering | Wiebe Wierda |
| The cord shall have a diameter of of $1mm^2$ and isolation | | Engineering | Wiebe Wierda |
| The cord winder shall have a volume of 0,015 dm3 for the cord and a total volume of 0,3 $dm^3$ | Now the cord winder is <160diameter * 55dept>, but this can be differed. Though it is important to take into account that smaller diameters can cause wound up problems in the cord. | Engineering | Wiebe Wierda |
| **10 Electrics** | | | |
| The electrics consist of an on/off switch | The most simple version doesn't need anything else | Engineering | Douwe de Jong |

| | | | |
|---|---|---|---|
| The electrics will consist a printing board on which the suction power can be adjusted | printing board depends on the power regulator | Engineering | Douwe de Jong |
| The electrics must have wires to connect the cord winder to the motor and printing board | | Engineering | Douwe de Jong |
| **11 Housing** | | | |
| The housing shall have a handle with 90 mm length, 32 mm diameter, 45 mm room between the handle and the housing and ergonomic finger grip | | ARC | Bert van Kalker |
| The housing shall have reusable click links to reach the dust management system | | ARC | Bert van Kalker |
| The housing shall have reusable click links to reach the replaceable filters | | ARC | Bert van Kalker |
| The housing shall have a thickness of at least 2,5 mm | The smaller a construction, the more complex a good spreading of the forces. | Engineering | Ben Kuiper |
| The housing shall be reinforced by ribs for extra strength | | Quality | Erik Engels |
| **12 Wheels** | | | |
| The wheels shall be able to move the appliance over a threshold of 25 mm height. | | Quality | Erik Engels |
| The wheels shall consist one wheel with a 360 degree rotation freedom | | Quality | Erik Engels |
| The wheels will define the stability in the horizontal plane of the appliance | | Quality | Erik Engels |
| The wheels shall allow the canister to be moved over a floor with a force of $\leq$ 20 Newton | | Quality | Erik Engels |

# Appendix E – Research to model dimensions

| **Stofzuiger: Marathon** | | |
|---|---|---|
| Lengte (mm) | Breedte (mm) | Hoogte (mm) |
| 470 | 315 | 335 |
|  |  |  |
| Gewicht: 7,2 kg | | |

| **Stofzuiger: Performer** | | |
|---|---|---|
| Lengte (mm) | Breedte (mm) | Hoogte (mm) |
| 460 | 320 | 275 |
|  |  |  |
| Gewicht: 6,3 kg | | |

| **Stofzuiger: Yoga** | | |
|---|---|---|
| Lengte (mm) | Breedte (mm) | Hoogte (mm) |
| 470 | 260 | 260 |
|  |  |  |
| Gewicht: 6,5 kg?? | | |

| **Stofzuiger: Dyson DC 19** | | |
|---|---|---|
| Lengte (mm) | Breedte (mm) | Hoogte (mm) |
| 435 | 280 | 345 |
|  |  |  |
| Gewicht: 8,5 kg | | |

| **Stofzuiger: Gemini** | | |
|---|---|---|
| Lengte (mm) | Breedte (mm) | Hoogte (mm) |
| 325 | 255 | 220 |
|  |  |  |
| Gewicht: 3,7 kg | | |

| **Stofzuiger: Rowenta Parquet** | | |
|---|---|---|
| Lengte (mm) | Breedte (mm) | Hoogte (mm) |
| 320 | 290 | 320 |
|  |  |  |
| Gewicht: 5 kg | | |

| **Stofzuiger: Dyson DC 22 (baby)** | | |
|---|---|---|
| Lengte (mm) | Breedte (mm) | Hoogte (mm) |
| 400 | 260 | 290 |
|  |  |  |
| Gewicht: 7 kg | | |

| **verhoudingen** | **Lengte** | **Breedte** | **Hoogte** |
|---|---|---|---|
| Marathon | 1 | 0,67 | 0,71 |
| Performer | 1 | 0,70 | 0,60 |
| Yoga | 1 | 0,55 | 0,55 |
| Dyson DC 19 | 1 | 0,64 | 0,79 |
| Gemini | 1 | 0,78 | 0,68 |
| Rowenta Parquet | 1 | 0,90 | 1 |
| Dyson DC 22 | 1 | 0,65 | 0,73 |
| **gemiddelde** | **1** | **0,70** | **0.72** |
| **Gem. Philips** | **1** | **0,68** | **0,64** |

Dit onderzoek is alleen uitgevoerd om enigszins een gevoel te krijgen voor de afmetingen en het gewicht van huidige stofzuigers. De gegevens worden gebruikt om tot de afmetingen van de afmetingen dummy te komen. Belangrijk hierbij is dat het grootste model niet groter of zwaarder wordt dan de Gemini aangezien deze al verkocht wordt en dus ook in grootte geaccepteerd wordt door de consument. De Gemini is er zowel in de bag als bagless variant, dus dat is niet van invloed op de gegevens.

| **Afmetingen \ Product** | Dyson DC 19 | Dyson DC 22 | Procent v/h origineel |
|---|---|---|---|
| Lengte | 435 | 400 | 92% |
| Breedte | 280 | 260 | 93% |
| Hoogte | 345 | 290 | 84% |
| **Volume** | **42021000** | **30160000** | **= 72%** |

| **Afmetingen \ Product** | Performer | Gemini | Procent v/h origineel |
|---|---|---|---|
| Lengte | 460 | 325 | 70% |
| Breedte | 320 | 255 | 80% |
| Hoogte | 275 | 220 | 80% |
| **Volume** | **40480000** | **18232500** | **45%** |

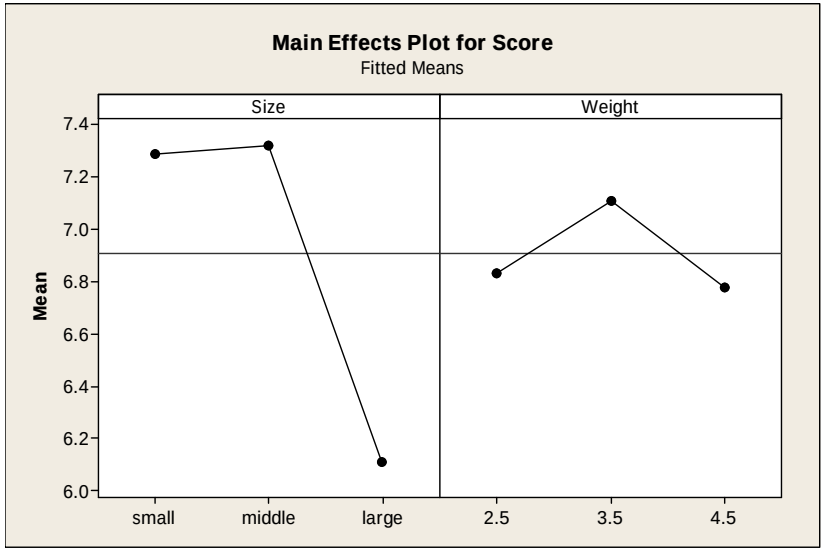
| **Afmetingen \ Product** | Yoga | Gemini | Procent v/h origineel |
|---|---|---|---|
| Lengte | 470 | 325 | 69% |
| Breedte | 260 | 255 | 98% |
| Hoogte | 260 | 220 | 84% |
| **Volume** | **31772000** | **18232500** | **57%** |

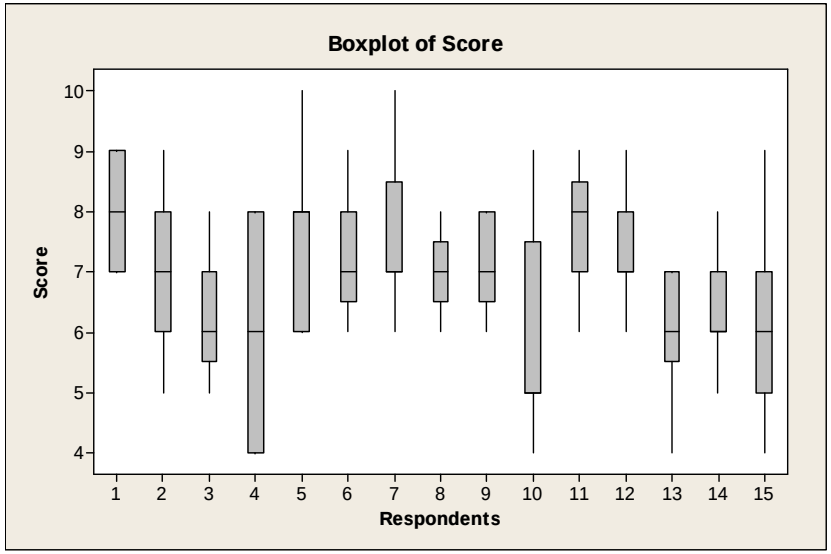
# Appendix F – consumer research plan

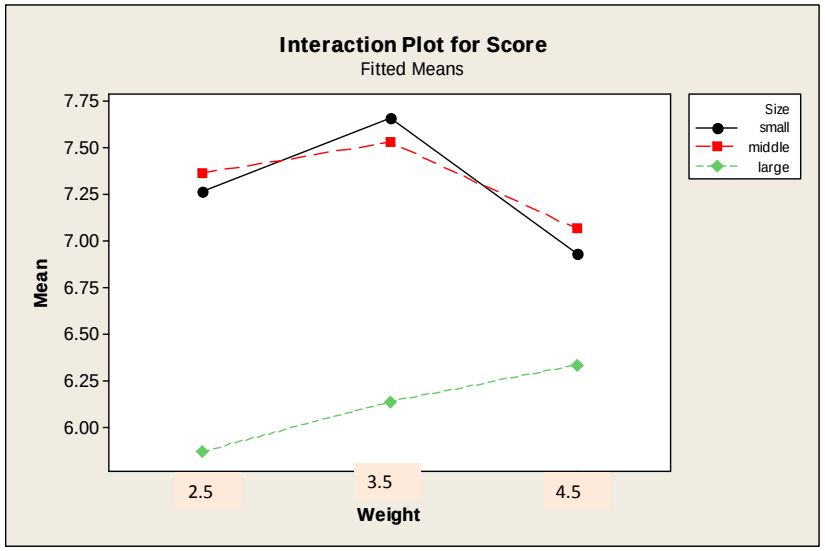
The consumer research plan is attached as an independent document. This document is called Appendix consumer research plan.

