CHALMERS

Sound Waste

From Industrial Waste to Sound Absorption

Master thesis at Industrial Design Engineering

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1 CONTENTS

1 INTRODUCTION

1.1 PROJECT DESCRIPTION

This thesis is a part of Mistra Closing the Loop project "From Industrial Waste to Product Design", where the process of Industrial Waste to Product Development (hereinafter IWtoPD) is being studied through exemplification of several significant types of waste material. The main theme for this particular thesis is one of these types of industrial waste, specifically PVC-cable sleeves. The material is collected from a plurality of sources and due to varying quality and sometimes unknown origin there is currently no efficient way to filter unusable from reusable material. This results in more material being piled up at recycling plants every day by means of landfill. Integrating the material into an open-loop life cycle would mean a tremendous decrease of environmental impact and reduce costs associated with the handling of waste material. In this thesis an IWtoPD process is implemented in order to find a viable solution for the ever increasing material quantities.

As the thesis requires a less than ordinary development process, a lack of common development methodology exists and needs to be addressed. In contrast to more conventional ways of product development where explicit needs or functions are translated into appropriate solutions, this thesis is constrained by one particular material that needs to be translated into a function. This type of development process will be increasingly more common as more sophisticated materials from less well-thought-out products are being recycled.

Efforts have been put into reapplying similar materials but most of the generated solutions are based on highly creative, and undocumented, methods. Thought provoking projects have been made in a large variety but few have been adopted at an industrial capacity, thus limiting (or decreasing) the environmental impact potential of the development projects. Which is why a correlation between the use of only creative methods (or lack of methods), and the low adoptability of the results seem plausible. As the amount of similar development processes increases, so does the need for a more structured and reliable methodology.

It is therefore necessary to investigate the following questions:

- How can the challenges presented by IWtoPD projects be addressed?
- Using the adapted methods, How can PVC-cable sleeves be reapplied?

1.2 PURPOSE/AIM

The purpose of this project is to suggest a methodology for IWtoPD-projects and test its effectiveness by applying said methodology to a real IWtoPD project aimed at generating a concept for reapplication of PVC-cable sleeves.

The aim is to deliver a methodology for how to address the challenges presented by IWtoPD projects; and to conceptualize a realizable reapplication area of PVC-cable sleeves.

1.3 DELIMITATIONS

The product development part in this thesis will be based on, and limited to PVC-cable sleeves.

Due to the limited time frame, the methodology will be tested to a limited capacity. A maximum of two iterations of testing of the methods will be conducted to ensure the quality of the last iteration.

1.4 PROJECT PROCESS

The project consists of two main phases, parts of which were executed concurrently. The first phase is method development whereas the second phase is product development. The methods developed in the first phase are tested and analyzed systematically during the first half of the product development phase. Both phases contain initial background studies, albeit of different subjects.

During the method development phase the background studies focuses on existing creative methods for ideation and similar applications in other fields. This is done through literature studies and consultation with experts. The background study provides a set of ways to enhance creativity, which is then tested in practice and analyzed iteratively. At the end of this phase conclusions are drawn based on the findings and the ideas generated are used for the continuation of the product development phase.

The product development phase commences with a background study and consultation with experts in order to map the outlines of the solution space. This is done by identifying the constraints imposed by recycling process, material properties and current/potential regulations. Ideas for application areas are then generated using the methods developed in method development phase and screened using criteria based on information from the background study. The most plausible application area is then handled as any other ordinary product development process and a final concept for this application area is then developed through ideation, screening, evaluation and verification in an iterative manner.

Figure 1. Project Process

PART 1

2 METHOD DEVELOPMENT

2.1 RESEARCH METHOD

Considering the relatively uncharted nature of an IWtoPD process it was determined early on in the thesis that practical experiments are needed for the analysis and conclusion. In order to build a sufficient and convincing basis for adequate recommendations for future IWtoPD projects, the experiments should be carried out in an organized manner to the extent of what is allowed by the time frame of this project.

Firstly, the differences between an IWtoPD project and a common PD project were identified and analyzed. As the phases where an IWtoPD project differs from a common PD-project are vague, mapping these phases helped identifying where research is best placed. As the main issue of IWtoPD projects proved to concern ideation, creative workshops were chosen as a base for method development.

Upon determining by which parts of the IWtoPD process this thesis will place its focus on, a background study of existing tools, methods and strategies for common PD projects were carried out by means of literature studies and interviews. Based on the registered differences and the findings from the background study a possible structure was suggested.

An iterative research process (*figure 2. Experiment method*) was then applied in order to generate recommendations on how to arrange effective workshops aimed at finding new applications for waste material with respect to the participants, activities, physical stimuli, context and moderation of workshops. In order to maintain the integrity of the conclusions, the criteria were predefined as comparable variables that reflect the particular aspects in an IWtoPD-process.

During a first iteration two set-ups of the aforementioned categories were tested in separate workshops, workshop 1 and 2. The workshops were very similar in regards to the choice of participants, stimuli, context and moderation. Participants, context and moderation were chosen according to recommendations found in existing research on creative workshops. Stimuli were chosen with the intent to provide the participants with relevant information needed to generate usable ideas. The workshop set-ups mainly differed with respect to the activities carried out. The activities of workshop 1 were chosen with the intent to create a competitive environment that would spur the participants´ idea generation. The activities of workshop 2 were chosen with the intent to create an environment that encouraged interaction and discussion between participants.

In each workshop the participants' task was to generate new ideas for a reapplication of discarded PVC cable sleeves. The performance of each workshop was judged based on four criteria: (1) Quantity of ideas generated, (2) Quality of ideas generated, (3) Diversity of ideas generated, and (4) Experience of the participants. By comparing the workshop performance, conclusions could be drawn regarding effective workshop set-ups, e.g. how to organize a successfully IWtoPD workshop by choosing participants, activities, stimuli, context and moderation style.

Quantity: Since the starting point of any IWtoPD project is characterized by the lack of ideas on possible application areas for the waste material it is important to generate as many ideas as possible, thus increasing the chance of finding some useful ideas. The Quantity was measured by calculating the number of ideas generated per minute during the ideation phase.

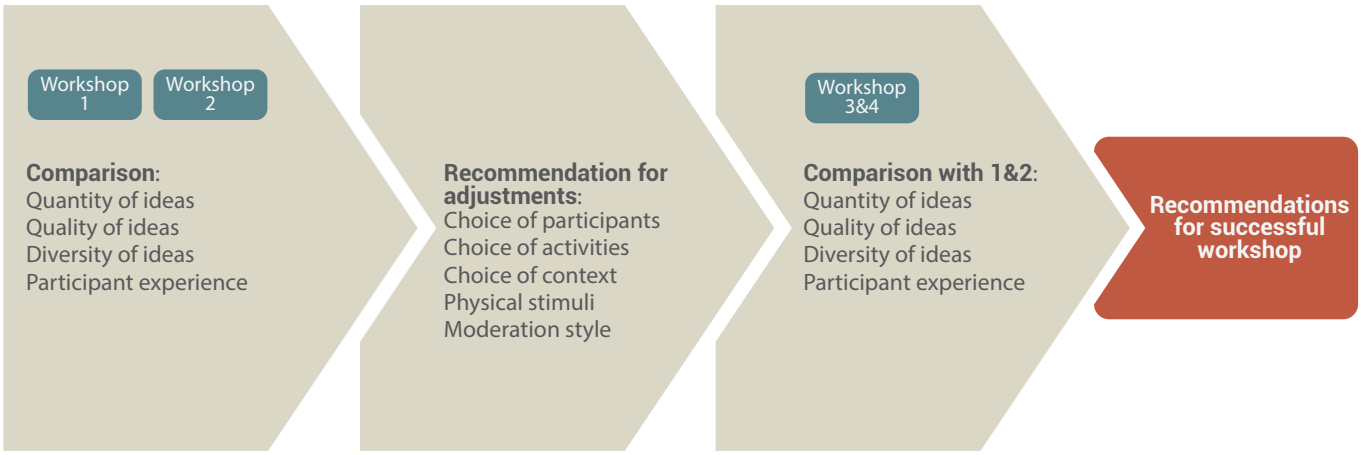


Figure 2. Experiment method

Quality: It is important to generate a lot of ideas during an IWtoPD project, but it is even more important to generate ideas that can actually be used. Only useful ideas will have a positive impact on the environmental situation. The Quality of the ideas generated was measured assessing the share of promising ideas generated and level of maturity of the ideas generated. The share of promising ideas generated, i.e. the share of ideas that passed the first screening, was calculated by taking the number of promising ideas generated over the total amount of unique ideas generated. The level of maturity was defined as the share of ideas that was sufficiently specified to be taken to the first screening out of the whole set of generated ideas.

Diversity: Since the domains of the final ideas are unknown and the solution space of an IWtoPD project is very large it is important to investigate a variety of domains to increase the chance of finding the best one. Diversity can be described as the number of domains touched by the ideas generated.

Participant experience: Creating a relaxed and creative environment will have a positive effect on idea generation in any workshop, which makes the participants´ experience of the workshop an important aspect to evaluate. In an IWtoPD workshop the situation is most likely unknown to the participants, which makes this aspect even more important. They shall feel comfortable and feel they are able to contribute. Also, if a method is unable to provide the users with a satisfactory experience it is unlikely that they will ever use the method again. The participants experience were registered by use of interviews and observations.

Based on the conclusions from the first two workshops, a new optimized set-up for IWtoPD workshops was developed for and tested in workshop 3 and 4. The quality of workshop 3 and 4 were documented and analyzed using the same criteria previously used in workshop 1 and 2. The findings of both analysis resulted in a set of final recommendations regarding successful workshop set-ups aimed at finding new applications for waste material.

2.2 THE CHALLENGE OF IWTOPD

Common PD projects, in particular design projects, are often carried out as a problem to solution process; where a problem is expressed, a solution desired and the solution is gradually transformed into a product that solves the problem or satisfies the need. The process of doing so is often described as a funnel where ideas are elaborated and gradually refined into one final product. *(Pugh, 1991) figure 3. Product development process described by Pugh 1991*

The common PD process often begins with a design objective as a starting point, with an exploration before defining the objective.*(Ulrich, Eppinger, 2008)* An IWtoPD project on the other hand has a different starting point. Here, a given material is the sole basis of the project. Solution space is practically open and the developer needs to define a direction before proceeding with development. In other words a design objective needs to be identified before proceeding with the common PD process.

The significant difference is thus, the greater need of upfront activities in an IWtoPD-process in comparison with the common PD-process. *(Ordoñez et. al., 2012)* This pre-process is not to be confused with the aforementioned exploration phase in common PD process. The aim of a pre-process in an IWtoPD process is to define a direction for the following development.

According to Ordonez et al. the phases of a pre-process in an IWtoPD process are Analysis, Ideation and Screening. The main purpose of the analysis is to gather information on all possible aspects of the material affecting the possibilities and limitations of the design objectives in the end of the pre-process. The ideation phase aims to generate ideas on previously unknown application areas for the waste material. In the screening phase the generated ideas are critically evaluated and the design objectives for the continued part of the IWtoPD process are set.

All phases of the pre-process in an IWtoPD process revolve around coming up with good and previously unknown application areas for the waste material. This suggests that the ideation phase is central in such a process. In the IWtoPD

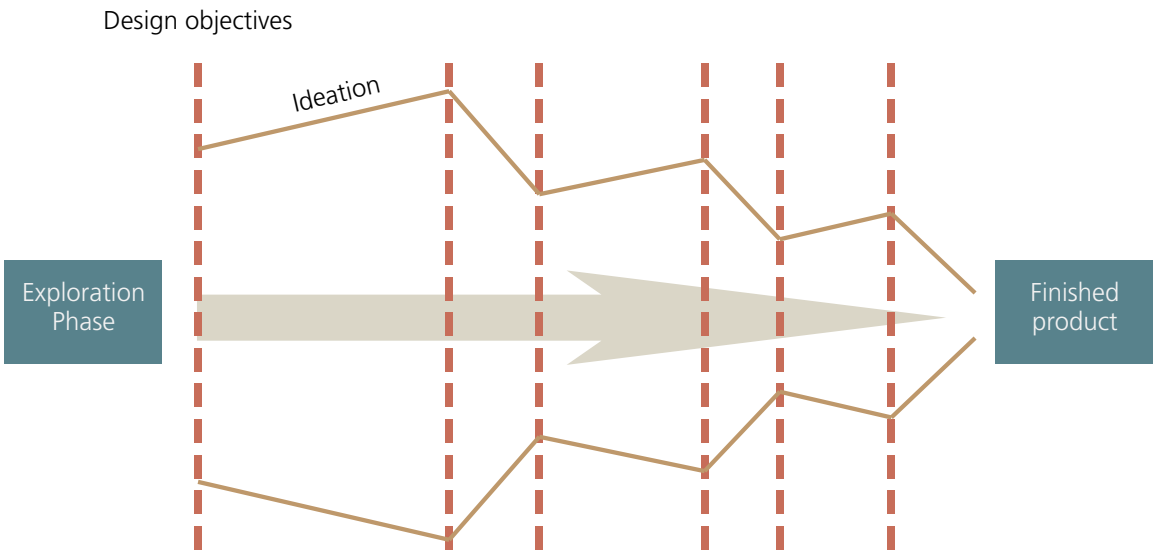


Figure 3. Product development process described by Pugh 1991

process, were the solution space is very large, there should preferably be activities that support generation of new and useful ideas in a wide range of areas. The ideas should be innovative because no existing solution solves the problem, hence the term waste material. The ideas should be useful because simply generating a lot of ideas of no use will not solve the problem. The ideas should cover a wide range of application areas because the solution space has no definite boundaries and there is no reliable way to speculate what the final design objectives might be.

In this thesis, the method for generating new useful ideas on how to utilize waste material in a wide range of application areas is suggested to be cross-disciplinary creative workshops. Cross-disciplinary workshops are believed to provide a lean solution to the problem of coming up with a possible application area for the waste material for two reasons. Firstly, workshops are presumed to be an efficient way of generating a lot of qualitative ideas and secondly, cross-disciplinary workshops are believed to facilitate generation of ideas in a wide range of application areas.

2.3 WORKSHOP METHODOLOGY

Research on methods for eliciting customer/user requirements suggests that such a generative method consists of four main aspects: data collection method, context, participants and mediating object. *(Engelbrektsson, 2004)* Adapted to better fit the workshop format they can be referred to as activities, location, participants and stimuli. In a workshop format it is also possible to introduce moderation as a fifth aspect to consider.

2.3.1 PARTICIPANTS

In a workshop context participants contribute to the many benefits of group work compared to individual work. Groups are able to be more intelligent, more efficient and more innovative then any single individual. In addition to this synergies arising from the collaboration between people with different expertise may be used to enhance the positive effects. For example, it has been shown that the intersection between disciplines is a good incubator for original ideas. *(Ness, R. B., 2012)*

2.3.2 ACTIVITIES

There are many creative methods and principles that can be used as activities in a creative workshop, and there are several parameters to consider when planning those activities. Such parameters are: the amount of individual work/group work conducted, the tempo of the activity, the level of freedom/structure, the goal of the activity, the amount of evaluation included, the possibilities for refinement and the order of tasks performed. This chapter describes a few of the most common methods whose principles have been used in the workshops, albeit altered to better suit the objective of the IWtoPD project.