# Appendix F - consumer research results -

| \ model<br>proefpersoon \ gewicht | klein<br>2,5 kilo | klein<br>3,5 kilo | klein<br>4,5 kilo | middel<br>2,5 kilo | middel<br>3,5 kilo | middel<br>4,5 kilo | groot<br>2,5 kilo | groot<br>3,5 kilo | groot<br>4,5 kilo |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 9 | 9 | 9 | 9 | 8 | 8 | 7 | 7 | 7 |
| 2 | 7 | 7 | 6 | 9 | 8 | 8 | 5 | 7 | 6 |
| 3 | 6 | 8 | 7 | 7 | 6 | 7 | 5 | 6 | 5 |
| 4 | 8 | 8 | 7 | 6 | 6 | 8 | 4 | 4 | 4 |
| 5 | 8 | 6 | 6 | 8 | 8 | 6 | 8 | 6 | 10 |
| 6 | 7 | 9 | 6 | 8 | 8 | 8 | 6 | 7 | 7 |
| 7 | 7 | 9 | 10 | 6 | 8 | 7 | 8 | 7 | 7 |
| 8 | 7 | 7 | 7 | 7 | 8 | 8 | 6 | 6 | 7 |
| 9 | 8 | 7 | 7 | 8 | 7 | 8 | 6 | 6 | 7 |
| 10 | 7 | 5 | 4 | 8 | 9 | 5 | 5 | 6 | 5 |
| 11 | 9 | 9 | 8 | 7 | 8 | 8 | 6 | 7 | 7 |
| 12 | 7 | 8 | 7 | 9 | 8 | 8 | 7 | 7 | 6 |
| 13 | 6 | 7 | 7 | 6 | 7 | 7 | 4 | 5 | 6 |
| 14 | 7 | 7 | 5 | 7 | 8 | 6 | 6 | 6 | 6 |
| 15 | 6 | 9 | 8 | 6 | 6 | 4 | 5 | 5 | 5 |
| **Totaal** | **109** | **115** | **104** | **111** | **113** | **106** | **88** | **92** | **95** |
| Gemiddelde | 7,288888889 | | | 7,322222222 | | | 6,111111111 | | |




**Necessary formulas to calculate the effect of size, weight and size-weight combinations on consumer satisfaction.**

Y = score
V = Volume
W = Weight

$$Y = \alpha_0 + \alpha_1 * V + \alpha_2 * V^2 + \alpha_3 * W + \alpha_4 * W^2 + \alpha_5 * V * W + \varepsilon$$

$$Y_v = \alpha_0 + \alpha_1 * V + \alpha_2 * V^2$$

$$Y_w = \alpha_0 + \alpha_1 * W + \alpha_2 * W^2$$

**Calculation of the ideal volume. Made by Mark Schuld.**

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 1 | 1 | * | a | = | 7,29 |
| 8041175 | 15789987 | 23807437 | * | b | = | 7,32 |
| 6,46605E+13 | 2,49324E+14 | 5,66794E+14 | * | c | = | 6,11 |

De getallen zijn mm3

originele volume zijn:

| klein | middel | groot |
|---|---|---|
| 8041175 | 15789987 | 23807437 |

**Model**

**Score=a+b*volume+c*volume^2**

| | | | **residual^2** |
|---|---|---|---|
| **a** | 6,012282 | | 1,245E-06 |
| **b** | 2,38E-07 | | 3,765E-06 |
| **c** | -9,82E-15 | | 6,423E-06 |
| | | | |
| | | **sum of squares** | 1,143E-05 |

**Score = 6,01 + 2,38*10$^{-7}$ * volume + -9,82*10$^{-15}$*volume**

**maximum score when d Score/d volume = b+2c*volume=0**

| | | |
|---|---|---|
| volume | **12118126** | mm3 |
| score | **7,45** | |

**Trade off Properties**

| Nummer | Eigenschap | Cumulatief | Percentage |
|---|---|---|---|
| **1** | Handig op te bergen | **86** | 19% |
| **2** | Handzaam in gebruik | **120** | 27% |
| **3** | Goede performance | **97** | 22% |
| **4** | Milieuvriendelijk | **58** | 13% |
| **5** | Klein | **31** | 7% |
| **6** | Licht | **56** | 13% |
| | | | |
| | **Totalen** | **448** | 100% |

| totaal aantal | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 2 | 0 | 0 | 0 | 0 | 13 | 0 | 0 | 0 | 12 | 0 | 0 | 7 | 0 | 12 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 0 | 10 | 5 | 0 | 0 | 11 |
| **2** | 13 | 0 | 14 | 0 | 0 | 0 | 0 | 14 | 0 | 0 | 0 | 9 | 0 | 12 | 0 | 7 | 12 | 0 | 13 | 0 | 0 | 14 | 0 | 0 | 0 | 0 | 0 | 12 | 0 | 0 |
| **3** | 0 | 8 | 0 | 7 | 0 | 0 | 0 | 0 | 12 | 0 | 0 | 6 | 8 | 0 | 0 | 8 | 0 | 14 | 0 | 10 | 14 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 |
| **4** | 0 | 6 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 10 | 0 | 0 | 3 | 3 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 7 | 0 | 9 | 0 | 0 | 3 | 0 | 4 |
| **5** | 0 | 0 | 1 | 0 | 3 | 2 | 0 | 0 | 2 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 4 | 6 | 0 | 0 | 0 | 5 | 0 |
| **6** | 0 | 0 | 0 | 8 | 12 | 0 | 7 | 1 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 8 | 0 | 0 | 5 | 0 | 0 | 10 | 0 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| n =15 | **15** | **14** | **15** | **15** | **15** | **15** | **15** | **15** | **14** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** |

| | | | |
|---|---|---|---|
| Handig op te bergen | 17% | 83% | Handzaam in gebruik |
| Handig op te bergen | 80% | 20% | Klein |
| Handig op te bergen | 73% | 27% | Licht |
| Handig op te bergen | 40% | 60% | Goede performance |
| Handig op te bergen | 77% | 23% | Milieuvriendelijk |
| Handzaam in gebruik | 90% | 10% | Klein |
| Handzaam in gebruik | 93% | 7% | Licht |
| Handzaam in gebruik | 53% | 47% | Goede performance |
| Handzaam in gebruik | 80% | 20% | Milieuvriendelijk |
| Goede performance | 70% | 30% | Licht |
| Goede performance | 62% | 38% | Milieuvriendelijk |
| Goede performance | 90% | 10% | Klein |
| Milieuvriendelijk | 63% | 37% | Klein |
| Milieuvriendelijk | 50% | 50% | Licht |
| Klein | 27% | 73% | Licht |

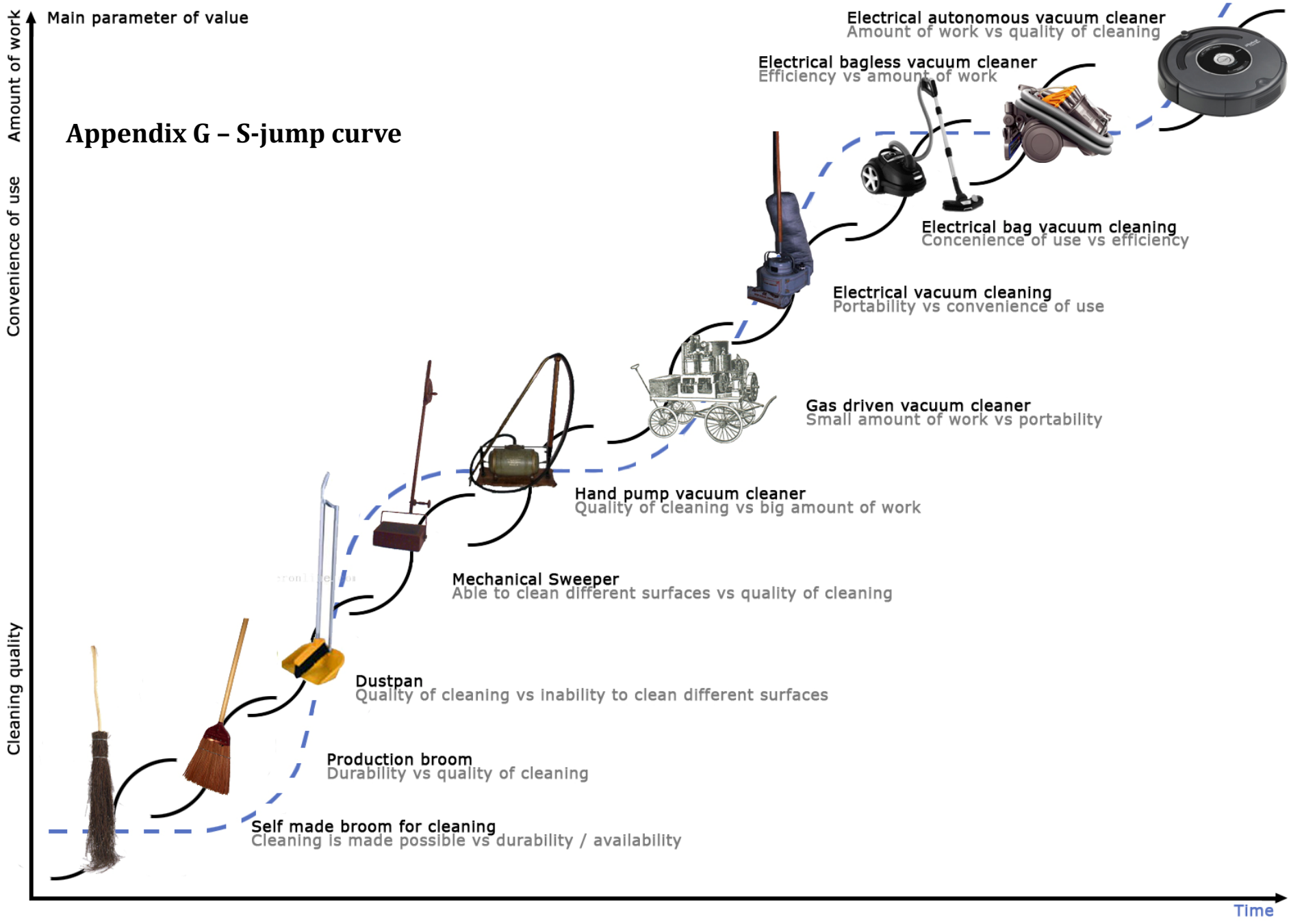
**Trade off Handlings**

| Nummer | Handeling | cumulatief | percentage |
|---|---|---|---|
| **1** | Stofzuiger pakken,opbergen | **77** | 17% |
| **2** | Stof weggooien | **50** | 11% |
| **3** | Stofzuiger in elkaar zetten,uit elkaar halen | **43** | 10% |
| **4** | Trap stofzuigen | **80** | 18% |
| **5** | Zuigkracht regelen | **79** | 18% |
| **6** | Vloer stofzuigen | **121** | 27% |
| | | | |
| | **Totalen** | **450** | 100% |