Brainstorming

Brainstorming is an activity were people, preferably of different discipline, work together to generate solutions to a predefined problem. The idea is that the participants will stimulate each other to be more creative and come up with more ideas than what would be the case if everyone tried to solve the problem separately. *(Hans Johannesson et al., 2005)*

Prior to a brainstorming session the participants should be informed about the problem that are to be addressed. There should be a moderator leading the session and presenting new information or rephrasing the problem question if needed. An aim for the brainstorming session should be to generate a large quantity of ideas and any form of negative criticism is strictly forbidden. Furthermore, wild and outlandish ideas should be encouraged as well as building on others ideas and combining ideas. Examples of existing solutions may be used as input in the session to trigger new ideas. *(Hans Johannesson et al., 2005)*

Brainstorming bash

Brainstorming bash is an exercise that adds competitive elements to the idea generation session. It is executed by dividing the group into three or more small teams of the same size. A moderator starts the session by posing a focus question or sharing the objective of the session. One team is then randomly selected to think of the most crazy and outlandish idea possible and share it with the other teams. The teams are then instructed to turn the idea of the first group into a feasible solution and present it to the rest of the group. The first team then decides upon which team presented the best solution, which in turn get to come up with a new crazy and outlandish idea. The procedure is then repeated several times and the team with the most wins in the end is awarded a prize. *(Miller, B. C., 2012)*

Stickies

Stickies is a creative exercise suitable for small

to medium size groups and ensures that all ideas are recorded. The exercise starts by a declaration of the purpose of the session and markers and stickers are handed out to each participant. The participants are then told to write down as many responses to the focus question as possible in a limited amount of time. When the time is up the participants share their ideas with the others and are encouraged to write down new ideas if they are inspired by the other participant's ideas. *(Miller, B. C., 2012)*

Reverse brainstorming

Reverse brainstorming allow the participants to approach the problem or question in focus in a new way. The participants are instructed to find the least favorable idea or solution to the problem. When enough ideas have been generated the next step is to take each recorded idea and reverse it to transform the idea into a favorable one. It can be used as a fun and relaxing exercise that encourage the participants to think in new ways. *(Miller, B. C., 2012)*

Roles

Roles is an exercise were the participants take on the perspective of other people to create ideas of a different character. The exercise can be used in a brainstorming session were the participants are instructed to answer the focus question by taking on the perspective of another person. These persons may be written down on cards and handed out to the participants before each round of brainstorming. *(Miller, B. C., 2012)*

Sudden death

This is an evaluative method which makes the participants in a workshop choose one final idea. The procedure is as follows, randomly select two of the generated ideas and let the group compare them to each other and choose the better one. This procedure is repeated until only one idea remains, which is considered to be the best idea.

2.3.3 STIMULI

Engelbrektsson 2004 describes mediating objects as something which stimulates discussion, enhances users' understanding of a product or a product concept, and/or simplifies the dialogue between the user and the developer. While activities can be included in this definition, it is analyzed as a seperate component in this thesis. In order to emphasize this difference the term stimuli is used to describe all other mediating objects, apart form activities, in this thesis.

2.3.4 LOCATION

It is recommended to locate workshops in spaces that facilitates the activities conducted. There should be enough room to use the space as a workspace. For example, walls or tables in a room could be used as notice-boards by taping papers with different ideas on it. *(Ness, R. B., 2012)*

2.3.5 MODERATION

Research on organizational innovation has identified important aspects to consider when establishing creative business environments. The recommendations are to enable freedom of choice of approach, avoid rigid oversight and refrain from judgment. Supervisory encouragement, i. e. managerial recognition of new ideas, is also recommended as a way of fostering a creative environment. *(Ness, R. B., 2012)*

2.3.6 CONSULTATION WITH EXPERT

In an interview with a representative of a company specialized in creative development, Realize AB, some general guidelines were gathered. The interviewee is very knowledgeable in the services that Realize provides to their customers and was able to convey some practical guidelines. The interview had five open questions, which at the time of the interview was the biggest concerns in the up and coming workshops:

- What types of personalities tend to stand out, in a positive or negative way, in an open creative session? How to address potential problems related to this?
- What do you mostly work towards, quantity of ideas or developing/validating the ideas?
- In regards to quantity of ideas, is it preferable to work with an unlimited amount or attempt to fill a certain amount of ideas?
- How to broaden the solution space of a creativity session? What potential hurdles are there to be overcome and how?
- How to document the ideas? Should it be left up to the participants or the moderator?

According to the interviewee, there is much more to creative sessions than just individuals. Increasing level of creativity can be roughly grouped into three levels: individual-, group- and organization level. On each level certain characteristics are sought after.

Individual level - Individuals who tend to enhance creativity in a session are typically brave, engaged and positive.
Group level - Groups that do better tend to have open attitude, good communication between participants and a relaxed mood that provides a safe environment where all ideas can be shared without repercussions. It is in particular important that all ideas are valued the same without prematurely deeming them good or bad.

Organization level - Organizations that work with creativity tend to have policies that allow new ideas and good possibilities to communicate such ideas.

In practice the aforementioned characteristics should thus be sought after actively by the moderators, there are of course many ways to do so but in general the moderators should address how to encourage the appropriate attitude, ask the right question and trigger ideas. Asking the right question is very important as too abstract will leave the participants bewildered and too detailed will limit the creativity. Choosing the suitable abstract level is rarely easy and should be addressed carefully.
In addition to working with the characteristics of a workshop the environment in which the session is carried out should also be carefully planned. The sessions should not be too long as creativity decreases with time and available food and drinks will help prolonging the period of effectiveness.
Generally the most typical advice for moderating a creative session is to separate quantity and quality of ideas and empty the ordinary ideas very early on. To further develop the sessions the moderators can also keep track of certain variables to be compared later on: originality, novelty, fluency, elegance and flexibility of ideas are examples of measurable factors in creative sessions.

2.3.7 SUGGESTIONS FOR IMPLEMENTATION

Early on in the thesis work the comparison between an IWtoPD process and a common PD process resulted in a decision to use cross-disciplinary creative workshops as method for generating new useful ideas on how to utilize waste material in a wide range of application areas. Then, important elements of creative workshops in general were mapped in order to create a first suggestion on the set-up of IWtoPD workshops. The relevant findings of the background study and a suggestion on how to incorporate these into an IWtoPD workshop are presented below.

Participants

Participants of different disciplines will be used in the IWtoPD workshops as they create positive synergy effects and increase the level of intelligence, efficiency and innovation within a group. A cross-disciplinary group is also believed to widen the solution space.

Activities

There are many ways of working with creativity and problem solving in workshops. However, it is hard to predict on beforehand which combination of activities will achieve the best results in an IWtoPD workshop. Therefore a selection of aspiring activities is to be chosen for the first two workshops, which should be arranged to enable comparison of the different activities. Although evaluative activities will be conducted during the second half of each workshop, to further clarify generated ideas and reach a conclusion, the focus of the workshop and the workshop analysis will lay on ideation activities.

Stimuli

In an IWtoPD workshop stimuli is considered to be very important in terms of facilitating idea generation and getting the participants aware of the possibilities and limitations regarding the material. Stimuli may also be used as a way to increase the participants engagement in the workshop objective. Efficient stimuli in an IWtoPD workshop are presumed to be the material itself, pictures of existing products and background information regarding material properties, manufacturing methods, and the like.

Location

The background study suggests that the location of an IWtoPD workshop should provide enough space to accommodate and enable overview of the ideas generated. Presumably, it is also beneficial for the workshop result if the location provides an open non-distractive environment.

Moderation

Moderation in an IWtoPD workshop is believed to benefit from an encouraging and unobtrusive approach. The moderator´s main tasks should be to ensure that the workshop activities are carried out as intended and within the specified time frames.

Workshop 1				
Participants	Activities	Stimuli	Location	Moderation
Three engineering students from different disciplines	Focus on competitive activities	A short introduction to material properties and current applications.	A typical conference room	Unobtrusive but encouraging.
Workshop 2				
Participants	Activities	Stimuli	Location	Moderation
Three engineering students from different disciplines	Focus on interaction and discussion	A short introduction to material properties and current applications.	A typical conference room	Unobtrusive but encouraging.

Figure 4. Workshop setup of workshop 1 and 2

2.4 WORKSHOP 1&2

2.4.1 SETUP

The set-up of workshop 1 and 2 are listed in *figure 4. Workshop setup of workshop 1 and 2*. Both workshops were arranged as cross-disciplinary workshops because research has shown that this enhances group intelligence, innovativeness and efficiency. Cross-disciplinary setup was also considered to be important for IWtoPD workshops because diversity of ideas is presumed to be advantageous.

The workshops started with a short background introduction concerning material properties, origin of the material, possible manufacturing methods, existing products etc. This was done to provide the participants with enough background information for them to be able to generate ideas that are within reasonable limits of what is possible. Knowledge on the possibilities of the material may also spur creativity.

The choice of location for workshop 1 and 2 was addressed as any other ordinary workshop. This was done because in both cases the most important aspect to focus on is to create a safe, relaxed and creative environment that will facilitate idea generation. The workshops were arranged in typical conference rooms with low risk of distractions.

Moderation was handled in an unobtrusive and encouraging manner, allowing the participants to freely chose the direction of the idea generation. The risk would otherwise have been that the superior background knowledge of the moderators would have influenced the character of the generated ideas.

The evaluative activities conducted in workshop 1 & 2 were identical. First the participants got to evaluate the generated ideas with respect to realizability and potential material usage. The highest rated ideas were then subjected to a final screening where each idea was discussed and a winner was chosen. However, the ideation activities performed in workshop 1 were different from the ideation activities performed in Workshop 2. This was done to enable comparison of these activities, as the task of an IWtoPD workshop is unusual and there is a level of uncertainty regarding the usefulness of existing activities.

Detailed description of the ideation activities conducted in Workshop 1

Quantity before quality

The participants were presented with the instructions: Write down as many ideas as possible, in a limited time frame of 2 minutes, which answers the focus question. The participants were then asked to write down the three best ideas of their own choice and share them with the rest of the group. The participants were awarded one point for each idea. During a second iteration the participants were asked to try to double the amount of ideas from the first round in a limited time frame of 3 minutes. Again, the participants were then asked to write down the three best ideas of their own choice and share them with the rest of the group. For each new idea they were awarded one point and if they managed to double the amount of ideas they were awarded an additional ten points.

Forced relationships

During the method Forced Relationships the participants were given a deck of cards, called Cue Cards *(figure 5. Cue cards: example, figure 6. Cue cards.)*, with various instructions that the participants were told to incorporate into new ideas an-

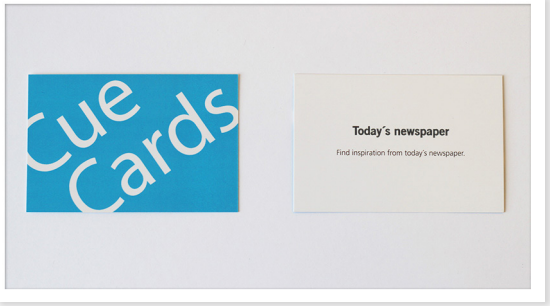


Figure 5. Cue cards: example

Figure 6. Cue cards

swering the focus question. The participants each took a card simultaneously and were given a time limit of one minute to follow the instructions on the card and come up with a new idea. The ideas were then shared within the group and the participants were then asked to vote for the best idea, but they were prohibited to place a vote on their own idea. The method was iterated and each time the originator of the winning idea was awarded five points.

Brainstorming bash
One randomly selected participant were asked to think of the most crazy, outlandish and ridiculous idea possible and share it with the group. The other participants were then, in a time frame of two minutes, asked to create a feasible solution out of the idea and share it with the rest of the group. The originator of the crazy solution was then told to choose the best altered idea whereupon its originator was awarded with five points. The winner of the challenge then got to come up with a new crazy solution and the procedure was repeated all over again two more times.

Detailed description of the ideation activities conducted in Workshop 2

Mind narrowing brainstorming
The method Mind narrowing brainstorming was used in collaboration with stereotype-cards that were prepared beforehand. The stereotype-cards showed pictures of different famous people (fictional or otherwise) to intentionally invoke subjective associations. Coupled with each personality was two keywords, place and event, that may be associated with the picture on each card. The connection between the picture and the keywords on the stereotype-cards were meant to be vague and sometimes include a humorous element. The words on the cards were meant to lighten the mood and if needed make a suggestion as to what connection can be made between the problem and the picture.

For the first five minutes each participant drew a card randomly from the pile and wrote down whatever idea they could come up with that was associated with the card. Whenever they felt they were stuck they were allowed to draw a new card and no long thinking sessions were meant to take place during this phase.

After the first phase each participant presented the ideas and the associated cards for the team and each idea was discussed briefly. Any new ideas generated during this discussion were then written down.

The third phase of this method consisted of a collaborative brainstorming with one card at a time, also drawn randomly from the pile. Each idea was then discussed along with the thinking process.

Flip it!
The participants were told to think of the worst solutions for the problem they could think of, during a given time frame of approximately five minutes. After the five minutes each participant presented the worst ideas on their list and the other participants were told to point out why the idea was bad without input from the idea owner.

For each idea presented and discussed, a follow-up question was also posed. All participants discussed together what improvements can be done to turn the bad idea into a good one.

Role play
During the method Role play each participant took on the roles/perspectives of the other two participants. The time frame for each role was three minutes and during this time the participants were asked to solve the problem in a

Performance of workshop				
	Quantity of ideas	Quality of ideas	Diversity of ideas	Participant experience
Workshop 1	117 unique ideas (55 minutes) 2,13 ideas/minute	- 30 promising ideas (25,6 % of the ideas) - Low maturity level of ideas	7 domains	Mixed
Workshop 2	90 unique ideas (45 minutes) 2 ideas/minute	- 26 promising ideas (28,9 % of the ideas) - Medium maturity level of ideas	7 domains	Mostly positive

Figure 7. Performance of workshop 1 and 2

fashion suitable for the role they were in. After the idea generation round the ideas from each field were presented to the field representative, who was then given the chance to comment on the ideas and open for discussion.

2.4.2 RESULT AND PERFORMANCE ANALYSIS OF WORKSHOP 1&2

Although both workshops were successful in regards to generating new application areas for cable sleeves, each workshop had its strengths and weaknesses. As shown in *figure 7. Performance of workshop 1 and 2*, each workshop showed potential improvements that can be implemented in the coming workshops.

For generating a high quantity of ideas, workshop 1 worked slightly better than workshop 2. It also generated more ideas per minute. Potentially the competitive theme of the activities in workshop 1 created a drive among the participants to generate a large amount of ideas. The first activity, quantity before quality, in particular proved successful in this aspect. The order of activities also seemed to be an important factor in regards to the quantity of ideas. In the latter activities, the participants reacted positively to more methodological stimuli such as perspective changes or unexpected topics. More specific and random, sometimes even outrageous, stimuli seemed to spur more ideas during the latter half of workshop.