| totaal aantal | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 12 | 0 | 0 | 7 | 0 | 0 | 0 | 12 | 0 | 0 | 3 | 0 | 0 | 8 | 0 | 9 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 6 | 0 | 7 | 0 | 11 | 0 |
| **2** | 3 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 5 | 0 | 0 | 0 | 7 | 0 | 3 | 6 | 0 | 0 | 7 | 0 | 0 | 0 | 6 | 0 | 0 | 3 | 0 | 5 | 0 | 0 |
| **3** | 0 | 5 | 0 | 0 | 3 | 0 | 0 | 3 | 0 | 3 | 0 | 0 | 8 | 0 | 0 | 0 | 5 | 0 | 8 | 0 | 3 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 4 | 0 |
| **4** | 0 | 10 | 0 | 8 | 0 | 0 | 2 | 0 | 10 | 0 | 0 | 9 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 9 | 0 | 0 | 10 | 0 | 2 |
| **5** | 0 | 0 | 7 | 0 | 0 | 10 | 0 | 0 | 0 | 12 | 0 | 6 | 0 | 7 | 0 | 0 | 0 | 3 | 0 | 5 | 12 | 0 | 9 | 0 | 0 | 0 | 8 | 0 | 0 | 0 |
| **6** | 0 | 0 | 8 | 0 | 12 | 0 | 13 | 0 | 0 | 0 | 12 | 0 | 0 | 0 | 12 | 0 | 0 | 12 | 0 | 0 | 0 | 13 | 0 | 14 | 0 | 12 | 0 | 0 | 0 | 13 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| N= 15 | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** |

| | | | |
|---|---|---|---|
| Stofzuiger pakken/opbergen | 70% | 30% | Stof weggooien |
| Stofzuiger pakken/opbergen | 77% | 23% | Stofzuiger in elkaar zetten/uit elkaar halen |
| Stofzuiger pakken/opbergen | 43% | 57% | Trap stofzuigen |
| Stofzuiger pakken/opbergen | 50% | 50% | Zuigkracht regelen |
| Stofzuiger pakken/opbergen | 17% | 83% | Vloer stofzuigen |
| Stof weggooien | 47% | 53% | Stofzuiger in elkaar zetten/uit elkaar halen |
| Stof weggooien | 33% | 67% | Trap stofzuigen |
| Stof weggooien | 37% | 63% | Zuigkracht regelen |
| Stof weggooien | 20% | 80% | Vloer stofzuigen |
| Stofzuiger in elkaar zetten/uit elkaar halen | 33% | 67% | Trap stofzuigen |
| Stofzuiger in elkaar zetten/uit elkaar halen | 20% | 80% | Zuigkracht regelen |
| Stofzuiger in elkaar zetten/uit elkaar halen | 13% | 87% | Vloer stofzuigen |
| Trap stofzuigen | 63% | 37% | Zuigkracht regelen |
| Trap stofzuigen | 13% | 87% | Vloer stofzuigen |
| Zuigkracht regelen | 33% | 67% | Vloer stofzuigen |

# Appendix G – S-jump curve



# Appendix H – Explanation of the trends of evolution scores

Source of the theory: Souchkoz V.V.: 2009; *xTRIZ TRIZ and Systematic Innovation*; ICG Training & Consulting, Enschede, The Netherlands



## EVOLUTIONARY POTENTIAL ANALYSIS

One of possible ways to forecast how a selected system or an object will be evolving further is to evaluate the object or the system against its evolutionary potential and apply the TRIZ lines of evolution to propose next generation of the system or the object. Although the entire process of further system evolution with TRIZ can be rather complicated (it usually evolves Multi-Screen Diagram of thinking, S- and Bell-Curve analysis), using the Evolutionary Potential Analysis (EPA) can provide with rather quick results.

EPA can be used both independently as well as after Value-Conflict Mapping where a specific part of a system is selected for further evolution.

**Step 1: Selecting object**

Select a system or an object for EPA. It can be both a very simple object (for instance, spoon, chair), or a part of a more complex system (e.g. engine in a car or its braking system). Performing EPA of a complex system (e.g. a car as a system) is not recommended since it conisists of too many parts each of which has its own evolution path and the results will be mixed and inconsistent.

At this stage, you should select a specific object or a system, not a generic one. If you want to evolve, for example, a toothbrush, you have to choose a specific toothbrush.

**Step 2: Matching the object selected and the TRIZ Lines of Evolution.**

At this step we define how our selected object matches each TRIZ line of evolution. In the current version, we use 26 lines of evolution. If the object has not yet evolved completely accordingly a selected line, it means that the object has a potential to evolve along this line. To estimate the degree of evolution along each specific line, we introduce a range from 1... to 10. Each line of evolution contains numbers which correspond to a stage of evolution, and there is a different number of stages in each line. To visualize the process, we assign 1 to the first stage of evolution and 10 to the latest stage, and calculate intermediate values. For instance, the line of "Decreasing the dynamics of a substance" consists of seven stages. In the right column you can see all the values for all stages:

| | | |
|---|---|---|
| Increasing the dynamics of substance | 1. Solid substance | 1 |
| | 2. Fragmented solid substance, granules, thin plates | 1,7 |
| | 3. Powder | 3,4 |
| | 4. Liquid, gel | 5 |
| | 5. Aerosol | 6,7 |
| | 6. Gas, plasma | 8,4 |
| | 7. Field | 10 |

Thus we have a complete table with all values per each line of evolution:

| | | |
|---|---|---|
| Increasing the degree of freedom (dynamics) of an object | 1. Rigid object | 1 |
| | 2. Object with two rigid parts | 2,5 |
| | 3. Two objects with a flexible link (single hinge) | 5 |
| | 4. Many objects with flexible links (Accordion-type objects) | 7,5 |
| | 5. Completely flexible, elastic object | 10 |
| Increasing the dynamics of substance | 1. Solid substance | 1 |
| | 2. Fragmented solid substance, granules, thin plates | 1,7 |
| | 3. Powder | 3,4 |
| | 4. Liquid, gel | 5 |
| | 5. Aerosol | 6,7 |
| | 6. Gas, plasma | 8,4 |





| | | |
|---|---|---|
| | 7. Field | 10 |
| Increasing dynamics of a field | 1. Permanent field | 1 |
| | 2. Pulsed Field | 2,4 |
| | 3. Varied frequencies of oscillations, series of pulses | 4 |
| | 4. Non-permanent field with changed phase, wavelength, waveform, Doppler effect | 5,6 |
| | 5. Using effects of diffraction, interference, refraction | 7,2 |
| | 6. Non-linear fields with gradient, anisotropy | 10 |
| Coordination /de-coordination of operating frequencies | 1. Non-coordinated frequencies | 1 |
| | 2. Coordinated frequencies | 3,3 |
| | 3. Intentional de-coordination of frequencies | 6,7 |
| | 4. Using natural frequency | 10 |
| Actions Coordination | 1. Not-coordinated actions/events | 1 |
| | 2. Coordinate two or several actions/events in time to provide best results or optimal performance | 2,5 |
| | 3. Coordinate several actions/events in time | 5 |
| | 4. Filling pauses | 7,5 |
| | 5. Full synchronization of actions/events | 10 |
| Action Evolution | 1. Continuous action or no action | 1 |
| | 2. Introducing periodic action | 2,4 |
| | 3. Pulsating action | 4 |
| | 4. Pulsation in resonance mode | 5,6 |
| | 5. Several actions together | 7,2 |
| | 6. Standing wave | 10 |
| Shape/Form Coordination | 1. Non-matching shapes | 1 |
| | 2. Rigidly matching shapes | 3,3 |
| | 3. Dynamically matching shapes | 6,7 |
| | 4. Intelligently matching shapes | 10 |
| Linear Evolution | 1. Dot/point | 1 |
| | 2. Straight line | 2,5 |
| | 3. 2D Straight line | 5 |
| | 4. 2D Curve line | 7,5 |
| | 5. 3D Curve line | 10 |
| Volumetric Evolution Volumetric Evolution | 1. Plane | 1 |
| | 2. Box | 2,5 |
| | 3. Cylinder | 5 |
| | 4. Spherical shape | 7,5 |
| | 5. Complex 3D shape | 10 |
| Symmetry | 1. Fully asymmetric system | 1 |
| | 2. Increasing of the degree of symmetry of the object(s) | 5 |
| | 3. Fully symmetric system | 10 |
| Assymetry | 1. Fully symmetric system | 1 |
| | **2.** Intentionally decreasing the degree of symmetry of the object(s) | 5 |
| | **3.** Fully asymmetric system | 10 |
| Adaptation of a field to existing substance | 1. Non-optimal fields use | 1 |
| | 2. Semi-optimal fields use | 5 |
| | 3. Optimal fields use | 10 |
| Reducing energy loss | 1. Non-energy optimized system | 1 |
| | 2. Reducing the length of energy flows conductors | 3,3 |
| | 3. Reducing a number of field types in a system | 6,7 |
| | 4. Replacing a system which has many types of fields with a system with a single field | 10 |
| Object segmentation | 1. Monolith | 1 |
| | 2. Granules/segments | 2,4 |
| | 3. Powder | 4 |

| | | |
|---|---|---|
| | 4. Gel, Liquid | 5,6 |
| | 5. Gas, Plasma | 7,2 |
| | 6. Field | 10 |
| Surface Segmentation | 1. Flat surface | 1 |
| | 2. Surface with stripes | 2,5 |
| | 3. Corrugated surface | 5 |
| | 4. "Powdered" surface | 7,5 |
| | 5. Surface with active pores | 10 |
| Volume Voidness increase | 1. Monolith in a solid state | 1 |
| | 2. Monolith with a single cavity | 2,5 |
| | 3. Monolith with many cavities | 5 |
| | 4. Capillary and/or porous material | 7,5 |
| | 5. Capillary-porous material with active pores filled with gel, liquid or gas | 10 |
| Objects with a higher degree of control | 1. Non-controlled object | 1 |
| | 2. Adding a new field to existing object to control it or to increase the object's controllability | 3,3 |
| | 3. Partially self-controlling object | 6,7 |
| | 4. Fully self-controlling object | 10 |
| Fields with a higher degree of control | 1. Mechanical | 1 |
| | 2. Acoustic | 1,43 |
| | 3. Thermal | 2,9 |
| | 4. Chemical | 4,3 |
| | 5. Electric | 5,7 |
| | 6. Magnetic | 7,2 |
| | 7. Electromagnetic | 8,6 |
| | 8. Biological | 10 |
| Visible transparency increase | 1. Opaque Systems | 1 |
| | 2. Partially transparent systems | 5 |
| | 3. Fully transparent systems | 10 |
| Use of senses:<br>• Voice<br>• Vision<br>• Smell<br>• Touch<br>• Taste | 1. Single sense | 1 |
| | 2. Two senses together | 2,5 |
| | 3. 3 senses | 5 |
| | 4. 4 senses | 7,5 |
| | 5. All 5 senses | 10 |
| Level of Automation Increase | 1. No automation | 1 |
| | 2. Partial automation | 2,4 |
| | 3. Full automation | 4 |
| | 4. Adaptive automation | 5,6 |
| | 5. Self-evolving systems | 7,2 |
| | 6. Self-reproduction | 10 |
| Human Involvement Decrease | 1. Operations produced by a human without a tool | 1 |
| | 2. Human + Tool | 2,5 |
| | 3. Human +Semi-automated tool | 5 |
| | 4. Human + Automated tool | 7,5 |
| | 5. Fully autonomous tool | 10 |
| Systems Merging | 1. Non-merged objects/systems | 1 |
| | 2. Merging identical objects/systems to a system | 2,4 |
| | 3. Merging objects/systems with similar structure / functionality | 4 |
| | 4. Merging different objects/systems to a system | 5,6 |
| | 5. Merging objects/systems with inverse functionality | 7,2 |
| | 6. Alternative systems merging (hybridization) | 10 |
| Mono-bi-poly evolution | 1. A single object/system | 1 |
| | 2. Combining two objects/systems (bi-systems) | 5 |
| | 3. Combining many objects/systems (poly-systems) | 10 |
| Convolution | 1. Non-convoluted system: no components in a system share functions of other components | 1 |





| | | |
|---|---|---|
| | 2. Function sharing: a function of one component is transferred to another component or subsystem | 2,4 |
| | 3. Function self-delivery | 4 |
| | 4. Replacing many objects delivering many functions with a single object delivering many functions | 5,6 |
| | 5. Removing a function from a system and transferring it to a supersystem | 7,2 |
| | 6. Function elimination: Reducing a number of subsystems which deliver correcting and servicing functions by eliminating the need for these functions | 10 |

The task now is to assign a specific value (right column) for each line of evolution (left column). It is needed to build a radar plot diagram which will visualize the evolutionary potential of your object.

For example, let's consider that our selected object are bristles in a toothbrush:

We complete (in MS Excel) the following table:

| LINE OF EVOLUTION | VALUE |
|---|---|
| DYNAMIZATION OF OBJECT | 10 |
| DYNAMIZATION OF SUBSTANCE | 1 |
| DYNAMIZATION OF FIELD | 2,4 |
| FREQUENCY COORDINATION | 1 |
| ACTION COORDINATION | 5 |
| ACTION EVOLUTION | 4 |
| SHAPE AND FORM COORDINATION | 6,7 |
| LINEAR EVOLUTION | 5 |
| VOLUMETRIC EVOLUTION | 5 |
| SYMMETRY | 5 |
| ASYMMETRY | 5 |
| ADAPTATION TO SUBSTANCES | 5 |
| REDUCED ENERGY LOSS | 10 |
| SEGMENTATION OF OBJECT | 1 |
| SEGMENTATION OF SURFACE | 1 |
| VOIDNESS INCREASE | 1 |
| DEGREE OF CONTROL / OBJECTS | 3,3 |
| DEGREE OF CONTROL / FIELD | 1 |
| VISIBLE TRANSPARENCY | 5 |
| USE OF SENSES | 1 |
| AUTOMATION INCREASE | 1 |
| HUMAN INVOLVEMENT DECREASE | 1 |
| SYSTEM MERGING | 4 |
| BI- AND POLY-SYSTEMS | 10 |
| CONVOLUTION | 1 |

| **Line of evolution of a canister vacuum cleaner** | |
|---|---|
| *Dynamization of object: 5 points* | |
| Current situation: | A canister vacuum cleaner consists of a canister and a tube-nozzle that are connected trough hose. |
| Abstracted situation: | Two rigid parts wit flexible link |
| Potential: | Completely flexible elastic object |
| *Dynamization of substance: 8.4 points* | |
| Current situation: | A canister vacuum cleaner uses air as a working substance. |
| Abstracted situation: | The used substance is a gas |
| Potential: | Using a field instead of a substance |
| *Dynamization of field: 1 points* | |
| Current situation: | A canister vacuum cleaner uses a constant air flow. |
| Abstracted situation: | Permanent field |
| Potential: | Non-linear fields with gradient, anisotropy |
| *Frequency coordination: 1 points* | |
| Current situation: | A canister vacuum cleaner does not use frequencies in the cleaning process. |
| Abstracted situation: | Non-coordinated frequencies |
| Potential: | Using natural frequencies |
| *Actions coordination: 1 points* | |
| Current situation: | A canister vacuum cleaner does not coordinate actions. |
| Abstracted situation: | Not-coordinated actions |
| Potential: | Full synchronization of actions / events |

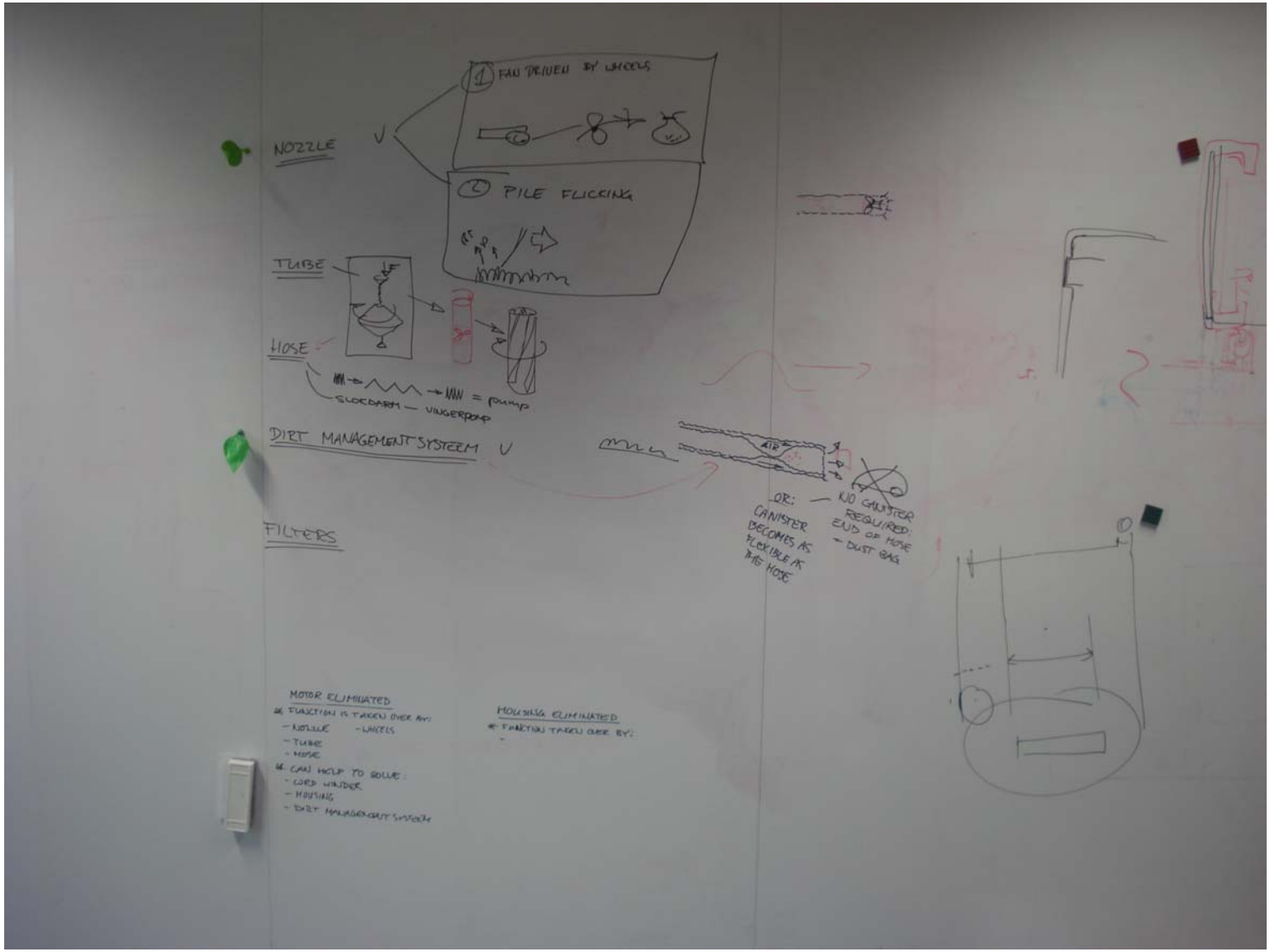
| | |
|---|---|
| *Action evolution: 1 points* | |
| Current situation:<br><br>Abstracted situation:<br>Potential: | A canister vacuum cleaner uses constant air suction.<br><br>Continuous action<br>Standing wave |
| *Shape/Form coordination: 3.3 points* | |
| Current situation:<br><br>Abstracted situation:<br>Potential: | A canister vacuum cleaner is ergonomic formed on the parts that interact with the end user (handles and buttons).<br><br>Rigidly matching shapes<br>Intelligently matching shapes |
| *Linear evolution: 10 points* | |
| Current situation:<br><br>Abstracted situation:<br>Potential: | A canister vacuum cleaner can be designed with 3d curved lines.<br><br>3D curve lines<br>3D curve lines |
| *Volumetric evolution: 10 points* | |
| Current situation:<br><br>Abstracted situation:<br>Potential: | A canister vacuum cleaner can be designed in a 3D shape.<br><br>Complex 3D shapes<br>Complex 3D shapes |
| *Symmetry: 1 points* | |
| Current situation:<br><br>Abstracted situation:<br>Potential: | A canister vacuum cleaner is completely asymmetric.<br><br>Fully asymmetric system<br>Fully symmetric system |