However, workshop 2 performed better than workshop 1 in terms of quality of ideas. As seen in *(figure 7. Performance of workshop 1 and 2)*, workshop 2 generated a higher percentage of ideas that survived the consequent screening process. In comparison many ideas from workshop 1 were very vague and undefined. In later development process these ideas would need refinement and most probably show more weaknesses during said refinement process. Most likely the difference in quality was caused by the different activities and the common theme in each workshop. While workshop 1 had a competitive theme, workshop 2 focused on the interaction between participants, mutual triggering of ideas and initial evaluation through discussion.

In regards to diversity both workshops resulted in 7 identical domains despite the difference in participants and their background. The 7 domains of ideas were relatively unrelated to each other and can thus be deemed to be of high diversity. The cross-disciplinary setup surely contributed to this, as did the stimuli that were of exploratory character.

The participants' experience in each workshop also seemed to vary, both between the two workshops and between each activity. In the feedback gathered after the workshops, the participants of workshop 1 seemed to display a mix of negative and positive reactions towards the competitive theme. While one participant appeared to be triggered by the competitive aspects the other two seemed more uncomfortable with the situation. In the activity Brainstorming bash some of the participants felt a slight stagnation of creativity. From the feedback for workshop 2 however, it was clear that the generally perception of the performance was fun, more motivating and in general more positive.

Evaluation of Ideation activities conducted in Workshop 1 & 2

Since the main purpose of Workshop 1 and 2 was to test and evaluate different ideation activities a more thorough evaluation of these activities is stated below:

Quantity before quality
A large amount of ideas were gathered in a short period of time during the ideation activity Quantity before quality. This activity was perceived as a regular brainstorming method divided into two steps, with the additional step of selecting the three best ideas to share with the rest of the group. The participants appreciated the step of sharing ideas with each other because it enabled them to get new input and see alternative approaches to the problem, which helped them generate new ideas during the second iteration. A negative aspect of this was of course that during the first iteration the participants experienced difficulties and uncertainties regarding what type of ideas that were sought after. The method of collecting ideas could also be improved, as it was hard to interpret the meaning of some of the ideas that were not discussed after each session.

Forced relationships
The method Forced relationships resulted in new types of ideas which had not been thought of during the first method. The participants used the Cue Cards in a surprisingly relaxed manner and associated rather effortlessly on the given instructions. The method was appreciated simply because it gave the participants new input which helped them think of new ideas. The idea generation did not seem to depend on the character of the new input, i.e. the card instructions, because all of the instructions resulted in some sort of new idea. The participants also appreciated that they all got different cards because this reduced the competition factor. A possible improvement could be to ask the participants to elaborate on their choice of idea or ask them how an idea that was voted out could be improved. Such a discussion would possibly generate new ideas and create better understanding of the criteria by which decisions were made.

Brainstorming bash
The method Brainstorming bash resulted in new types of ideas that had not been thought of during the previous methods. The method was perceived as fun because it was different than it´s preceding methods and approached the problem in a whole new way. It was mentioned that it would be appreciated to have some sort of aid to help the participants to come up with a crazy idea. The users also mentioned that it was unnecessary that one participant became inactive during a part of the session, because this lowered the creativity level.

Mind narrowing brainstorming
Ideas gained from this method were highly divergent which proves the effectiveness of the mind narrowing. On many occasions associations were made between the card and the participant's field of expertise. For instance one of the participants, a civil engineer, thought of podium when presented with the word "speech". Mind narrowing brainstorming was perceived as a very good way to force the mind into thinking in new ways and the randomness of the card drawing felt relaxed and fun. The use of stereotypes created a good climate for discussion within the group. For this method to work it is important to keep track of each idea that spawns during the discussion and the connection between cards and ideas should be noted for future evaluation. Since the card was the more invigorating part of the method it should be kept and considered for other similar association games.

Flip it!
In reality almost no bad ideas were presented, at least not after the rest of the group through discussion turned each bad idea into a good idea. High participation level was achieved during this method, the mood was lighter and more refreshing than during the previous method and the participants acknowledged it was fun to use this method.

A longer session would be preferred for this method since the discussion was very important. The lighter mood created a more creative atmosphere in the group.

Role play
The results gained from this method were mostly ideas that surprised each field representative, even within their fields they appeared to have somewhat limited view of solutions. This of course spurred even more ideas that were then discussed and developed as well. The most positive aspect of this method was to have a field that was provocative and had a strong stereotype associated with it. In this session it turned out that IT, which has a very remote connection to the problem, was very stimulating for the other participants.

2.4.3 POTENTIAL IMPROVEMENTS FOR NEXT WORKSHOPS

The result of workshop 1 and 2 suggests that the importance of quantity as a criterion for the performance of waste material workshops should be reassessed. It was shown that quality of generated ideas is a more important criterion as it is directly correlated with the amount of usable ideas generated. Judged by this reasoning workshop 2 were more successful than workshop 1. However, the overall performance of the workshops implies that there is room for improvement in workshop 2 as well.

The quality of the ideas generated in both workshops can potentially be improved by providing the participants with more extensive background information. However, the main workshop parameter affecting the quality of the ideas is the amount of interaction between the participants resulting in discussions, collaborative activities and initial evaluations of ideas. This aspect was promoted in workshop 2, which also outperformed workshop 1 in regards to quality of ideas.

The different disciplines represented by the participants are believed to have contributed to the diversity of ideas. Considering the fact that the participants of workshop 1 and 2 were students with layman level knowledge of their fields, unlike experienced professionals, there is reason to believe that improvements can be made in this aspect. More experienced participants with deeper specific competences were therefore suggested for workshop 3 & 4. Furthermore, a lack of specific competence regarding the waste material was registered during the workshop.

The fact that all participants were students probably also affected their attitude towards the workshop and the workshop objective in a negative way. Since they were no stakeholders they attended the workshop with a more experimental attitude, whilst more experienced participants allocating their working hours to even attend the workshop could be expected to have more genuine interest in the workshop outcome.

The importance of stimuli became evident during both workshops. As soon as the participants became uncertain as to whether a certain idea would work in practice or not the idea generation stagnated. More extensive use of stimuli would probably have increased the understanding of the material and help them envision the solution space more clearly.

2.5 WORKSHOP 3&4

2.5.1 SETUP

figure 8. Workshop setup of workshop 3 and 4

Based on previous findings from workshop 1 and 2, a list of adjustments was implemented for workshop 3 and 4. Not all areas were altered, some methods were found to be beneficial and were directly inherited into workshop 3 and 4; and some methods were planned to be tested in workshop 3 and 4 and intentionally left out of workshop 1 and 2 due to circumstances. The changes implemented in workshop 3 and 4 were the following:

• Workshop 3 and 4 had a much more extensive background introduction.
• The location of workshop 3 and 4 was more open and non-distractive.
• Workshop 3 and 4 had more professional participants with diverse professional expertise and inherests in the outcome.
• In both Workshop 3 and 4 a material expert was participating.
• The structure of depletion-forced relationship-relaxing-evaluation was applied in Workshop 3 and 4 but not in its entirety in workshop 1 and 2.
• More physical stimuli were used in Workshop 3 and 4 and the stimuli were packaged in a more visually appetizing way.
• The activities performed during Workshop 3 and 4 involved more interaction and discussion between participants.

The most remarkable change made in Workshop 3 and 4 was the extensive background seminar that was provided to the participants before the actual workshop. The seminar included the research perspective, the industry perspective and practical information about the task ahead. The background seminar was a way to engage the participants early, in particular the participants who had some technical know-how and had personal interest in the outcome of the workshop.

In order to facilitate a creative and relaxed environment for workshop 3 and 4 they were arranged in open rooms with full height windows. The rooms were isolated from external disturbances, such as loud noise and distracting movement, to keep the participants focused on the subject.

In order to increase the quality and diversity of the ideas, a group of more diverse participants was chosen. The participants who showed up for workshop 3 and 4 included architects, interaction designers, policy makers, chemists and product designers. The total of participants amounted to 9 and they divided between workshop 3 and 4. The planned setup, in regards to diversity, was matched almost perfectly. One field expert was

Workshop 3&4				
Participants	Activities	Stimuli	Location	Moderation
- Professional participants with diverse expertise and interests in the outcome. - One participant was an expert on the material	- Focus on discussion and evaluation	- Extensive background seminar - Material Box, -'Random' stimuli during activities,	- Lighter locale	Unobtrusive but encouraging.

Figure 8. Workshop setup of workshop 3 and 4

Figure 9. Material box

included in each group which was expected to be useful for moving discussions forward in a constructive manner.

To increase the quantity and quality of the ideas generated in workshop 3 and 4, the structure and order of activities were altered. The following structure was used:
Depletion - depleting ordinary ideas in a quick and easy manner to facilitate generation of new creative ideas.

Change of perspectives - using random stimuli to give participants unexpected and clear directions in which they can steer their ideas.

Relaxing/disarming - Using methods that deliberately force the participants to think of dumb ideas thus releasing the tension/stigma of contributing with good ideas will relax the participants, the important part is to allow discussion and through which achieve more mature ideas.

Evaluation - letting participants do an initial screening of ideas will spawn even more ideas during the discussion, more importantly ideas will be combined into new ones potentially reaching higher maturity.

Without further investigation it is hard to provide quantitative proof that this structure works every time but in this instance it was expected to have a large impact on the quantity and quality of ideas generated in the workshops. The premise for this can be considered a resource distribution method where the attention and creativity of participants are strategically utilized during the different phases of the workshop.

A large part of the physical stimuli used in workshop 3 and 4 were packaged into a Material Box *(figure 9. Material box)*. The box itself was made with care to be visually "appetizing" to demonstrate the degree of seriousness behind the session. It was important to give the participants a visual impact early to let them realize the importance of the project and hopefully engaging them early on. Ultimately it was expected to be a pleasant surprise for the ones who were not expecting much of this workshop.

Each activity in workshop 3 and 4 was also changed in order to:
• include an iterative process consisting of individual spawning of ideas, interaction and discussion. This lead to mutual stimulation, triggering and development of ideas.
• exclude competitive tendencies, which in practice were suspected to result in less ideas generated for the sake of quality.
• include more extensive and clearer boundaries, defined by the background seminar and participating expert.

The improved activities are described below.

Quantity before quality
Participants are asked to generate as many ideas

Figure 10. Contents of material box

possible in a limited time frame, share the best ideas with each other, discuss them and then iterate.

Cue cards
The participants are presented with cue cards containing visual and/or verbal input to be incorporated into new ideas. This method was a combination of the methods Forced relationships and Mind narrowing brainstorming used in workshop 1 and 2.

Flip it!
All participants are asked to think of the worst idea possible and to write it down. The ideas are then gathered and replaced with ideas from another group. The participants are then asked to point out why the ideas are bad and together discuss ways to transform them into good ideas.

Though many things were altered for workshop 3 and 4, many factors that were deemed successful in workshop 1 and 2 were also used in workshop 3 and 4. Those were the following:
• The basic idea behind three of the used ideation activities from workshop 1 and 2 were kept and adjusted according to the lessons learned.
• One moderator in each workshop. The moderator's function was up keeping of given time frame, encouraging constructive/positive discussion and making sure evaluation took place.
• The workshops consiated of four phases, three creative methods and one evaluation, and were conducted in the morning.

Full Agenda can be found in Appendix B.

2.5.2 RESULT AND PERFORMANCE ANALYSIS OF WORKSHOP 3&4

figure 11. Performance of workshops
The outcome of workshop 3 and 4 were once again evaluated on a performance basis using the actual results, feedback from participants and the moderators' notes. The workshops were analyzed with respect to the aforementioned criteria quantity, quality, diversity and participant experience and compared to workshop 1 and 2. *(figure 11. Performance of workshops)*

Quantity of ideas
Workshop 3 and 4 resulted in 156 unique ideas (1,3 ideas/minute) which is significantly lower than the result of workshop 1 and 2 with 188 unique ideas (1,88 ideas/minute). This result is not suprising considering the shift of focus from activities promoting quantity to activies promoting more qualitative ideas. More time for dicussion amongst the participants resulted in fewer ideas per minute.

Quality of ideas
The quality of ideas in workshop 3 and 4 was better than previous workshops with 48 (30,7%) promising ideas that made it through the first screening and a high level of maturity compared

Performance of workshops				
	Quantity of ideas	Quality of ideas	Diversity of ideas	Participant experience
Workshop 1&2	188 unique ideas (Workshop 1: 55 minutes 2,13 ideas/minute. Workshop 2: 45 min, 2 ideas/minute) 1,88 ideas/minute	- 42 ideas (22,3 % of total) made it through first screening - Low-medium maturity level of ideas	7 domains	Mixed
Workshop 3&4	156 unique ideas (60 x 2 minutes) 1,3 ideas/minute	- 48 ideas (30,7 % of total) made it through first screening - high maturity level of ideas	7 domains	Positive

Figure 11. Performance of workshops

to 42 (22,3%) promising ideas and low to medium level of maturity. The main reasons are believed to be the following:

• Each activity in workshop 3 and 4 included an iterative process consisting of individual spawning of ideas, interaction and discussion. This lead development of more thought through ideas of higher quality.

• Workshop 3 and 4 had no competitive characteristics, which in practice meant fewer ideas that were simply spawned for the sake of quantity.

Diversity of ideas

Despite the very different background and expertise of participants, the domains touched by ideas spawned from each workshop showed strong convergence. In fact, the same 7 domains were represented in all four workshops indicating that there perhaps is a fixed, albeit vaguely defined, spectrum where realizable ideas can be found even for this type of project.

Participant experience

The participants overall experience in the latter workshops was more positive then what was the case in workshop 1 and 2. The main reason for this was the exclusion of the competitive elements and a generally more relaxed, open and creative environment. A lot of positive feedback was received during workshop 3 and 4, in particular Material Box looking good etc. The controlled nature of each workshop helped the participants to realize that the workshops were not simply a meeting, there had been a lot of work and thoughts put into the event. Ultimately it was a pleasant experience for the participants which engaged them in a good way.

Evaluation of Ideation activities in Workshop 3 & 4

A thorough evaluation of the ideation activities of workshop 3 and 4 is stated below:

Quantity before quality

The main purpose of the method was to target the ideas that are easily generated, i.e. the low hanging fruits, early on in the workshop. The result was very pleasing and paved the way for more innovative ideas.

A large amount of ideas were generated and the participants were very thorough when sharing their ideas which was different from workshop 1. During the second iteration of the method the participants elaborated on some of the ideas that they shared with each other instead of trying to come up with new ones.

Observations of the participants made it clear that some of them found it hard to generate ideas during the second iteration. That in combination with the thorough documentation of the ideas makes it likely to believe that the participants were engaged in the exercise and wanted to perform good.

Cue cards

The basis for this method, randomized stimuli, created a fun element that seemed to be appreciated. In particular cue cards that instructed the participants to ask each other for special instructions such as specifying an object as inspiration.

Some of the participants, not surprisingly, jokingly gave bad instructions when given the chance. The result often ended up being useful regardless of the instructions, since the more active the participants seemed to be the more discussion and the more ideas would appear. In fact this method was so engaging it posed a challenge to keep the time frame.

One element that worked very well for this method was the individual ideation intervals

where each participant wrote down their ideas according to instructions. The notes later allowed an easy documentation process and it was easy to follow the ideas in combination with drawn cue cards.