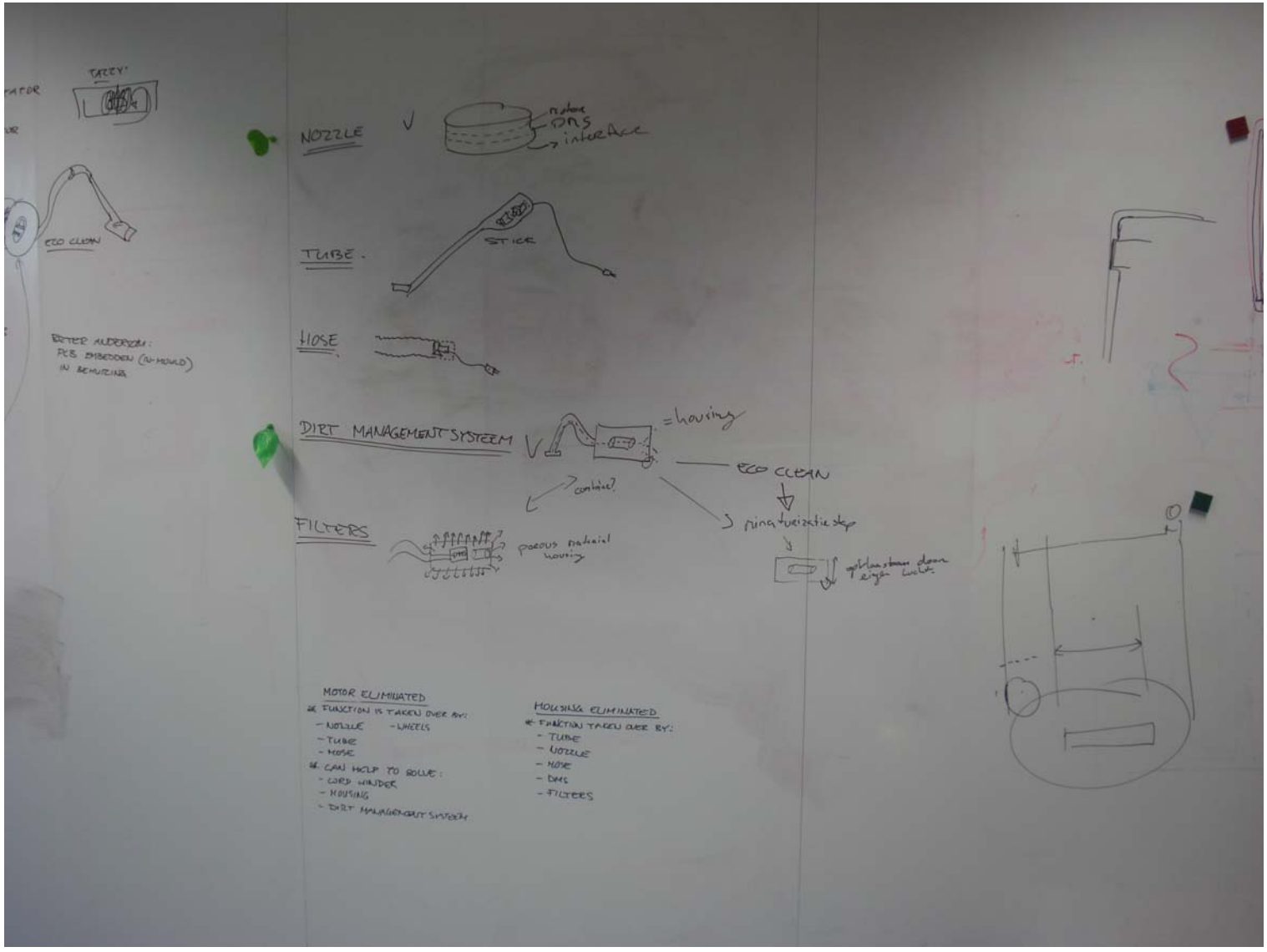
| | |
|---|---|
| *Asymmetry: 10 points* | |
| Current situation:<br><br>Abstracted situation:<br>Potential: | A canister vacuum cleaner is completely asymmetric.<br><br>Fully asymmetric system<br>Fully asymmetric system |
| *Adaptation of field to substance: 1 points* | |
| Current situation:<br><br>Abstracted situation:<br>Potential: | A canister vacuum cleaner uses an external airflow to move dust.<br><br>Non-optimal field use<br>Optimal field use |
| *Reducing energy loss: 3.3 points* | |
| Current situation:<br><br>Abstracted situation:<br>Potential: | A canister vacuum cleaner is able to shorten the travel length of the dust to the garbage bin by moving the canister.<br><br>Reducing the length of energy flows conductors<br>Replacing the system for a single field |
| *Object segmentation: 2.4 points* | |
| Current situation:<br><br>Abstracted situation:<br>Potential: | A canister vacuum cleaner consists of a couple of different components.<br><br>Segments<br>Field |
| *Surface segmentation: 1 points* | |
| Current situation:<br><br>Abstracted situation:<br>Potential: | A canister vacuum cleaner consists of flat surfaces (3D formed).<br><br>Flat surface<br>Surface with active pores |

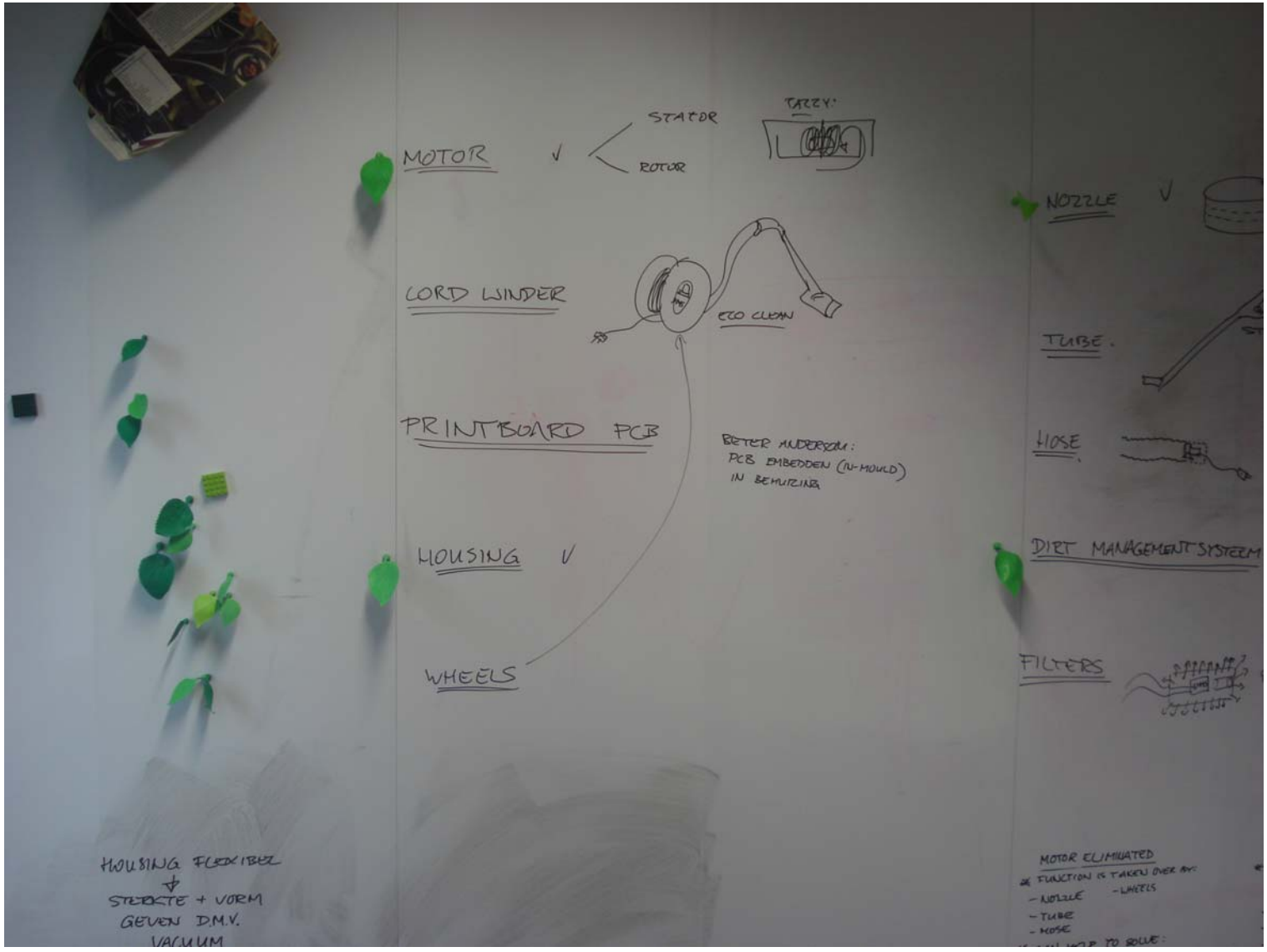
| | |
|---|---|
| *Volume voidness increase: 2.5 points* | |
| Current situation:<br><br>Abstracted situation:<br>Potential: | A canister vacuum cleaner has one opening for collecting dust.<br><br>Monolith with a single cavity<br>Capillary-porous material with active pores |
| *Degree of control / objects: 6.7 points* | |
| Current situation:<br><br>Abstracted situation:<br>Potential: | A canister vacuum cleaner collects the dust in one certain compartment.<br>Partially self controlling object<br>Fully self controlling object |
| *Degree of control / field: 5.7 points* | |
| Current situation:<br><br>Abstracted situation:<br>Potential: | A canister vacuum cleaner uses the electricity.<br><br>Electric field<br>Biological field |
| *Visible transparency increase: 5 points* | |
| Current situation:<br><br>Abstracted situation:<br>Potential: | A canister vacuum cleaner can have a transparent dust container.<br><br>Partially transparent system<br>Fully transparent system |
| *Use of senses: 5 points* | |
| Current situation:<br><br>Abstracted situation:<br>Potential: | A canister vacuum cleaner uses the senses voice, vision and taste.<br><br>Using 3 senses<br>Using all 5 senses |