Flip it!
The main goal of this method was, yet again, to reverse the participants way of approaching the problem. In reality the ideas were somewhat different from the ideas of the previous methods. The group did not succeed in transforming all of the bad ideas and some participants in one of the groups were silent whilst others were more dominant which made it hard for everyone to really get involved in the discussion. Although, it should be mentioned that some of the ideas generated during this method made it very far in the later screening of ideas, e.g. the idea *pallets*.

Observations and comments suggest that the participants enjoyed the unusual character of the method.

2.6 ASSESSMENT OF WORKSHOP SET-UPS

One reason for using participants of different disciplines in the workshops was to achieve a high level of diversity of the ideas generated. Two questions arose during the thesis work concerning this subject:
• Did the use of people with different disciplines contribute to the diversity of the ideas?
• Is diversity an important aspect in an IWtoPD project?

Judged by the result from all four workshops it is hard to conclude whether the use of different disciplines affect diversity or not. In workshops 1 and 2, where all participants were students, 7 domains were represented. As the same result was achieved in workshops 3 and 4, where the participants were more experienced in their fields and more fields were represented, it is difficult to argue that use of different disciplines had any substantial effect on diversity. Furthermore, workshops 1 and 2 and workshops 3 and 4 reached the same level of diversity yet workshops 3 and 4 were superior to workshops 1 and 2 in terms of quality of ideas. This implies that achieving high diversity is not as big of a challenge as previously suspected, it is rather more challenging to achieve high quality in high diversity. It could also be speculated that the level of diversity had already reached a saturated point at workshops 1 and 2, as a result of the disciplinary differences of the participants or because of the stimuli or activities used. The uncertainties imply that it might be good to investigate the matter further in order to establish the importance of diversity as a criterion for workshop performance in an IWtoPD project.

In addition to the diversity, the cross-disciplinary set-up seemed to have contributed to a higher quality of ideas. It could be suspected that the main reason for this was the often in depth discussions of interesting ideas. In a sense, the expert representation in workshops 3 and 4 often led to much more grounded and comprehensive perspectives in discussions, whilst the students in workshops 1 and 2 generated very creative suggestions. In regards to the quality of ideas, the professional participants contributed most but it was potentially triggered by the occasional bright idea of students that were participating at the same time.

The quantity of ideas turned out to be secondary to quality, but it is worth noting the importance of using quantity as a triggering device. While the result from gathering a large quantity of ideas may

not be as important as gathering a large quantity of good ideas, many of the more refined ideas were visibly triggered during the process of generating and presenting seemingly worthless ideas. In retrospect it can be concluded that the result from quantitative activities had a different value than the ideas that could be developed. In the same sense the participant experience was also concluded to be important, but with different value, for enhancing creativity.

2.7 RECOMMENDATIONS FOR WASTE MATERIAL WORKSHOPS

From the methodology research it can be concluded that cross-disciplinary workshops are effective for IWtoPD projects. In particular this suggested methodology enhances the ideation phase in IWtoPD projects and thus effectively addresses the challenges posed by this relatively uncharted phase in an IWtoPD project. As for how to organize and conduct an effecting workshop, a list of recommendations is compiled below.

For the performance of a workshop, preparations is a key aspect. The following actions should be taken in this regard:
1. Find participants from different disciplines. Unexpected fields and deep understanding of which are preferred. Number of participants should be around 4-6, or any manageable number for the moderator. The participants should also have a genuine interest in the outcome of the workshops.
2. One expert on the material is recommended for each group. Said expert should be briefed beforehand about the constructive manner he or she should present feedback in during the workshop.
3. The physical stimuli should be chosen with care to help the participants understand the waste material with its possibilities and limitations. All physical stimuli used during the workshop should be packaged and presented in a professional way to convey the serious tone of the workshop.
5. Though activities can vary and be freely chosen, a structure of depletion-change of perspectives-relaxation/disarming-evaluation is recommended. (see 2.5.1)
6. For mutual triggering of creativity, activities should be conducted in short bursts of ideation altered with discussion in several iterations.
7. Prepare an extensive background seminar to provide the needed information about the project and its boundaries. The amount and depth of information should correspond to the desired level of abstraction in the outcome.

During the workshop the moderator's job should be one of a background character. The following actions are recommended for this phase:
1. Avoiding steering discussions in directions.
2. Reinforce and maintain constructive criticism and positive attitude.
3. Help managing time to allow discussion and evaluation.

In order to make sure the ideas generated from workshops are further developed, the following actions are recommended to be taken in the end of the workshops and as soon as possible after the workshops:
1. Make sure participants document their ideas, if too many ask them to collect what they considered most valuable.
2. Document what you considered most valuable!

PART 2

3 PRODUCT DEVELOPMENT

3.1 INFORMATION GATHERING

3.1.1 METHOD

In an IWtoPD project a key area for successful project execution is early information gathering on the material and its properties. In the case with PVC it was important to get information regarding the following:

- virgin material
- the production industry
- additives
- end of life material
- material format characteristics
- health and environment
- rules and regulations
- manufacturing method

To obtain an initial understanding of the origin of the waste material a field study at the Stena Recycling cable granulation plant in Sundsvall was conducted. A tour of the plants in both Sundsvall and Timrå as well as an interview with branch manager Sven Widmark, concerning the separation process and handling of the waste material, provided a good insight in the waste handling process.

Literature studies were used as a way to build a solid knowledge foundation on both the material and the waste handling process. Concerning the material the literature covered areas such as virgin material properties, common additives, health and environment and rules and regulations. However, due to the complex nature of the material and its different compositions the literature needed to be complemented with interviews with experts of different fields. Experts from the virgin material production industry, recycling industry and research industry were consulted frequently for this purpose.

The background information gathered from all the previous methods was then collected, analyzed and compiled into a list of implications for product development. The list of implications for product development was later used as screening criteria for concepts, in other words a specification of demands.

3.1.2 PVC AS VIRGIN MATERIAL

PVC, PolyVinyl Chloride, is a polymer prepared from Vinyl Chloride Monomers. In an untreated state PVC it is white, brittle and solid; often granulated to small grains with 100 - 180 min diameter. Presently, around 90% of industrial PVC is produced from chlorination of ethylene. Ethylene itself is prepared in the petrochemical industry by steam cracking process and is one of the most important and biggest products in petrochemical industry.

PVC has a specific gravity at 1.35-1.45 and has a maximum continuous operating temperature, under untreated condition, of 60C. Due to the low operating temperature and its rigid structure, PVC is never used by itself. The virgin material is always mixed into a compound with different types of additives to fit the purpose of the material. *(Allsopp, M.W., Vianello, G, 2000)*

3.1.3 ADDITIVES

There is a large number of ways to enhance the virgin material in order to fit the specific needs of different products. *(Allsopp, M.W., Vianello, G, 2000)* For instance a product such as container might need higher strength in order to withstand what ever stress the application environment entails, or it could be that the material needs to be prepared in a way that fits certain manufacturing methods such as extrusion where the material

Additives

Commonly used in PVC industy

Type of functions
Heat stabilizer
Plasticizer
Impact modifier
Process aid
Lubricant
Filler
Flameretardent/smoke supressant
Pigment
Blowing agent
Biocide
Viscosity modifier
Antistatic agent
Antioxidant
UV-absorber
Antifogging agent
Binding agent

Figure 12. Additives used in PVC industry

tensile strength is essential. The way to enhance these properties, and much more, is to add appropriate additives into the virgin material during the manufacturing process.

There are many different additives put into different PVC products and most of them affect the way that PVC is recycled. Simply incinerating different PVC products will not only free a lot of chloride and increase acidification of the environment; it will also free a large amount of different compounds from the additives that will affect humans and environment in different ways. Over the year, there have been many different additives, some of which have been replaced due to technological advancement, some of which have been legally prohibited in parts of the world. Without an effective way to control the recycling source of PVC material, there is no way to guarantee what compounds and how much will be contained in what ever the recycled product is turned into *(figure 12. Additives used in PVC industry)* Some of the additives will be discussed in detail in following chapters due to their direct influence on the quality of recycled PVC.

Thermal/heat stabilizers

For most PVC products there is one common additive that needs to be used in most circumstances, and that is heat stabilizers. The main reason is that PVC destabilizes at around 70-80 celsius *(Allsopp, M.W., Vianello, G, 2000)*, at this temperature the chloride is freed and forms Hydrochloric acid which is harmful to most manufacturing equipments. This is of course unwanted as the temperature of many manufacturing methods exceeds this limit. As a solution to this problem a heat stabilizer is chemically bound to the virgin material, increasing the stable temperature limit to around 170-220 celsius depending on the heat stabiliser. *(Arkis, Balköse, 2005)* As a result of this particular additive, the material has a very long lifespan before degradation starts. Once the

stabilizer has fulfilled its capacity for preventing thermal degradation it loses the function and the product will start to degrade. Common visible properties once degradation has started could be black spots and cracks on the surface. The lifespan of common PVC products before such degradation starts is somewhere between one to several centuries, depending on the specific combination of additives*(Folarin, &Sadiku, 2011)*.

Plasticizers

Plasticizers is a complicated yet frequent topic for research and debates. Roughly 80-90% of the plasticizers used today is sold into the PVC-industry due to the properties of the virgin material. *(Rahman & Brazel, 2004)* There is a large number of different plasticizers that can be used for different applications. The main factors for choosing a plasticizer can be boiled down to its compatibility and efficiency. Most plasticizers are some kind of ester which separates the molecule chains and significantly lowers the glass transition temperature of the material, thus making the product more flexible.

There are two groups of plasticizers, primary and secondary. Primary plasticizers lowers the product's glass transition temperature and increases the elongation and softness of the material while secondary increases the effectiveness of the primary plasticizer. Most secondary plasticizers have low compatibility with PVC and doesn't increase the softness of the material by itself. Recently, there have been a few research adressing how to increase the compatibility of certain secondary plasticizers in order to utilize them as primary. It has been found that it is indeed possible to do so, but the synthesis process would require more resources and increase in cost. *(Karmalm, P., 2009)*

The plasticizer industry is today highly diversified due to the fact that many different solutions in the past have been found to be hazardous to health and environment in some way so the development of new plasticizers almost seem like a continuous effort to create new sophisticated solutions to this problem. The main challenges that this industry faces today is the existing regulations for various substances, functionality/ cost-effectiveness trade offs and of course the moral obligation to consider whether or not it is enough to simply follow regulations.

Among the most common and recent plasticizers, phtalate plasticizers are the most alarming ones in the PVC industry. Some of them have been found to affect human hormones and have been promptly regulated since the discovery of their effects. But the discovery is relatively recent and a lot of the effects are yet to be fully researched and understood. Meanwhile, more sophisticated, and not fully researched nor regulated, plasticizers are being implemented in the industry all over the world. In Sweden most of the aforementioned databases are regulated into monetary or incarceration penalties if the end product contains more than 0.1% of the regulated substance. *(see 3.1.5)*

One of the most notorious phtalates is DEHP, known for having harmful effects on the human body when it comes in contact with the human body for an extensive period of time. The effects are yet to be fully researched but so far it's been established that DEHP has harmful effects on the hormonal production system*(Center for devices and radiological health, US food and drug administration, 2011)*. There are many ways that a material can come in contact with the human body depending on the type of product. As an example of the most critical case a research about PVC(with DEHP) in medical equipment was studied for this thesis. The research addressed intravenous, inhalation, dermal and mucosal exposure. It was found that DEHP can be hazardous through parenteral exposure (other than mouth), intravenous exposure can be direct hazardous while inhalation

exposure for extended duration has been meassured to an acceptable amount. *(Center for devices and radiological health, US food and drug administration, 2011)*

Dermal and mucosal exposure amounts to a somewhat tolerable value. *(Center for devices and radiological health, US food and drug administration, 2011)*

Flameretardent

Though inherently flame resistant, PVC cable sleeves have over time contained different flame retardants to prevent extreme situations from inflaming the cables. Among the most commonly used plastics, PVC is the only one flame resistant without help of additives *(pvc.org)*. In a fire situation, PVC releases hydrogen chloride gas which protects the products from combustion reaction with oxygen. In comparison with other plastics PVC is relatively self-exstinguishing. The hydrogen chloride gas formed during combustion is also less dangerous to the human body than carbon mono oxide that is normally formed during a fire. In this sense PVC is an excellent material for indoor use as well as outdoor.

But some PVC products, mainly used for electronics and construction, still contain different kinds of flame retardents since they form a corrosive environment around critical construction elements and can lead to even bigger dangers such as collapsing of buildings. Through time PVC used in electronics have contained different hazardous flame retardants such as brominated retardants which are nowadays strictly forbidden.*(see regulations in 3.1.5)*

3.1.4 PROCESSING TECHNIQUES

Due to the high versatility of processed PVC, there are a lot of possible manufacturing methods. The raw material itself can be adapted to the relevant method using a suitable mix of additives. Ordinary manufacturing methods are following:

- Extrusion
- Calendering
- Injection moulding
- Extrusion/strech blow moulding
- Spreading/coating
- Rotational moulding
- Dip moulding
- Slush moulding

A big problem caused by the high versatility of PVC though, is the high divergence of the different compositions of additives. PVC products, even cable sleeves, have very different material properties and pose a big problem for the recycling process since for most reusable purposes a uniform material is preferred.

Depending what the original composition was, recycled PVC is also somewhat limited in regards to manufacturing methods. In this instance, cable sleeves tend to be prepared with plasticizers and flame-retardants. Historically these two types of additives have consisted of many questionable substances; many of them are now regulated in one way or another. Since some of the compositions are undocumented, in particular older products, the recycling process is often done without means to treat the substances freed during the process. In order to preserve the material properties, use of thermal methods should therefore be limited when using recycled PVC cable sleeves. In practice that means any manufacturing method that involves melting the material is excluded, in particular this concerns most molding and coating methods. Which means calendaring, pressing and to some degree extrusion methods are viable.

In conclusion the recycled PVC granule should be processed at temperature lower than 170 Celsius in order to not allow quick degradation of

the material. Thermal processing should also be limited as much as possible as any thermal energy deposited in the material will increase the rate of deterioration.