| | |
|---|---|
| *Automation increase: 4 points* | |
| Current situation:<br><br>Abstracted situation:<br>Potential: | A canister vacuum cleaner only has to be turned on / off and optionally regulated in suction power.<br><br>Full automation<br>Self reproductive |
| *Human involvement decrease: 7.5 points* | |
| Current situation:<br><br>Abstracted situation:<br>Potential: | A canister vacuum cleaner requires a human to be operated, but does the cleaning work self.<br><br>Human + automated tool<br>Fully autonomous tool |
| *Systems merging: 1 points* | |
| Current situation:<br><br>Abstracted situation:<br>Potential: | A canister vacuum cleaner is a standalone product. It does not collaborate with other systems.<br><br>Non-merged objects/systems<br>Alternative systems merging (hybridization) |
| *Mono-bi-poly-systems: 1 points* | |
| Current situation:<br><br>Abstracted situation:<br>Potential: | A canister vacuum cleaner is a standalone product.<br><br>A single object / system<br>Combining many objects / systems |
| *Convolution: 1 points* | |
| Current situation:<br><br>Abstracted situation:<br>Potential: | A canister vacuum cleaner does not consist of any component with multiple functions.<br><br>Non-convoluted system<br>Function elimination |

## Appendix I – SIT session pictures




NOZZLE
TUBE
HOSE
DIRT MANAGEMENT SYSTEEM
=housing
ECO CLEAN
FILTERS
STICK
MOTOR ELIMINATED
HOUSING ELIMINATED
- TUBE
- NOZZLE
- HOSE
- DMS
- FILTERS


MOTOR
STATOR
ROTOR
TARZY:
CORD WINDER
ECO CLEAN
PRINTBOARD PCB
BETER ONDERZOEK:
PCB EMBEDDEN (IN-MOULD)
IN BEHUIZING
HOUSING
WHEELS
NOZZLE
TUBE.
HOSE.
DIRT MANAGEMENT SYSTEEM
FILTERS
HOUSING FLEXIBEL
+
STERKTE + VORM
GEVEN D.M.V.
VACUUM
MOTOR ELIMINATED
FUNCTION IS TAKEN OVER BY:
- NOZZLE
- WHEELS
- TUBE
- HOSE

# Appendix J – Idea list

| Idea | Comment | Feasibility |
|---|---|---|
| Clean using water | Already done in Oceanos | |
| Clean heated | Maybe the warm exhausted air is usable | |
| Make the whole vacuum cleaner flexible in size | | |
| Motor with filtering system in it | Combining components is a good way of decreasing the overall vacuum cleaner size. The other way around is also an option. | |
| Motor with dust storage in it | The other way around is also an option. | |
| Include handheld in the appliance | Already done in Olympus | |
| Spread dust instead of collecting it | | |
| Use blown air to collect dust | | |
| Clean the sealing instead of the floor | | |
| Clean with ultrasonic sound | | |
| Make a vibrating nozzle to stir up dust | | |
| Use electrostatic energy to pick up (more) dust | | |
| Use a rotating brush to stir up / collect dust | A combination of a rotating brush and an airstream could decrease the necessary vacuum. | |
| Use water (or water damp) to decline the dust size in storage | Oceanos collects dirty water. Maybe there is overlap? | |
| More filters with different porosity behind each other | This could replace a DMS when it can also store dust | |
| Inflatable dust storage | dust storage large when turned on, decreasing when turned off. Like a big frog throat | |

| | | |
|---|---|---|
| Separate different types of dust to reduces storage volume | |  |
| Introduce a special hair filter | Filters get often clogged by hairs |  |
| Make an extendable hose | Compact unless extension needed |  |
| Making the vacuum cleaner consist of two sub parts | Like a wasp body. For example separate the cord winder |  |
| Instead of having to clean the whole room in once, clean different areas in a different time span | Less dust storage and no cord winder needed |  |
| Clean with a lot of small motors | |  |
| Collect dust in a small one-time-use cup that you have to throw away after use every time | Like the Senseo and Nespresso |  |
| Make the cord winder consist of several cords | Every cord only used when needed / extended |  |
| Make a plug entrance and sell cords & winders separately | |  |
| Adapt the shape on the most functionally used shape | Round |  |
| Store the cord asymmetric | |  |
| 3D rotational cord winder | |  |
| Increase the broadness of the winding space for the cord winder | |  |
| Change the motor type into a motor with a flexible body | |  |
| Use air enriched with a glue like substance | Substance must only sticks to little particles |  |
| Use electrostatic forces to make the dust come to the surface of the carpet and suck it up there | Less or no vacuum needed |  |
| Make modules out of the critical components that can form a snake kind of configuration | Or components can stay at the power plug |  |
| Make a docking station which can also be stored | This dock does not go with the user when using the vacuum cleaner |  |
| Develop a disposable vacuum cleaner | |  |

| | | |
|---|---|---|
| Use bacteria and / or animals to clean | biological cleaning |  |
| Different air speeds within the same airstream for cleaning in different levels | For instance different depths in a carpet |  |
| Apply a certain suction power adjusted to the required cleaning task | |  |
| Synchronize the nozzle settings, suction power settings, speed of movement and required effort to gather the dust for an optimal result | |  |
| - Use one periode (pulsed) suction<br>- Use varying period suction<br>- Use suction in the natural frequence of the dust<br>- Vibrate and have suction power at the same time<br>- Suck up dust with a standing wave suction | |  |
| Use a brushless motor to lose the hepa filter for carbon particles | |  |
| Use a motor that only produces an airflow, no vacuum | Computer fan |  |
| Make the floor porous so there is no dust on the floor | |  |
| Make the whole canister attract dust, not only the nozzle | |  |
| Use a capillary nozzle | |  |
| Combine the vacuum cleaner with an air filter/purifier | |  |
| Combine a vacuum cleaner with the floor / wall | |  |
| Make a head docking station in the garage or anything and have small appliances in every room | |  |
| Make a canister with small, dust collecting mouses | |  |
| A garbage bin that can collect dust | |  |

## Appendix K – Component roadmap

| | Roadmap components of a canister vacuum cleaner | | | |
|---|---|---|---|---|
| **Component** | **alternatives** | **2010** | **2012** | **2015** |
| Nozzle | Currently used | 295 mm breed, 73 mm lang, 50 mm hoog<br>Passive nozzle | More efficient shape, less leakage | No leakage, efficient shape |
| | Active brush | Not much used, a bit bigger size then a passive nozzle | Smaller mechanism, but still quite a size | Effective and small size. (Used combined with low energy motor) |
| Tube | Currently used | To short, standard interface size | Less leakage, less tolerance in the extension mechanism, longer tube | Less leakage. Other material, other extension mechanism |
| Hose | Currently used | 'Normal' hose | Less leakage | Less leakage, other material is used |
| | Retractable hose | With spiral wire in it (Has a constant radial force) | Less radial force, less leakage, stronger. | No radial force, as strong as 'normal' hose<br>Other material is used |
| Dust management system | Bag | Standard interface, minimal 1,5 L loose dust in a bag | Same as in 2010 | Less used (maybe even a phase out) or better, more effective materials used |
| | Bag less | Different types of bag less filtering, requires a motor inlet filter | More effective filtering | No motor inlet filter required |
| | Compress dust system | Start development | Functional prototype | Working mechanism |

| | | | | |
|---|---|---|---|---|
| Motor inlet filter | Currently used | Small filter between DMS and motor | Same as in 2010 | Less used, phase out |
| Exhaust Filter | Discard able filter (Currently used) | Fixed size (Electrolux):<br>25 dik, 150 breed, 121 hoog | Same as in 2010 | Less used, phase out<br>OR change in volume and effectiveness |
| | Permanent filter | More flexible size (no standards) but (at least) same volume | Same as in 2010 | Less used, phase out<br>OR change in volume and effectiveness |
| | Washable filter | More flexible size and flexible dimensions | Same as in 2010 | Less used, phase out<br>OR change in volume and effectiveness |
| Motor | Currently used (global 2) | Diameter ± 120 mm<br>Height ± 100 mm<br>1800 W input power<br>800 – 900 grams<br>48% efficiency | Same size and weight, 1200 W input power and 50% efficiency | Same size and weight, 750 W input power and 52% efficiency |
| | Brushless motors | Same as the brush motors, though more expensive | Same as the brush motors, a bit more expensive | Same as the srush motors |
| | Swiss reluctance motor | Contact Wessel Otten for specifications | Contact Wessel Otten for specifications | Contact Wessel Otten for specifications |
| | Axial Flux (flat) motor | Diameter ≤ 100 mm<br>Height ≤ 30 mm<br>50 W input power<br>Low weight<br>At least same efficiency | All the same but increase input power | All the same but 750 W input power |
| Cord winder | Currently used (vertical) | Diameter ± 160 mm,<br>Width ± 60 mm | A bit smaller size available | More flexible sizes to implement |
| | Horizontal cord winder | Not yet that far developed | Good working prototype | An option for using it in the vacuum cleaner |

| | | | | |
|---|---|---|---|---|
| | New cord winder configuration | Start development | Functional prototype | Working system |
| PCB | Silicon printed PCB | 'Normal' PCB | Smaller size | Smaller size and more flexible |
| | PCB printed on the material | | Start pilot project | First working prototypes in Philips CL |
| Housing | ABS | Thickness of 2,5 required | Same as in 2010 | Same as in 2010 |
| | Recycled material | Material quality is harder to control | Same as in 2010 | Can be used just as good as new raw materials |
| | New material | | | New material with assigned different properties (strength, weight, inflatable) |
| Wheels | Two stiff and one rotating wheel | 'normal' wheel configuration | Same as in 2010 | Same as in 2010 |
| | Three rotating wheels | 'normal' wheel configuration, research to the implementation | Same as in 2010 | Same as in 2010 |
| | A configuration using 'trackball(s)' | 'normal' wheel configuration, not used | Same as in 2010 | Same as in 2010 |

# Appendix L – Process proposals

Next to the ideas for innovation, proposals for future opportunities were formed by getting to know Philips as a company, with the department floorcare in particular.