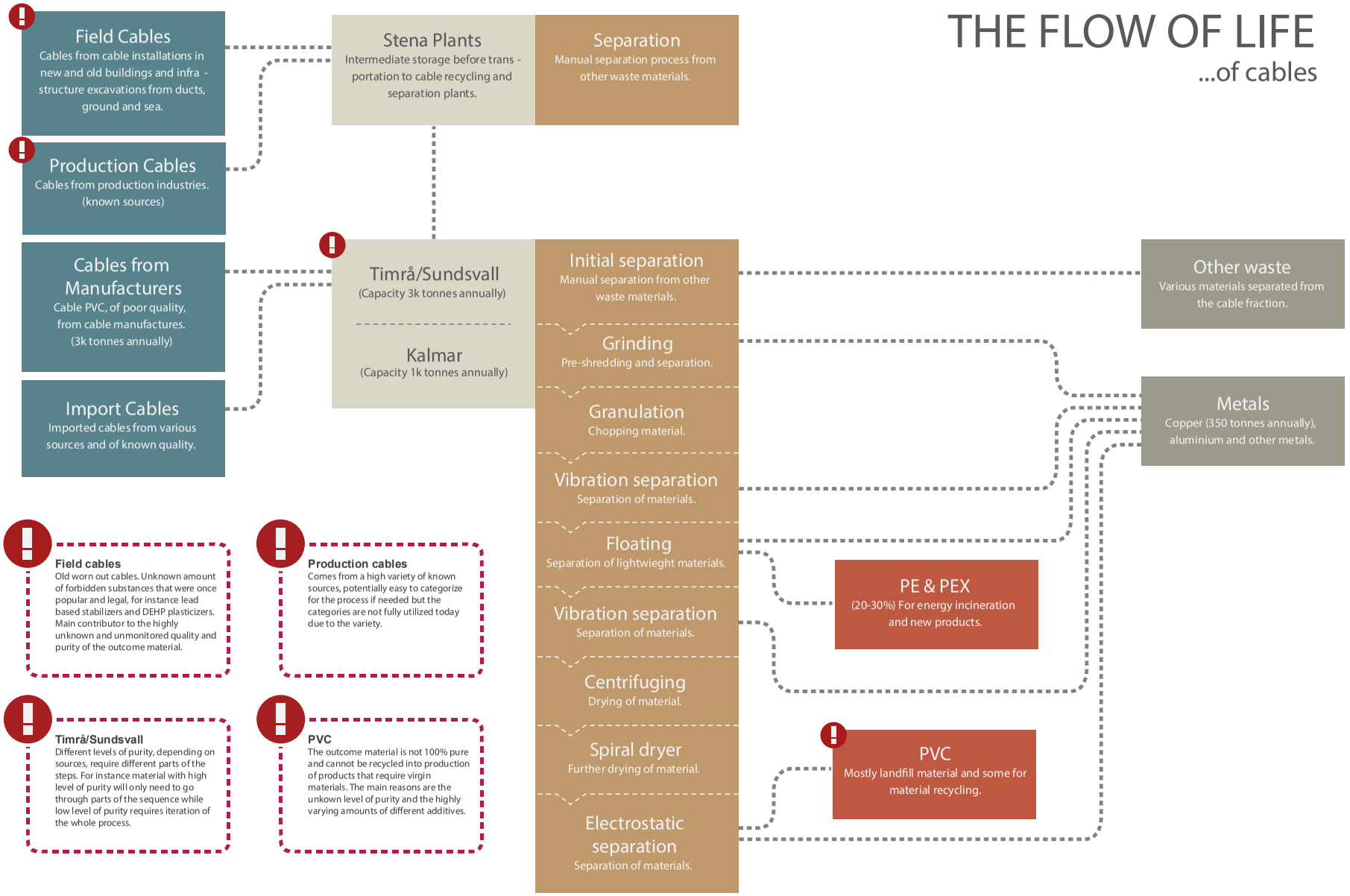


Figure 13. The life cycle of PVC cables

3.1.5 PVC AS END OF LIFE MATERIAL

figure 13. The life cycle of PVC cables

What's recycled?

The recycling process implemented at Stena Recycling AB today has been incrementally refined over the years; the purity level has been greatly increased much thanks to the work of a group of researchers at Swerea IF, Stena and other chemical companies. The recycled material today comes from mainly four different types of sources: cable manufacturers, various production industries, waste importers and general waste handlers.

Cable manufacturers provide, what can be assumed to be, the purest fraction of material. Most of it is production waste that the manufacturers themselves cannot put back into production, but as all the manufacturers are bound to follow all regulations presently in effect it is relatively easy to keep track of what their waste material consists of chemically.

Production industries can be assumed to be the providers of second highest level of purity among the four fractions. Most of the material recycled from this type of provider is spill waste that the providers have no equipment to reuse.

Waste importers provide cables from other countries, some of which are able to track where and when the cables are produced but it's fairly optimistic to assume that the chemicals in the material is 100% known.

The source material also comes from general recycling, in expert terms *field cables*. This fraction is highly untested in regards to the age, source and contents. Some of the material can be manufactured before the current regulations and most of it lack documentation. These three unknown variables make this fraction a high uncertainty in regards to following current regulations.

Where is it recycled?

Cable waste collected by Stena recycling AB is mainly handled by two facilities, situated in Timrå/Sundsvall and Kalmar. Together they have a large capacity for extracting metal from the waste. The majority of the remaining cables is being contained until it can be handled in a more effective and profitable way.

How is it recycled?

As the material arrives at the specialized facilities they often come in big piles of cables mixed with other cable waste. The first step is to hack it up into small enough pieces to separate the metallic components inside the cables. This is done several times, each time into finer grains than previous, in order to gradually extract the remaining metals.

Once enough metal has been extracted the remaining fraction, now mostly plastic, is put on vibration tables of different sizes and inclination to separate the lighter materials from the heavier. The lighter plastics are mostly Polythene of different density and the heavier fraction is PVC. The Polythene separated from this process is then transferred to other facilities to be incinerated for energy production. From these process even more heavy materials, such as aluminum and copper, is extracted.

After the vibration separation the material is put through a floating method. By this time most of the metals should be out, as this method is most effective for separating PE from PVC. PE usually has a density below the density of water while PVC is above which makes this method suitable. The floating method works through a vibration board put in a pool of water, which enhances the separation of plastics.

The PVC contained in the source product is gradually refined into higher purity through repetitions of the three methods mentioned above. After the last sequence of floating method the material is then dried in a centrifugal mechnism and then placed in a spiral dryer. Then the dried up material, consisting mostly PVC, is put through the last method called electrostatic separation which polarizes the particles and separates the remaining metals from the material.

The outcome from this process is the PVC grains of different purity, additives and chemically bound compounds are not separated at all which is why it's important to keep track of the original source of the material and not mix in known material with unknown.

What happens after recycling?

The recycled material is ground into pellets approximately half the size of a grain of rice. Most of it is black due to the predominately black products that are recycled, but there are frequent presence of more colorful grains and sometimes even metallic grains. Nowadays the metallic grains rarely slip through the filtering process so it will become harder and harder to spot the aluminum grains, but the different color mixed in with the black grains will most likely persist. The shape of the grains are roughly cylindrical and has a density of somewhere between 1.35 and 1.45 g/cm3 *(http://www.pvc.org/en/p/specific-gravity-density)*. Since the process is unable to guarantee the purity of the material, it is safe to assume that the recycled grains will be in the higher fraction of, if not slightly above, the density of virgin PVC.

3.1.6 HEALTH AND ENVIRONMENT

Generally speaking, there are five long-term challenges in the current PVC industry: carbon neutrality, closed loop waste management, no build-up of persistent organic compounds, additives with persistent compounds and/or toxic effects and general awareness. In order to meet these demands the industry is highly regulated by governmental units on different levels to strive for minimal impact on health and environment aspects. Since PVC manufacturing is not a very complicated process not much can be done to it besides limiting the usage and thus also extraction of raw material. This is why it is more important to regulated its additives.

Over the years, quite a few notorious additives have been found to be hazardous and are therefore heavily regulated in some countries. In Europe most of these are continuously added into three different regulation databases, REACH, ROP and ROHS. These documents function as guidelines to what should be avoided and regulated in the european union member nations. The regulations and penalties are defined on a national level based on these documents.

The substances regulated in these documents are critical substances in many industries and new substances are continuously added as more substances are analyzed. For PVC industries there are a few substances that are included in these documents *(figure 14)*.
Due to the continuous development of new ways to process PVC, there are new substances added to the industry all the time. Some of these lower the environmental impact, some increases it but many of them are yet to be evaluated and regulated, the trend seems to be leaning towards better substances and harder regulations for the old bad substances. Later this year some of the guidelines imposed by the previously mentioned documents will most likely be converted to European laws/regulations with a central driven penalty system. The guidelines for now, since the general direc-

Laws and regulations for PVC

Type A	0.1% of total content weight		
Type B	Absolute prohibition		
Type C	0..01% of total content weight		
	region	substance	type of regulation
REACH	Registration, Evaluation, Authorisation and Restriction of Chemical substances		
ftalater	SV	DEHP	Type A prohibition for toys and child care products
	SV	DBP	Type A prohibition for toys and child care products
	SV	BBP	Type A prohibition for toys and child care products
	SV	DINP	Type A prohibition for toys and child care products that can be swallowed
	SV	DIDP	Type A prohibition for toys and child care products that can be swallowed
	SV	DNOP	Type A prohibition for toys and child care products that can be swallowed
	EU	Dialkylftalater	Type A
	EU	Di(2-metoxietyl)ftalat	Type A
pigment	EU	4,4'-Bis(dimetylamino)benzofenon	Type A
	EU	4,4'-Bis(dimetylamino)difenylmetan	Type A
	EU	a,a-Bis[4-(dimetylamino)fenyl]-4-fenylamino naftalen-1-metano	Type A
	EU	CI Solvent blue 4	Type A
	EU	TBTO	Type A
	EU	CI pigments	Type A
	EU	2-metoxi-bensenamin	Type A
curing agent	EU	Diaminodifenylmetan	Type A
	EU	MOCA	Type A
flamskydd	EU	HBCDD	Type A
	EU	Alkaner	Type A
POP	Persistant organic pollutants		
Flame retardents	EU	Brominated flame retardent	Type B
ROHS	Restrictions of Hazardous Substances		
	EU	Mercury(Hg)	Type A
	EU	Lead(Pb)	Type A
	EU	Chrome(Cr^6+)	Type A
	EU	Polybrominated Biphenyl	Type A
	EU	Polybrominated Biphenyl Ethers	Type A
	EU	Cadmium	Type C

Figure 14. Laws and regulations for PVC industry

tion of the regulations is to control the amount of certain substances, are to document all substances in raw materials used for new products. This particular demand is not likely to decrease which makes undocumented, uncontrolled compounds such as the "worst" fraction of material provided in this thesis undesirable. Controlled and consistent compounds are and will continue to be very important if the material is to be used as raw material. Controlled because the material will, otherwise, eventually be prohibited. Consistent because the material will otherwise increase the cost of production tremendously.

3.1.7 IMPLICATIONS FOR DEVELOPMENT (SPECIFICATION OF DEMANDS)

The information gathered, presented in previous chapter, included an enormous amount of data that have both direct and indirect effect on the product design work. The information came from many different sources and were initially compiled into one single list of demands (see appendix A). Due to the amount of sources for the information, there were a few conflicting demands as well as dubious demands which had to be addressed. The direct consequence of these initial demands were briefly mapped out in order to set the priority for further development. This initial list of demands was compiled gradually during the ideation phase with workshops and was continually used as checklist for ideas.

At this point, it was also concluded that it would be hard to identify sustainable product designs based on fractions of low purity. For further product development, a decision was thusly made to avoid these fractions and solely base the concepts on fractions with known source and content.

Once the ideation phase of application areas was over the initial list of demands was revised and condensed into a shorter, more comprehensible, version *(figure 15. Specification of demands)*.

The demands were divided into two categories, of which the first contains demands which do not have a direct influence on choice of application areas and the second which directly affect it. The first category of demands were kept for the later development process and the second was used as screening criterias in the following screening methods.

Potential for being realized within five years without excessive resources is one of the most important factors in determining what application area is most needed of an IWtoPD process. The reason being the alarmingly increasing rate of accumulation of this particular waste material, as well as many others. It is a problem that need to be solved as soon as possible both due to economical and environmental incentives.

As well as being realizable, the end product of this IWtoPD process should also have high market

Specification of demands

Priority	Specification	type of demand
2	The product may not contain rest metals on its surfaces	manufacturing specification
1	The source of the material should be known	quantifiable regulation
1	The material should not be processed in temperatures above 210 Celsius	manufacturing specification
2	Production should not contain materials that prolongs the natural degradation of the material	manufacturing specification
2	release of any hazarduos material or additives should be minimized during manufacturing process	manufacturing specification
2	release of any hazarduos material or additives should be minimized after manufacturing	manufacturing specification
1	the quantity of contained substances should be measured	quantifiable regulation
1	potential for being realized within five years without excessive esources	product properties
1	market potential	product properties
2	low manufacturing cost	manufacturing specification
1	safe in regards to health and environmental issues	product properties
2	low environmental impact	product properties
1	easily recollected	product properties
2	potential for being reused as raw material	product properties

Figure 15. Specification of demands, framed demands represent the criteria used in following screening methods

potential due to the enormous amount of material that needs to be disposed of. The environmental impact of the end product of this process is thus directly related to the amount of material that can be used, which is directly based on consumption. Due to the enormous amount of material that need to be recycled, it might not be realistic to create one single application area that will satisfy the gathered amount. In that sense the public exposure value (or marketing value) of the application areas should also be taken into account during development. The optimal product for this purpose should be an example of how the recycled material can be applied in a successful, industrialized and profitable way. Ultimately it is more desireable to create a solution that triggers more industries to develope more reapplication areas than to create one single solution that will solve a mere segment of the situation.

The end product should have a low manufacturing cost as this directly affects how much economical incentives there is behind taking on production of the end product. The less profit there is to the end product the less manufacturers is likely to start producing it which will also affect the rate of consumption. In comparison this demand can be considered secondary as this is only one out of two factors in determining the end product's potential for manufacturing. Along with the inherent value of the product, a ratio of cost/value is believed to determine the potential market interest. But since the inherent value of the product is hard to determine at this point, and very much dependant on later development, evaluation and screening of application areas will be done based solely on estimations of manufacturing costs.

The end product must be safe in regards to health and environmental issues. This demand is based on the relevant regulations and laws imposed by various agencies. It can expressed as two parts, firstly to follow all regulations and secondly avoid conflicts with future regulations. A thourough check with the specific demands needs to be performed as well as a subjective assessment of how exposed the application area is to future regulations. In other words it was important to assess how likely each specific application is to become prohibited, for instance critical conditions in which the material would degrade faster is undesired.

Low environmental impact refers to whether the application area is likely to increase environmental impact or decrease and how much. It is considered secondary since by reapplying the waster material is believed to have a significant effect on decrease of the virgin material's environmental impact.

As PVC cable sleeves is a compound that will not degrade quickly it is also important to recollect the material after use. The application area should thusly facilitate a good recollection system, for instance products with small sizes aimed at ordinary consumers is less desireable than bigger products with incentives to return the product after con-

sumption.

The material should, optimistically, be able to be reused more than once. In other words the less additional substances added to this waste material the better in this regard. It is unfortunately heavily connected to the properties of PVC being tailored for each application area, in this case cable sleeves which is very flexible, and using the material for other purposes would most likely require repurposing the material by altering its properties. Considering said limitations and the fact that the primary goal is to reapply the material, it was deemed secondary for the purpose of choosing application areas.

3.2 IDEA GENERATION

Several cross-disciplinary creative workshops were conducted with a total of 15 participants, both from academia and industry. A thorough review of the workshop structure can be found in Part 1. A selection of the ideas generated in the workshops is presented in section 3.3. For raw data of the ideas, see appendix C.

3.3 SCREENING

3.3.1 METHOD

Initial sorting and first screening - Elimination by categories

The screening phase began with an initial sorting of the ideas from the workshops into different categories to facilitate further handling. The categories were *construction and traffic*, *textile and soft products*, *food and hygiene*, *sport and leisure*, *surface material*, *interior*, *transportation* and *other*. The first screening iteration was done by comparing the ideas against a list of requirements based on the findings from the information gathering. The ideas that clearly did not meet the requirements were eliminated while other ideas where such a decision were not possible to make, due to lack of information, were kept for further investigation. The requirements regarded aspects such as manufacturability, rules and regulations, moral and ethics, environmental issues and health. 67 ideas out of the previous 158 ideas remained after this screening.

Second screening - elimination by marketing value

After elimination of inadequate solutions a second iteration of screening was conducted were the ideas marketing value was evaluated. The ideas that were considered to have an insufficient amount of marketing value potential for this IWtoPD project were not taken through to the subsequent screening iteration. They were, however, kept to serve as potential areas of application for the PVC granulate, which were passed on to Stena Recycling in accordance with the predetermined deliverables. 17 ideas remained after this method.

Third screening - concept screening matrix

A third screening iteration was conducted by use of a concept-screening matrix based on Pugh´s concept selection methodology *(Ulrich & Eppinger, 2005)*. In a concept-screening the first thing to do is to select a reference idea, e.g. the idea deemed to be best beforehand, a competing product or a randomly selected idea. The reference idea are given the value 0 (neutral) for each of the criteria listed in the matrix. The other ideas are then evaluated against the reference idea with regards to the criteria. If an idea is considered to perform better than the reference idea on a certain criteria it is given the value 1 and if it is considered to be inferior it is given the value -1. If there is not enough information to make such a judgement the idea is given a questionmark and the information gap must be filled. When all ideas have been evaluated their total sum is calculated, which are then used to rank the ideas after which decisions are made on whether the ideas should be taken through to the next screening iteration or not *(figure 16. Concepts screening matrix)*. The ideas were compared with regards to the criteria *realizable within five years*, *sales potential*, *manufacturing cost*, *safety*, *environmental impact*, *easy to recollect* and *recycling potential*. 13 ideas out of the previous 17 remained after this method.

Fourth screening - weighted relative decision matrix

For the fourth screening iteration a relative decision matrix with weighted criteria was used. The

Criteria	Alternativ				
	1 (Ref)	2	3	4	5
Requirement 1		0	+	0	-
Requirement 2		+	+	+	+
Requirement 3		0	0	-	-
Requirement 4		0	-	0	0
Requirement 5		-	+	-	-
Sum +		1	3	1	1
Sum 0		3	1	2	1
Sum -		1	1	2	3
Total	0	0	2	-1	-2
Rank	2	2	1	4	5
Decision	Yes	Yes	Yes	No	No

Figure 16. Concepts screening matrix (example)

Criteria	Alternativ				
	3 (Ref)	1	2	4	5
Requirement 1 (w=5)		-	-	0	0
Requirement 2 (w=4)		0	-	+	+
Requirement 3 (w=3)		-	0	+	+
Requirement 4 (w=5)		-	+	0	-
Requirement 5 (w=3)		-	-	-	-
Sum +		0	5	7	7
Sum 0		1	1	2	1
Sum -		16	12	3	8
Total	0	-16	-7	4	-1
Rank	2	5	4	1	3
Decision	Yes	No	No	Yes	Yes

Figure 17. Weighted decision matrix (example)

procedure of using such a matrix is similar to the procedure of the concept-screening matrix used before with the difference of weighted criteria. If the weight factors are determined in an objective way the ideas can be compared with a higher degree of precision than with an unweighted relative decision matrix *(Johannesson, et. al. 2005) (figure 17. Weighted decision matrix)*. The ideas were tested against the criteria *realizability*, *salespotential*, *manufacturing cost*, *safety*, *environmental impact*, *collectability* and *recycling potential*. The idea "Grips for climbing" was used as a reference idea to which the other ideas were compared. 7 ideas remained after this screening.

Evaluation of remaining ideas

The remaining 7 ideas that the previous screening methods resulted in were each evaluated and developed individually. After a quick brainstorming for each idea, product definitions for each of these ideas were vaguely formed in order to prepare for a more thorough evaluation.

Final screening - SWOT analysis

Using the rough product definition, these last ideas were then subjected to a background study with the purpose of establishing which idea(s) to develop further. Studies of competitors, market and rules and regulations were conducted to determine each idea´s potential of becoming a successful product. The information gained from each study was then compiled into a reflective SWOT analysis *(Piercy & Giles, 1989)* to map out where the critical points of each concept is. Ideas were then eliminated based on identified critical threats and/or weaknesses. From this screening the final application area was identified.

3.3.2 ELIMINATION BY CATEGORIES

A complete list of the categorized ideas can be found in Appendix C. The method resulted in 7 categories which represents the 7 domains of ideas previously mentioned in chapter 2.

The 7 categories, or domains, were the following:
- Interior(buildings)
- construction and traffic
- Sport and leisure
- Transportation
- Textile and soft products
- Food and hygiene
- Surface material

The ideas, once categorized, were than subjected to a quick screening, using the previously mentioned criterias and the remaining ideas were then compiled into one final table (*figure 18. Elimination by categories)* as result of this method. Most eliminated (implausibe) ideas, based on background information, were found in categories such as food and hygiene and textile/soft products. There are many unaddressed risks with using this material with food and hygiene which led to a swift elimination of most ideas in this category. Due to the relatively high density and challenge of creating a smooth and thin geometry of this material, ideas categorized as soft products were quickly eliminated as well. More ideas were generated in the interior and construction categories than others as expected.

Through this process 67 ideas were filtered from the previous 158 ideas

Elimination by Categories

Interior	Construction and Traffic	Sport and Leisure	Transporta-tion	Textile and Soft products	Food and Hygiene	Surface material
Light moveable structures for wall and floor (furniture), Screenwalls	Traffic dividers	Workout equipment	Pallets	Material for seating	Products for cleaning	Fender
Fence	Acoustic panels	Vibration protection	Shippingboxes	Material for protective equipment		Protection for cyclists
Folded or rolled carpets	Bus stop	Noise protection	Package solutions	Ties		Facade material
Outdoor furniture	Billboards	Bicycle racks	Distance pads for pallets	Ropes		Flooring material for cues
Flooring for exhibitions	Door moldings	Surface material for sport halls	Packing or wrapping			Flooring material behind cash desks
Rolled flooring material	Bumper, Impact protection	Equipment for horses, Hors jumping				
Soft flooring material	Sound and heat isolation	Handles				
Bulletin board	Slabs for advertising	Weights for heavy lifting				
Heavy public furniture (parkbench)	Soundproofing	Climbing grips				
Indoor furniture	Soundproofing under wooden floors	Filler material in rubberbags				
Handles	Sockets, outlets	covers for computer				
Gripping material	Aids to navigation at sea	Tools				
Tiles	Temporary shoreline protection	Bicycle saddle				
Shelves	Roof tiles					
Storage unit	Gutters					
Impact protection for Ipad/HDD	Flood protection					
Wheels to office chair	Anti-slip protection for carpets					
Frames	Roadside marker					
	Dock protection, bumper material					
	Outdoor staircase					
	Tiles for garden					

Figure 18. Results of Elimination by categories, see appendix for unscreened ideas.

3.3.3 ELIMINATION BY MARKETING VALUE

figure 19. Elimination by marketing value

Once subjected to the elimination by categories, the remaining application areas were put through an elimination. The main criteria for this elimination was how much marketing value each application area can be expected to possess. The marketing value of each application is estimated by the potential for public exposure of the material and potential for being perceived as a positive product once the application area is developed into a product. The potential for public exposure is vital in promoting more use of the waste material and can be physical exposure of the material or simply conversational exposure (envokes dialogs about using the waste material). Realistically, due to the enormous amount of waste collected, one application area will most likely not be able to consume the same amount of material as collected.

Therefore, the likelihood of the pioneering application areas will be considered as promoting agents for reapplication for the area must be addressed. The pioneering products should, preferably, trigger even more projects and products revolving this particular product. For example commonly used objects such as fence, different panels and flooring solutions have higher exposure than using the material as isolation material or components in other products.

Each application area was considered for this aspect and the ones believed to have low marketing value were eliminated. Eliminated ideas are marked with an asterix in *figure 19. Elimination by marketing value.*

Through this elimination 17 ideas remaind out of the previous 67. Many ideas were eliminated at this time due to the limited exposure that the applications areas imply. In particular ideas that involved putting the material inside other products, thus hiding the material all together, were deemed inferior in this particular aspect.

3.3.4 CONCEPT-SCREENING MATRIX

figure 20. Concept-screening matrix

The remaining 17 ideas were then subjected to screening using the predetermined criteria, derived from specification of demands. Each application area was compared to a reference, in this case fence, in order to establish a ranking among these application areas. According to the criteria, 13 of these ideas were deemed better than the reference in this method. The reference and the three inferior ideas were eliminated in this screening to preserve a reasonable number of plausible ideas..

3.3.5 WEIGHTED RELATIVE DECISION MATRIX

figure 21 Weighted Relative decision matrix

The 13 remaining ideas were evaluated through a weighted version of the previous matrix, i.e. same criteria but with weighting corresponding to the priority in specification of demands. With 3 criteria lowered in priority and storage unit as the new reference, 7 of the ideas remained plausible and potentially interesting. These ideas were then moved into the next phase, each idea were given time for futher investigation before following screenings. Description of each idea can be found in next section.

Elimination by marketing value

Interior	Construction and Traffic	Sport and Leisure	Transportation	Textile and Soft products	Food and Hygiene	Surface material
Light moveable structures for wall and floor (furniture), Screenwalls	Traffic dividers	Workout equipment	Pallets	*Material for seating	*Products for cleaning	*Fender
Fence	Acoustic panels	*Vibration protection	*Shippingboxes	Material for protective equipment		*Protection for cyclists
*Folded or rolled carpets	*Bus stop	*Noise protection	*Package solutions	*Ties		*Facade material
Outdoor furniture	*Billboards	Bicycle racks	*Distance pads: pallets	*Ropes		*Flooring material for cues
Flooring for exhibitions	*Door moldings	Surface material for sport halls	*Packing or wrapping			*Flooring material behind desks
*Rolled flooring material	*Bumper, Impact protection	*Equipment for horses, Hors jumping				
*Soft flooring material	*Sound and heat isolation	*Handles				
Bulletin board	*Slabs for advertising	*Weights for heavy lifting				
*Heavy public furniture (parkbench)	*Soundproofing	Climbing grips				
*Indoor furniture	'Soundproofing under wooden floors	*Filler material in rubberbags				
Handles	*Sockets, outlets	*Protective covers: computer				
*Gripping material	*Aids to navigation at sea	*Tools				
*Tiles	*Shoreline protection	*Bicycle saddle				
*Shelves	*Roof tiles					
Storage unit	*Gutters					
*Impact protection for Ipad/HDD	*Flood protection					
*Wheels to office chair	*Anti-slip for carpets					
*Frames	Roadside marker					
	*Dock protection,					
	*Outdoor staircase					
	Tiles for garden					

Figure 19. Elimination by marketing value, colored ideas were eliminated.

Concept screening matrix

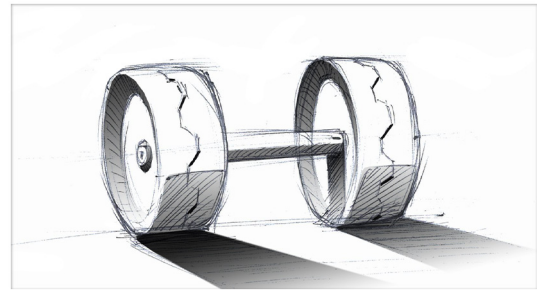
Idea	Realizable within five years	Sales potential	Manufacturing cost	Safety	Environmental impact	Easy to recollect	Recycling potential	Total	Rank	Decision
Fence (Reference)	0	0	0	0	0	0	0	0	6	no
Light moveable structures for wall and floor (furniture), Screenwalls	0	1	-1	0	0	1	-1	0	6	no
Outdoor furniture	0	0	0	-1	1	1	0	1	5	yes
Flooring for exhibitions	0	-1	1	0	-1	1	1	1	5	yes
Bulletin board	0	-1	1	1	0	-1	1	1	5	yes
Handles	0	0	0	-1	-1	-1	-1	-4	7	no
Storage unit	0	1	1	1	1	1	1	6	1	yes
Traffic dividers	0	1	0	1	1	1	1	5	2	yes
Acoustic panels	0	1	0	1	1	1	1	5	2	yes
Roadside marker	0	-1	0	0	1	1	1	2	4	yse
Tiles for garden	0	0	1	0	-1	0	1	1	5	yes
Workout equipment	0	0	-1	1	-1	1	1	1	5	yes
Bicycle racks	0	0	0	1	0	1	1	3	3	yes
Surface material for sport halls	0	1	1	-1	1	1	0	3	3	yes
Climbing grips	0	-1	1	-1	-1	1	1	0	6	no
Pallets	0	1	1	0	1	1	1	5	2	yes
Material for protective equipment	0	1	1	1	0	-1	-1	1	5	yes

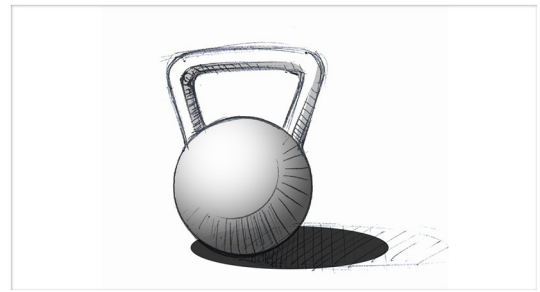
Figure 20. Concept-screening matrix

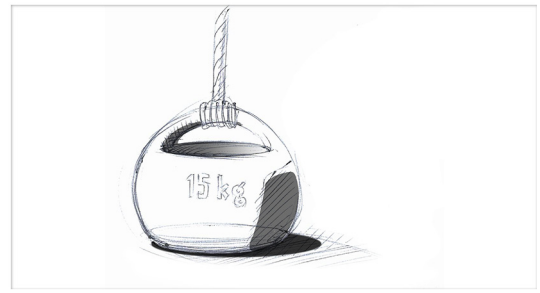
Relative decision matrix - Weighted

Idea	Realizable within five years	Sales potential	Manufacturing cost	Safety	Environmental impact	Easy to recollect	Recycling potential	Total	Decision
Weight	2	2	1	2	1	2	1	11	
Storage unit(referens)	0	0	0	0	0	0	0	0	
Roadside marker	0	-2	1	0	0	2	-1	0	
Outdoor furniture	0	0	0	2	-1	2	1	4	Yes
Flooring for exhibitions	0	-2	1	2	-1	2	1	3	Yes
Bulletin board	0	-2	0	-2	-1	-2	0	-7	
Traffic dividers	0	0	1	0	0	0	1	2	Yes
Acoustic panels	0	0	1	2	0	0	-1	2	Yes
Tiles for garden	0	-2	1	2	-1	-2	1	-1	
Workout equipment	0	-2	0	0	0	2	1	1	Yes
Bicycle racks	0	0	-1	2	0	2	-1	2	Yes
Surface material for sport halls	0	-2	0	-2	-1	-2	-1	-8	
Pallets	0	2	1	0	1	2	0	6	Yes
Material for protective equipment	0	2	1	0	-1	-2	-1	-1	

Figure 21. Weighted Relative decision matrix







3.3.6 PRODUCT DEFINITION OF THE 7 POTENTIAL IDEAS

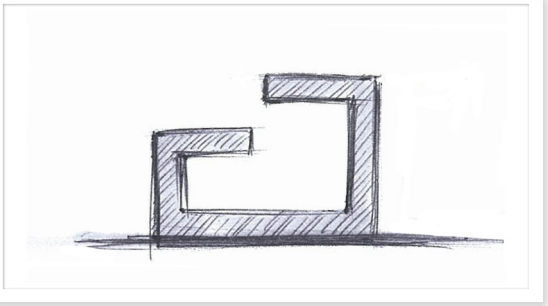
These 7 last potential ideas were translated into a different product solutions, each described below with the exception of acoustic panels. Acoustic panels were later chosen as the final application area and is further described in later chapters.