*The first process proposal is* ***to intensify the collaboration between the development department and the purchasing department.*** Together they must determine a purchasing strategy, based on the floorcare vision and product roadmap, and share this strategy with involved suppliers.

The Philips floorcare department did not have a product roadmap for a long period of time. There was no vision on floor cleaning and therefore no mission to achieve. Not that long ago a vision and roadmap were created and Philips now knows where they want to go with their products. This is a good development, but this plan also has to be executed. Therefore it is time to undertake actions to achieve the goals.

The vision can be communicated more clearly to the people working in the floorcare department and, most important, to the suppliers! Without the suppliers working towards the same vision, there will not be any components to use as Philips buys most of the components from extern manufacturers. If Philips does not share their vision they will be set back in new product development.

Philips floorcare is slowly but consistently translating from a product developing company to a co creating company and off the shelf trader. So also the company vision supports the co development by suppliers. Co-creation has a meaning on purpose: dream, share and create together!

*The second proposal* ***is to define the purpose that Philips wants their products to have and then make translations back to the effort that is being put into the project to realize the product.***

As a large international consumers electronics company, Philips must have a certain consistency in their new product launches, to sell a certain volume of vacuum cleaners and keep a certain market share / market position. This means not every project will have the same size and or risks. This must be coordinated correctly so Philips at least remains a stable company with a certain share of the vacuum cleaner market.

When a product has the purpose of keeping the Philips vacuum cleaner market share consistent, the product does not requires big innovations. This type of vacuum cleaners must keep up with competition on dust pickup and efficiency, but does not have to deviate itself from their competitors that much. Therefore less effort can be put into the projects to realize these vacuum cleaners. These vacuum cleaners are going to be 'normal' vacuum cleaners without a big impact.
When a product has the purpose of really having an impact and expanding the market share, it really has to deviate from competitor models and more time and effort are required. The benefits that these products will have must be very sufficient so customers and resellers can directly tell that the product is different, better suitable for a certain (multiple) cleaning job. To achieve this type of products all attention, focus and innovations must be on the project. Launch dates and costs are very important, but it cannot decrease the benefits of the product, because then the potential effect that has been defined will not be achieved. To support this proposal a couple of short examples are listed on the next page:

*The Yoga project*

The yoga vacuum cleaner project was set up to be the world's most silent vacuum cleaner. Sound is a really important (dis)satisfier in a vacuum cleaner. But it is also one of the most complex variables of a vacuum cleaner. This is a high risk, high effort project, without moving the vacuum cleaning world that much. After all the function will be the one of "just another vacuum cleaner".

Furthermore, in the project a different, more efficient, motor was chosen for efficiency reasons. This choice negatively influenced the benefit of the product; a very low noise vacuum cleaner. As a result a competitor, Electrolux, already has a more silent vacuum cleaner on the market.

*The Oceanos project*

In this project a new floor cleaning product, based on a new technology, is being made to combine dry and wet cleaning. This product has the potential to really move the market and therefore a lot of people should be able to work in this project (and that is happening).

*The Olympus project*

Because in this project a competitor will be copied in order not to lose market share in this floorcare area, very little attention and development should be put into the product. If an off the shelf product is an option this would be a very low cost, time efficient answer to the competitor product.

PHILIPS
sense and simplicity

**Philips Consumer Lifestyle – i&D floor care**

Tussendiepen 4, 9206 AD, Drachten

# Appendix F - Consumer Research plan

| | |
|---|---|
| Category: | Floor Care |
| Project: | Miniaturization |
| Phase: | Research |
| Author: | Leon van Dijk |
| Department: | i&D floor care |
| Date: | 2009-12-18 |
| Version: | 1 |
| Status: | Draft 5 |
| Reference: | IDA APC Miniaturation |
| No. of pages**:** | 15 (incl. This page) |

# Table of Contents

# Introduction

The miniaturization project is focussed on decreasing the size of vacuum cleaners, without decreasing performance or durability. Market research shows that a big / bulky vacuum cleaner is disliked by European consumers. To meet in consumer satisfaction, Philips decided to do a research to the miniaturization of vacuum cleaners.

*Dimension & Weight*

At Philips there have been numerous user researches to new products. In these researches consumers have to test a lot of different aspects of a product. Size and weight is always included, but never quantified. Most of the time the outcome states that a certain (competitor) model is too big / bulky.

Other research to weight and dimension was done in the Reina project. In this research the goal was to find a maximum limit in size and weight that is accepted by consumers. This research was done because of a technical decision which would increase user comfort, but also increase size and weight. If these last two properties would decrease the user comfort more then the technical aspect would gain, the feature would not be built in.
This same decrease in user comfort is thought to be found when decreasing the size and / or weight. To provide the miniaturization project with input from consumers about the minimum acceptable weight and volume, this test has been set up.

# 1. Research Plan

### 1.1 Research goal

The goal of this research is to find the minimum acceptable volume and weight of a vacuum cleaner. An inferior goal of the research is to gather consumer insight in the relation between size and weight of a vacuum cleaner. Research questions that need to be answered to reach this goal:

1. Which model size is appreciated most by consumers when able to choose from all sizes together?
2. Which weight is appreciated most by consumers when choosing from all weights together?
3. Does the preference of consumers towards the size and weight differ when tested independently?

### 1.2 Hypothesis

The hypothesis that belong to the research questions are stated below. There is an expected hypothesis H0 and the alternative H1 for every aspect of the research.

*Hypothesis 1: Size*
H0; The smallest size available is not the most preferred size by consumers.
H1; Consumers prefer the smallest size available.

*Hypothesis 2: Weight*
H0; The lightest weight available is not the most preferred weight by consumers.
H1; Consumers prefer the lightest weight available.

*Hypothesis 3: Size & Weight combination*
H0; Combining different sizes and weights change consumer preference.
H1; Combining different sizes and weights doesn't change consumer preference.

### 1.3 Research variables

Per hypothesis a list of variables can be determined. To prevent concluding wrong, factors which influence these variables must be as stable as possible during the research. The variables can be distinguished to:

- Dependent variables: The goal of research
- Independent variables: The factors which are researched if and how they influence the dependent variables
- Environmental variables: The factors from the environment which can influence the research results.

Underneath is an overview of which variables are of importance for each hypothesis.

*1.3.1 Hypothesis 1; The smallest size available is not the most preferred size by consumers.*

Dependent variables
- Participant satisfaction

Independent variables
- Handlings with different model sizes

Environmental variables
- Environmental distraction
- Test installation
- Briefing
- Execution of the procedure
- Testing time
- Age of the participant
- Healthiness of the participant

*1.3.2 Hypothesis 2; The lightest weight available is not the most preferred weight by consumers.*

Dependent variables
- Participant satisfaction

Independent variables
- Handlings with different model weights

Environmental variables
- Environmental distraction
- Test installation
- Briefing
- Execution of the procedure
- Testing time
- Age of the participant
- Healthiness of the participant

*1.3.3 Hypothesis 3; combining different sizes and weights does differ the consumer preference.*

Dependent variables
- Participant satisfaction

Independent variables
Handlings with different model size-weight combinations

Environmental variables
- Environmental distraction
- Test installation
- Briefing
- Execution of the procedure
- Testing time
- Age of the participant
- Healthiness of the participant

### 1.4 Research method

There are different ways to research the minimal accepted size and weight of a vacuum cleaner. However a use study with direct interaction between the model and the participant is found the best option, because practitioners can put the size and weight best in context. During this use study, information will be gathered through questioning, observation and a questionnaire.

*Prevent carryover effects*
To prevent carryover effects the dummies will first be shown all together, where after different combinations of sizes and weights will follow independently in a random order. They participants will be asked to judge the handling of the model, user satisfaction, for each model. However they do not know how dummy is changed compared to the previous dummy.

### 1.5 Task selection

Practitioners will be asked to perform a number of proceedings. While executing these proceedings, the practitioners will be observed and proceedings which cause trouble will be noted. The proceedings that have to be executed are:
1. Cleaning a laminate floor
2. Cleaning a carpeted floor
3. Cleaning the stairs

### 1.6 Test environment

The test will be done in the Philips home test lab in Drachten to keep the environmental conditions as stable as possible so the results will not be influenced.

### 1.7 Participants

The participants are adults from the Happy Home segment. Happy Home is the biggest group of vacuum cleaner users in Europe (target area) and consists of mainly woman. The age of the participants can differ from 25 – 54.

*1.7.1 Extraordinary participants*

Because this research is not mainly focussed on the usability of a product, but on the acceptability of size and weight, extraordinary participants are not included in the research.

### 1.8 Procedure and planning

The participant enters and will be introduced to the researcher and the research. After the introduction, the researcher explains the procedure of the research and hands him/her a document with instructions and useful information for the research. While the instructions are being read, the researcher prepares everything for the participant to choose the most convenient size from all different sizes. After this choice, the participant can choose the most convenient weight from all the weights. When both choices are made, he/she starts performing the instructed actions with combinations models with different sizes and weights. While the participant performs these actions, the researcher observes the participant, asks questions about user comfort and writes down notes of the progress. The questionnaire will be filled in and the disclaimer will be signed after all different models have been tested. The participant will be thanked for their effort and the participant will leave.

| Action | Time (minute) | Total time (minute) |
|---|---|---|
| 1. Entry participant | 1 | 1 |
| 2. Introduction | 1 | 2 |
| 3. Explanation of the procedure | 1 | 3 |
| 4. Participant reads the instructions | 3 | 6 |
| 5. Participant chooses from all dummy's | 3 | 10 |
| 6. Participant performs actions with different sizes and weights<br>*While doing this, the participant is observed on the form* | 25 | 35 |
| 7. Participant fills in the questionnaire | 6 | 41 |
| 8. Signing the a declaration to never claim | 1 | 42 |
| 9. Thank the participant | 1 | 43 |
| 10. Leaving of the participant | 1 | 44 |

Because the testing time takes about 45 minutes, one hour will be scheduled for each participant. If the planning is correct there can be tests with six persons every day.