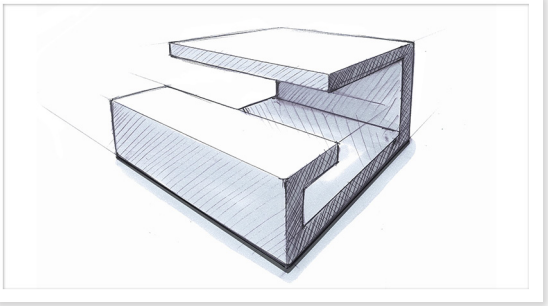
Exercise equipment

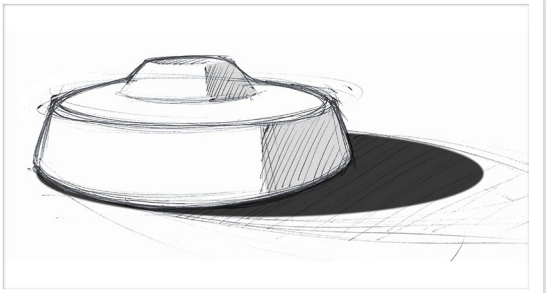
The bulky nature of PVC cable sleeves material implies that it might be suitable for exercise equipment. Existing exercise equipment consists of material such as iron, rubber and bronze. Many of the free weights on the market have some sort of metal core with rubber coating. The rubber is mainly used because it reduces noise when weights are dropped on the floor or clash together. The density of PVC is lower than the density of metal used in free weight applications and would therefore result in much larger weights (approx. 5,66 times larger), which might be a problem. (http://www.engineeringtoolbox.com/density-solids-d_1265.html) Perhaps other types of workout equipment could be an alternative option. For example, outdoor training stations have increased in popularity many of them lack free weight-like equipment.

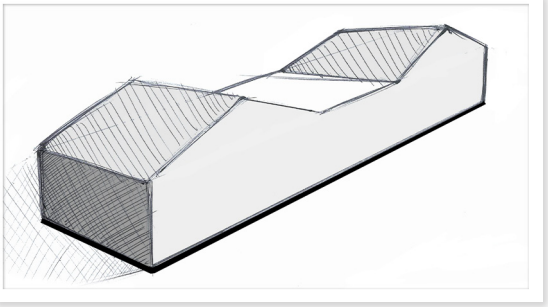
Outdoor furniture

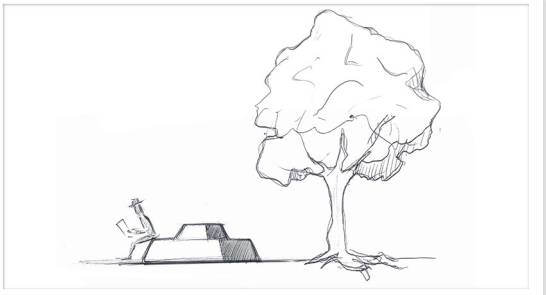
Outdoor furniture is an application area that already uses recycled PVC. However, the PVC used is mainly from production scrap and therefore results in smoother surfaces than what is possible to achieve using field cables (unless it is melted which should be avoided). It might be possible to niche the product to avoid the surface discussion and the heavy competition that exists on this market. Since recycled PVC is already used in this application area it is possible that the price margins, which is a big incentive for this type of product, are not as big as in other areas.

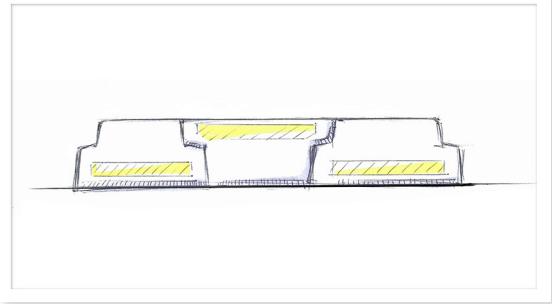






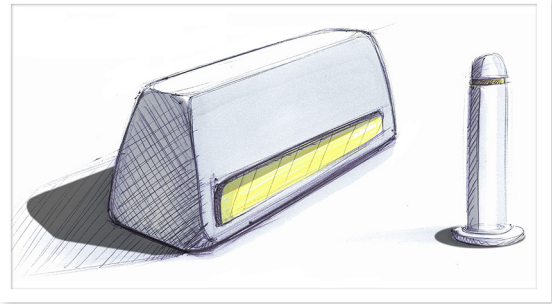






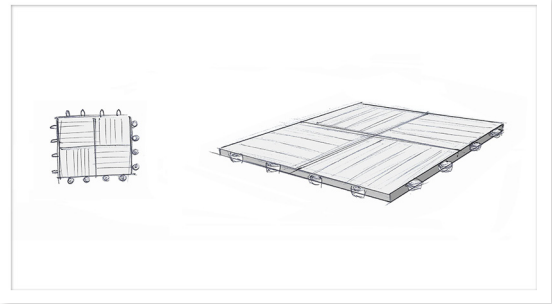
Traffic divider

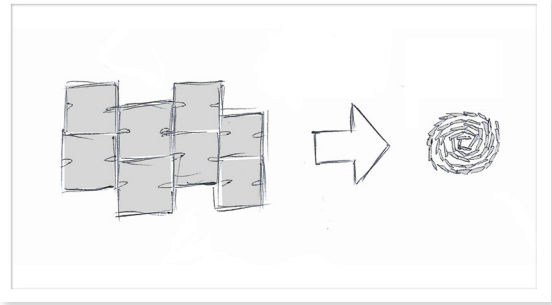
The high density of PVC in combination with the large quantities of material available makes it suitable for large solid applications, such as traffic dividers. It could for example be used as temporary traffic dividers adjacent to ongoing roadwork or more permanent applications such as car barriers on bicycle lanes. Applications like these could be constructed in a way that would minimize the damage if cars or cyclists were to collide with them.



Flooring material for exhibitions

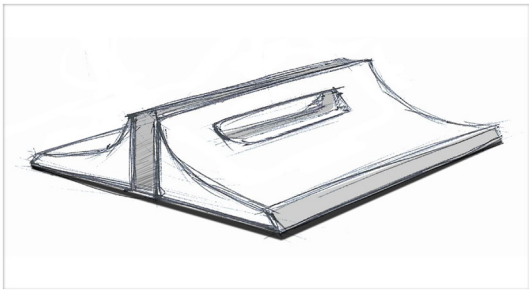
The softness and the anti-slip (frictional) qualities of the cable PVC indicate that it might be used as flooring material in various contexts. A modular flooring solution could be used in exhibitions, on festivals, in cues, and the like.





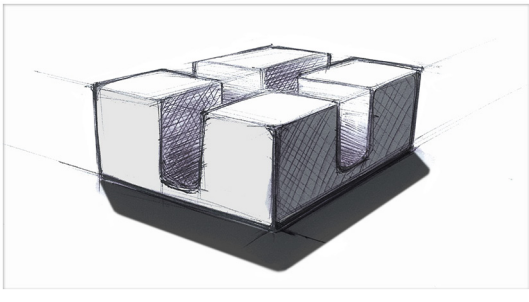
Bicycle racks

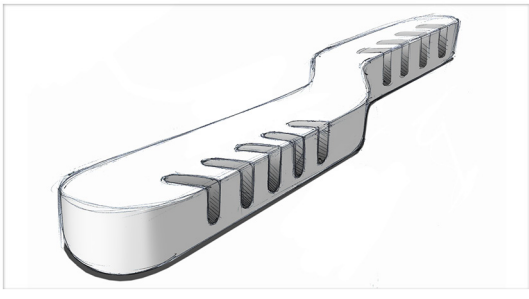
A different application for the PVC material could be to use it for bicycle racks. If granulate of the right composition (restrictive use of plasticizers) are pressed together it might be possible to create shapes with enough strength and durability to serve as bicycle racks. Preferably the bicycle racks are placed under roof to be protected from weather degrading effects.



Pallets

A lot of goods today are being transported on wooden pallets. The weight of a wooden pallet is greater than the weight of a plastic pallet. Of course the wooden pallets are largely biodegradable contrary to the plastic pallet. However, if the plastic pallets were to be made from recycled PVC the environmental advantage of wooden pallets would not be as obvious. It might also be possible to add functionality to a PVC pallet that would make it a viable alternative to wooden pallets. Such functionality could be use of dividers and modular composition to enable more goods to be transported at the same time and thereby increase transport efficiency.





3.3.7 SWOT ANALYSIS

figure 22. Elimination by SWOT

A brief market and background research of each of the previously described application areas showed that each have different strengths and weaknesses. Four of these ideas had unfortunately shown potential for running into critical threats/weaknesses and were thus not chosen for further development.

Sporting goods market have shown that there are only a handful of manufacturers and the market seems already saturated, thus not allowing a lot of room for big changes in regards to new competitors on the market or one of the manufacturers deciding to make a big product change in a saturated market.

Temporary flooring market has proven to be mainly run on leasing basis since it is not a product of high consumption rate. Therefore a low material usage can be expected here and is not desirable for the purpose of reapplying large amounts of recycled material.

Bicycle stands on the other hand tend to have long lifespans and low level of market demand, which makes the consumption rate reasonably low as well. Thus not suitable for the purpose of reapplying large amounts of recycled material either.

Freight pallets, while very desirable in regards to amounts of material used and ease of manufacturing and handling, come with an inherent risk of travelling unexpected distances and encountering many different systems of recycling. It can thusly be expected that the risk of a freight pallet not being recollected or recycled expectedly is very high. In particular if it travels abroad.

Elimination by SWOT - final 7 products

Based on quick market research on Swedish market, elimination by critical weakness/threat

Product	Strengths	Weaknesses	Opportunities	Threats	Further investigation
Sport equipments	The material is already made to be with-stand weather and is very stable	not a well developed market, could be low demand	potential for more expansion with more and better solutions	few established manufacturers already occupying the curent market	No
Acoustic panels	increasingly popular to accomodate acoustic demands in offices with visual products	Current materials used for this type of products have better acoustic properties	this material is suspected to be cheaper and more environmental friendly	growing trend of avoiding PVC products, needs to show clearly that it's recycled	Yes
Outdoor furnitures	The material is already made to be with-stand weather and is very stable	aimed at individual consumers, harder to recollect	potential to convince many manufacturers to use this material	Many competitors on the current market are using recycled PVC	Yes
Road construction equipments	The material is already made to be with-stand weather and is very stable	well explored market in some regions	potential for more visually pleasing con-crete blocks on roads	limited use of material	Yes
Temporary flooring (i.e. For events)	the material looks better than current competitors(white tiles)	already exists at leasing capacity	Easy to make a more outstanding product than competitors	not enough use of material	No
Bicycle stands	Few competitors	long lifespan which means slow consump-tion	potential for making special stands for marketting purposes	purchase may be done by municipalities which can mean slow consumption	No
Freight pallets	fast consumption of material	Subject to very specific material regula-tions	high consumption in export	very hard to recollect once abroad	No

Figure 22. Elimination by SWOT

3.3.8 THE NECESSITY OF PRODUCT DEVELOPMENT

The remaining three application areas were all deemed highly plausible for reapplying the material, but as this project is about IWtoPD process a choice had to be made regarding which of the ideas should be further developed. This posed a fundamental question, what happens to the other ideas that were eliminated during this process. It is likely that many of the ideas can actually be realized without going through a thorough product development process. In which case, is product development absolutely necessary for the purpose of reapplying industrial waste?

The answers is of course related to how receptive the potential market is to use of this particular material, how attractive and competitive the end product is in the market and much more. Due to the limited resource at hand for this project, a decision was made to focus the further development on one of these three application areas. The final application area of this extensive screening process was then decided to be acoustic panels. With this in mind, an extra deliverable was added to this project at this point to avoid wasting the other potentially valuable ideas.

These ideas, despite being eliminated, were recognized as plausible for reapplication. They can potentially be realized without an extensive product development process and require a different further investigation to be realized. These were compiled into a list (*figure 23. Ideas suited for actions outside product development)* as a secondary outcome from the screening process before carrying on with the development of acoustic panels.

Ideas suited for actions outside product development

Ideas worth investigating for possible business pursuits without the help of product development

Product	Description	Suggested action
Sport equipments	replacing current material used for non-supporting elements in equipments both out-doors and indoors, i.e. Weights, seats etc.	investigating the potential with one of the major manufacturers
vibration absorption for electronics	replacing current materials used for this purpose	investigating the potential with one of the major manufacturers
construction material (heat isolation)	filler materials in walls etc	testing and confirming the safety of this material for this purpose and replace current material
construction material (abrasive absorption)	i.e. Blocks at harbours that separates boats from the walls	testing and confirming the safety of this material for this purpose and replace current material
Temporary flooring (i.e. For events)	visually pleasing and enduring flooring tiles for temporary use	Start a competitive leasing service of this product with another manufacturer that can process this material
Bicycle stands	specialized stands that can represent a municipality or company	investigating the market potential further
Freight pallets	replacing current materials used for this purpose	investigating and detailing the relevant regulations for this type of products
Flooding protection	sack of this material for flooding protection	testing and confirming the safety of this material for this purpose and replace current material

Figure 23. Ideas suited for actions outside product development

3.3.9 FINAL APPLICATION

As the screening process ended, the one application area that was deemed most plausible to make a big impact was acoustic panels. The market for acoustic panels are currently benefiting from the growing trend of thoughtful interior design and its connection to acoustic design. Office landscape and public space planning in particular are nowadays including acoustic design to a much broader scale than before and more resource is put into creating a pleasant room for the users/habitants of these locales.

Office landscapes nowadays often include big rooms accommodating many people at the same time, which sets a high requirement for good privacy without seclusion between workers. The reason for this is to increase the workers' performance with a good social environment that also allows focus if needed. In comparison to "older" office designs where interiors were often divided into either cubicles and private offices, an open office landscape design is much more popular due to it often decreases the hierarchical feeling and facilitates vertical communication in an organization *(Jacobsen, 2002)*.

Public space planning on the other hand has not changed as much, it is still very much about how to make a big space functional. In particular big public space indoors, that tend to be used for big events and houses a large amount of people, tend to require a good acoustic setting that absorbs sounds and removes the enormous amount of reverberation that otherwise would create an undesired disturbance to the event.