### 1.9 Question survey

After the test, participants will be asked to fill in a question form. In this question form the questions underneath have to be answered. The questionnaire will be in Dutch because the research is done with Dutch participants.

**Een deel van het onderzoek beslaat het invullen van een tweetal vragenlijsten en een kleine reeks open vragen. Onderstaand vind u het eerste deel. Het is de bedoeling dat u dit deel invult in de eerste wisseling van modellen. Het tweede deel begint wederom met een introductie. Het is de bedoeling dat u dat deel pas in vult in de tweede wisseling van modellen. De open vragen worden naderhand ingevuld.**

**Deel 1**

*Het kiezen van de juiste stofzuiger is het kiezen van de juiste set eigenschappen die een bepaald apparaat bezit. Deze eigenschappen zullen niet voor iedereen gelijk zijn omdat verwachtingen en omgevingsfactoren hier een wezenlijke invloed kunnen hebben. Onderstaand volgt een reeks van gepaarde eigenschappen van een stofzuiger. Hoewel u beide eigenschappen belangrijk kunt vinden, vragen we u uw voorkeur aan te kruisen.*

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

O **Handig op te bergen** O **Handzaam in gebruik**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

O **Goede performance** O **Milieuvriendelijk**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

O **Handzaam in gebruik** O **Klein**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

O **Licht** O **Goede performance**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

O **Klein** O **Licht**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

O **Handig op te bergen** O **Klein**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

O **Licht** O **Milieuvriendelijk**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

O **Handzaam in gebruik** O **Licht**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

O **Klein** O **Goede performance**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

O **Handig op te bergen** O **Licht**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

O **Klein** O **Milieuvriendelijk**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

O **Handzaam in gebruik** O **Goede performance**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

O **Handig op te bergen** O **Goede performance**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

O **Handzaam in gebruik** O **Milieuvriendelijk**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

O **Handig op te bergen** O **Milieuvriendelijk**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

O **Goede performance** O **Handzaam in gebruik**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

O **Handzaam in gebruik** O **Handig op te bergen**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

O **Goede performance** O **Licht**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

O **Klein** O **Handzaam in gebruik**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

O **Milieuvriendelijk** O **Goede performance**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

O **Goede perfomance** O **Klein**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

O **Licht** O **Handzaam in gebruik**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

O **Milieuvriendelijk** O **Licht**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

O **Klein** O **Handig op te bergen**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

O **Milieuvriendelijk** O **Klein**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

O **Licht** O **Handig op te bergen**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

O **Goede performance** O **Handig op te bergen**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

O **Milieuvriendelijk** O **Handzaam in gebruik**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

O **Licht** O **Klein**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

O **Milieuvriendelijk** O **Handig op te bergen**

Deel 2:

*Naast de eigenschappen die een stofzuiger moet bezitten is het natuurlijk ook erg van belang dat het apparaat voldoet aan de gebruikswensen. Deze bestaan uit de handelingen die mogelijk moeten zijn met een stofzuiger. Onderstaand volgt een reeks van gepaarde handelingen met een stofzuiger. Hoewel u beide handelingen belangrijk kunt vinden, vragen we u uw voorkeur aan te kruisen.*

Welke van de twee onderstaande handelingen vindt u het belangrijkst?

- O **Stofzuiger pakken / opbergen**
- O **Stof weggooien**

Welke van de twee onderstaande handelingen vindt u het belangrijkst?

- O **Stofzuiger in elkaar zetten / uit elkaar halen**
- O **Trap stofzuigen**

Welke van de twee onderstaande handelingen vindt u het belangrijkst?

- O **Zuigkracht regelen**
- O **Vloer stofzuigen**

Welke van de twee onderstaande handelingen vindt u het belangrijkst?

- O **Stofzuiger pakken / opbergen**
- O **Trap stofzuigen**

Welke van de twee onderstaande handelingen vindt u het belangrijkst?

- O **Stofzuiger in elkaar zetten / uit elkaar halen**
- O **Vloer stofzuigen**

Welke van de twee onderstaande handelingen vindt u het belangrijkst?

- O **Zuigkracht regelen**
- O **Stof weggooien**

Welke van de twee onderstaande handelingen vindt u het belangrijkst?

- O **Vloer stofzuigen**
- O **Trap stofzuigen**

Welke van de twee onderstaande handelingen vindt u het belangrijkst?

- O **Stofzuiger pakken / opbergen**
- O **Stofzuiger in elkaar zetten / uit elkaar halen**

Welke van de twee onderstaande handelingen vindt u het belangrijkst?

- O **Trap stofzuigen**
- O **Stof weggooien**

Welke van de twee onderstaande handelingen vindt u het belangrijkst?

- O **Stofzuiger in elkaar zetten / uit elkaar halen**
- O **Zuigkracht regelen**

Welke van de twee onderstaande handelingen vindt u het belangrijkst?

- O **Stofzuiger pakken / opbergen**
- O **Vloer stofzuigen**

Welke van de twee onderstaande handelingen vindt u het belangrijkst?

- O **Zuigkracht regelen**
- O **Trap stofzuigen**

Welke van de twee onderstaande handelingen vindt u het belangrijkst?

- O **Stofzuiger in elkaar zetten / uit elkaar halen**
- O **Stof weggooien**

Welke van de twee onderstaande handelingen vindt u het belangrijkst?

- O **Stofzuiger pakken / opbergen**
- O **Zuigkracht regelen**

Welke van de twee onderstaande handelingen vindt u het belangrijkst?

- O **Vloer stofzuigen**
- O **Stof weggooien**

Welke van de twee onderstaande handelingen vindt u het belangrijkst?

- O **Stof weggooien**
- O **Stofzuiger pakken / opbergen**

Welke van de twee onderstaande handelingen vindt u het belangrijkst?

- O **Trap stofzuigen**
- O **Stofzuiger in elkaar zetten / uit elkaar halen**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

- O **Vloer stofzuigen**
- O **Zuigkracht regelen**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

- O **Stof weggooien**
- O **Stofzuiger in elkaar zetten / uit elkaar halen**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

- O **Trap stofzuigen**
- O **Zuigkracht regelen**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

- O **Zuigkracht regelen**
- O **Stofzuiger in elkaar zetten / uit elkaar halen**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

- O **Vloer stofzuigen**
- O **Stofzuiger pakken / opbergen**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

- O **Stof weggooien**
- O **Zuigkracht regelen**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

- O **Vloer stofzuigen**
- O **Stofzuiger in elkaar zetten / uit elkaar halen**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

- O **Trap stofzuigen**
- O **Stofzuiger pakken / opbergen**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

- O **Stof weggooien**
- O **Vloer stofzuigen**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

- O **Zuigkracht regelen**
- O **Stofzuiger pakken / opbergen**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

- O **Stof weggooien**
- O **Trap stofzuigen**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

- O **Stofzuiger in elkaar zetten / uit elkaar halen**
- O **Stofzuiger pakken / opbergen**

Welke van de twee onderstaande eigenschappen vindt u het belangrijkst?

- O **Trap stofzuigen**
- O **Vloer stofzuigen**

**De volgende vragen kunt u naar eigen inzicht invullen.**

1. Stel, de stofzuiger wordt kleiner; vindt u het logisch dat de slang, buis en zuigmond ook kleiner worden?

   ……..
   ……..
   ……..

2. Vindt u het bezwaarlijk als u bij het schoonmaken van een ruimte de stekker van stopcontact moet wisselen omdat het snoer niet lang genoeg is?

   ……
   ……
   ……
   ……
   ……

3. Bent u bereid om meer te betalen voor een compacte stofzuiger met de zuigkracht van een traditionele stofzuiger? Zo ja, hoeveel?

   ……
   ……
   ……
   ……
   ……

4. Wat zijn de leukste dingen aan het stofzuigen?

   ……
   ……
   ……
   ……
   ……

5. Wat zijn de minst leuke dingen aan het stofzuigen?

   ……
   ……
   ……
   ……
   ……

6. Wat zou voor u de ideale stofzuiger zijn?

   ……
   ……
   ……
   ……
   ……

### 1.10 Observation paper

While performing the tasks the participants are observed. Difficulties that participants experience and other remarks are filled in the table underneath.

| Model | Task | Difficulties / remarks |
|---|---|---|
| 1 | Cleaning an empty<br>*Carpet*<br>*Laminate* | |
| | Cleaning the stairs | |
| 2 | Cleaning an empty<br>*Carpet*<br>*Laminate* | |
| | Cleaning the stairs | |
| 3 | Cleaning an empty<br>*Carpet*<br>*Laminate* | |
| | Cleaning the stairs | |
| 4 | Cleaning an empty<br>*Carpet*<br>*Laminate* | |
| | Cleaning the stairs | |
| 5 | Cleaning an empty<br>*Carpet*<br>*Laminate* | |
| | Cleaning the stairs | |
| 6 | Cleaning an empty<br>*Carpet*<br>*Laminate* | |
| | Cleaning the stairs | |
| 7 | Cleaning an empty<br>*Carpet*<br>*Laminate* | |
| | Cleaning the stairs | |
| 8 | Cleaning an empty<br>*Carpet*<br>*Laminate* | |
| | Cleaning the stairs | |
| 9 | Cleaning an empty<br>*Carpet*<br>*Laminate* | |
| | Cleaning the stairs | |

User comfort op een schaal van 1 tot 10.

| **Groote\Gewicht** | 2,5 kg | 3,5 kg | 4,5 kg |
|---|---|---|---|
| Model 1<br>Kleinste model | | | |
| Model 2<br>Basis model | | | |
| Model 3<br>Grootste model | | | |