Currently there are good solutions to the aforementioned problems. Often these are panels of different materials mounted under the ceiling or on walls. Offices in particular tend to cover the whole ceiling with acoustic panels and separate the panels a bit from the ceiling. Typically the acoustic panels used today, due to cost and function reasons, are made of light plastic granules, wood granules or fibrous minerals. These solutions share one common characteristic, which is porous structure. More ways of acoustic design will be described in following chapters.

As the current solutions tend to be mounted onto walls and ceilings, they have low mobility and is bound to the original architectural design of the room which leaves the interior design almost no flexibility. A large open office space for instance has no good ways to dividing the office space using only the aforementioned acoustic panels. This is normally solved with movable screens that separate different areas. These screens are usually made of two layers of fabric separated by a frame, the acoustic performance is thus much lower than the mounted acoustic panels. Yet these screens are very popular for both office settings and public event settings due to its mobility and flexibility. Therefore a need for flexible acoustic solutions with high acoustic performance exists and it seems plausible that, due to its materialistic properties, PVC granules can be used to manufacture a competitive solution that is both high performing and cheap.

The application area is, thusly, an acoustic panel that can be used as room separator with the following functions:

- Good acoustic performance to separate sounds by absorption and diffusion from both sides.
- Good flexibility in regards to adjustable absorption levels and size.
- Good mobility, movable in a room.
- Visually pleasing, discrete and non-disruptive.

3.4 CONCEPT DEVELOPMENT

3.4.1 METHOD

Based on the definition of application area, mentioned in previous part, a rough development plan was drawn to include an investigative phase, a concept generation phase and an evaluation phase. Due to product being outside of the project team's area of expertise, regular consultation with acoustic experts were conducted along with an iteration of these three phases. Consultation interviews were done with an acoustic analyst consultant at Semcon, program director at sound and vibrations masters at Chalmers University of technology, a masters student at the same program and two plastic manufacturing experts at Swerea AB.

Initially a general literature study was done on acoustic design principles, potential manufacturing methods and existing acoustic panels to lay grounds for a general understanding of how acoustic designs work. Once a general understanding was achieved, a list of guidelines was compiled for concept generation. Concepts were then generated according to these guidelines, most of the concepts were initially focused on form design as the product definition, material properies and acoustic design guidelines together gave little room for other aspects of changes at this stage.

Form studies were then conducted using mock up prototyping, sketches and research of similar products. After which ideas were generated with the principles of cheap manufacturing cost, easily mass-produced, easily transported and visual originality. The form studies were conducted in short iterations, after each a brief evaluation of the concepts was done according to the four principles and consultation with experts were done to confirm the potential functions and manufacturing methods. After each iteration the list of guidelines were slightly updated until the final form was defined. Early iterations were done to define the product form on a trial and error basis as limited resources were given to conduct thourough studies in architectural acoustic design. While later iterations were focused on how to manufacture the desired form and a construction with high strength.

figure 24. Development process

Development process

Acoustic panels

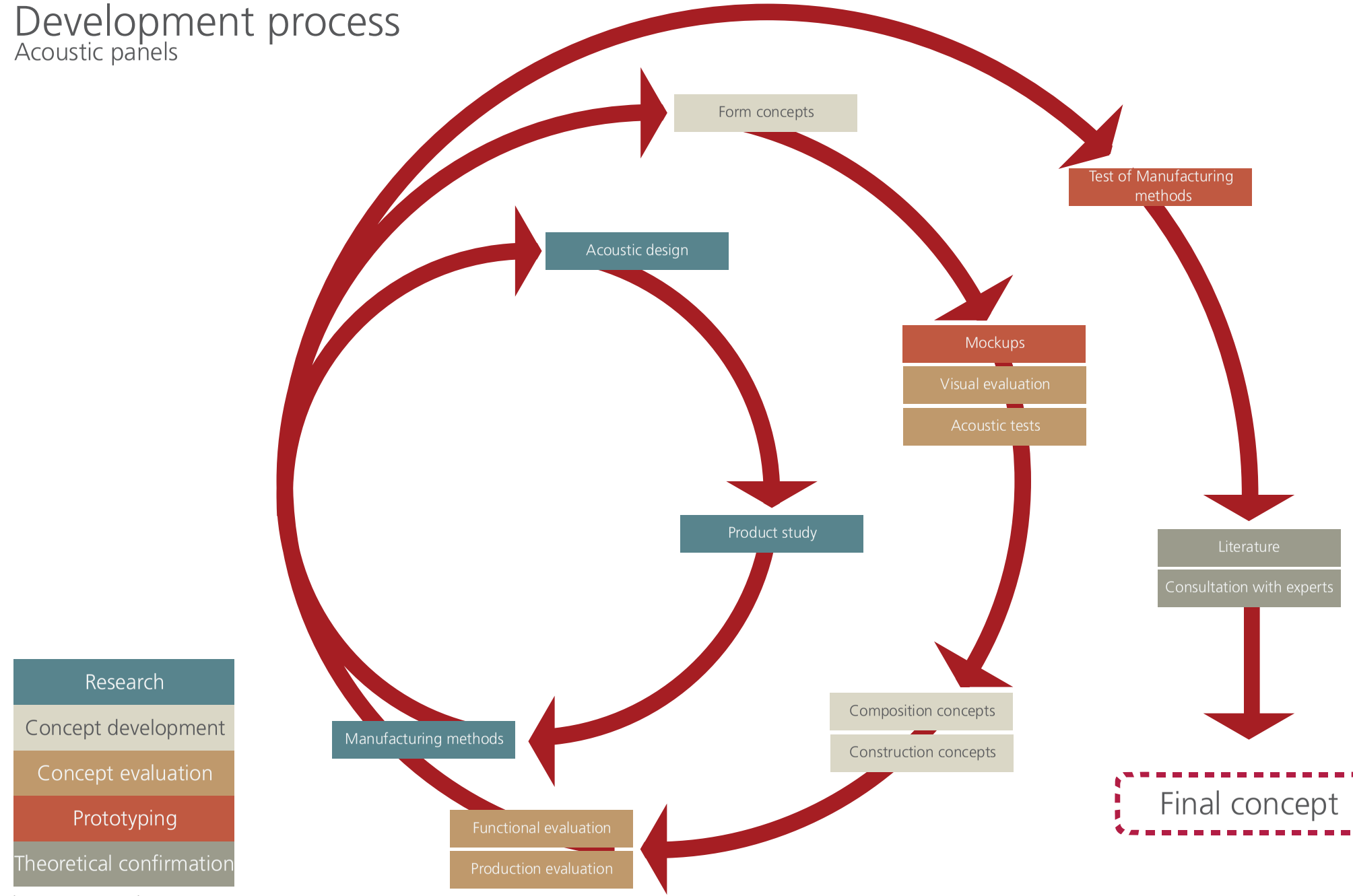


Figure 24. Development process

3.4.2 ACOUSTICS THEORIES

Absorption and reverberation

Contrary to residential spaces, public commercial spaces usually present different design related issues in regards to acoustic performance. This is due to the higher possibilty of the structure to contain a central air flow unit, more mechanical equipments and more stories than a residential building. The acoustic demands of commercial spaces can vary depending on the architectual plan but it usually revolves around speech privacy levels and ambient sound levels (Long, 2006).

Speech and ambient sound differ in frequency and needs to be treated separately. There are few ways to tackle this particular problem; control the sound source, increase the sound attenuation and increase the masking sound level (marshal long). Masking requires additional sound source equipments and will not be treated in this project, controlling the sound source is also outside the limits of this project. This leaves attenuation as design alternative. Attenuation can be divided into absorption or reverberation. Each of which have different principles to be followed in acoustic design and is usually done by professionals in combination with architectual planning. All geometrical measurements and surrounding equipments need to be taken into account for an accurate calculation and design. Which in practice leaves little room for adjustments once the space is actually being used.

Speec privacy level is described by Marshal Long *(2006)* as the following:

[Source sound level]-[sound attenuation]-[masking sound level]=[signal to noise ratio(privacy)]
Where the sound attenuation is achieved by absorption equipments and masking sound is produced by masking equipments (Marshal Long). In an office space acoustic design should be aimed at speech privacy and ergonomical ambient sound level. In practice this means speech should be absorbed between intended divisions of a room, to a degree that allowes separate conversations on each side of the absorption mechanism undisturbed by each other. It also implies that low frequency sound in commercial environments should be absorbed as much as possible to create a working environment with good acoustic ergonomics.

For use of acoustic screens, the goal is to subdivide an open space and maximize the sound attenuation between them to control local build-up of reverberations and noise levels. The screen should, according to (the Armstrong guide to building acoustics), aim at the following:
• screens should be placed closer to the sound source than the receiver
• minimizing the free height above the screen and use sound absorbing ceiling
• avoiding and minimizing gap between screens and surrounding objects
• avoiding and minimizing gap between the screen and the floor, well carpeted floor is to be prefered

Different principles of sound absorption

There are several ways to absorb sound, the basic principle is loss of energy by use of different mechanisms. The reduction of energy is generally due to convertion into thermal energy by friction. The different absorption mechanisms are resonant, porous and panel absorbers. Each of these mechanisms are effective for absorbing different range of frequencies and are used for different purposes *(The Armstrong guide to building acoustics, 2006)* (*figure 25. Absorber response curve)*. Porous absorbers are typically more effective against middle to high frequencies, the interconnected voids of

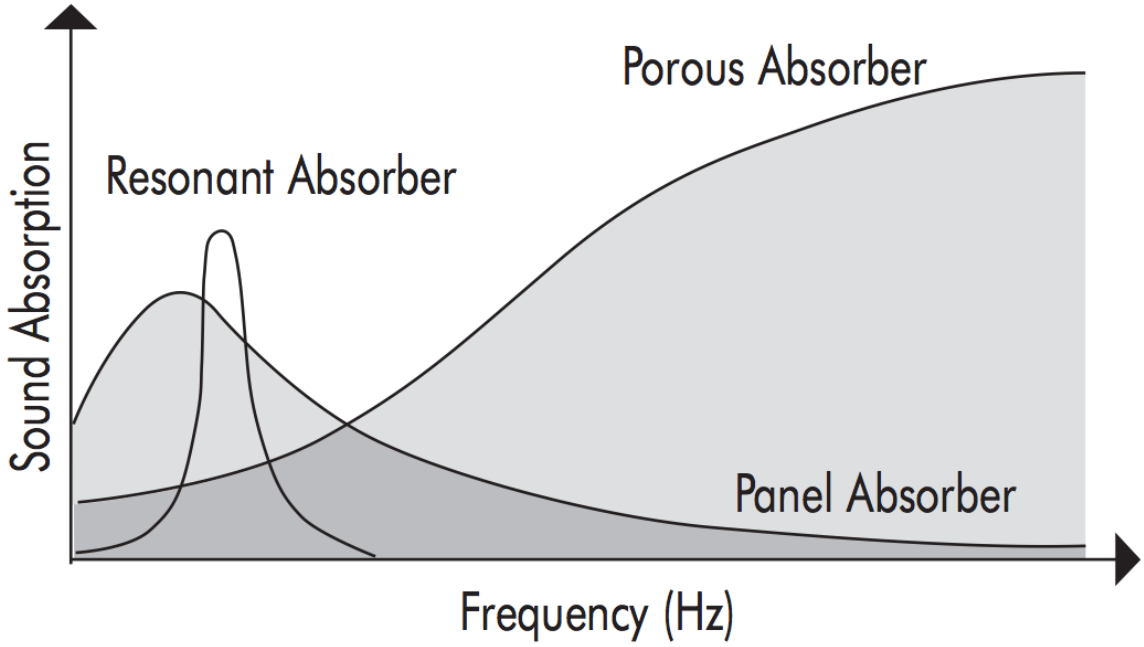


Figure 25. Absorber response curve (The Armstrong guide to building acoustics, 2006)

the material structure creates a large amount of surfaces with which sound waves can interact and cause friction. Resonant absorbers are generally more effective against specific frequencies by using an enclosed cavity with narrow opening to cause resonance with the targeted range of frequencies. Resonant absorbers can be used in combination with porous absorbers in the cavity to broaden the targeted range. Panel absorbers have a maximum effective frequency at 500 Hz and work through a thin rigid panel that causes friction when set into vibration by sound waves *(The Armstrong guide to building acoustics, 2006)*. Practical applications in architectural design of porous and resonant absorbers are further described below, while panel absorbers will not since it is suspected to be imcompatible with the material properties of PVC.

Porous absorbers

Porous absorbers are highly dependant on the material properties of the absorbers. Typically higher porousity and higher thickness implies large friction surface, while the materials flow resistance is also an important factor. Thickness of the absorber needed for complete absorption of a specific range of frequencies can be calculated but is often very high and not suitable for use in residential or commercial environments. (Armstrong) For acoustic design in buildings the aim should thus be as thick as possible without compromising other aspects such as aesthetics and space management. As the material is already determined in this project, the flow resistance of the material leaves little to no room for adjustments and can be disregarded. Which leaves the porousity of the end product the most important factor. The more porous the end product is the better the sound absorption performance. *figure 26. Porous absorber*

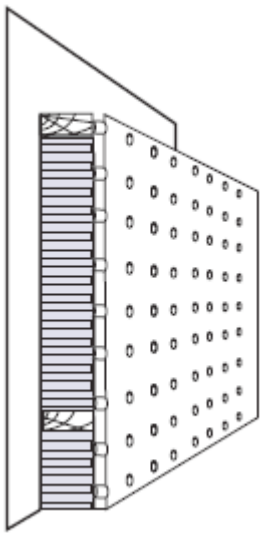


Figure 26. Porous absorber

Resonant absorbers

Also known as Helmholtz resonators, resonant absorbers are usually implemented in buildings to absorb the low frequencies emitted by mechanical equipments *(The Armstrong guide to building acoustics, 2006)*. One of the typical ways to do so is use a perforated panel separated from the back wall or ceiling. The space between the panels and the

structure behind acts as the enclosed cavity and the panels as narrow openings (*figure 27. Resonant abosorber)*. This is sometimes combined with using a porous absorption panel inside the cavity to absorb a broader range of frequencies.

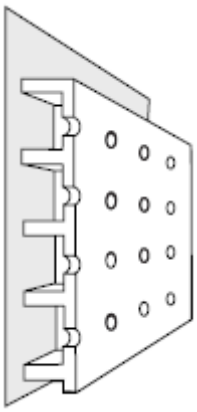


Figure 27. Resonant abosorber

Different principles of reverberation

In addition to absorption, controlled reverberation is also prefered in buildings. More specifically scattering of sound, or diffusion of sound. Scattering the sound in multiple directions increases the length of the path sound travels and decreases the tendency to direct reverberation of sound (echo). In architectural design this implies different depth and angles should be implemented in the acoustic design mechanisms, such as panels. (*figure 28. Principles of reverberation)*

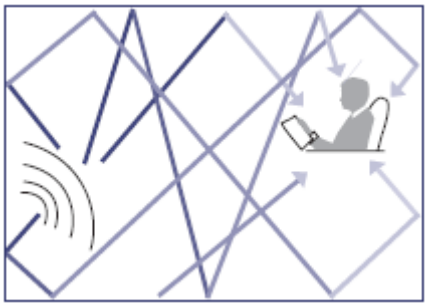


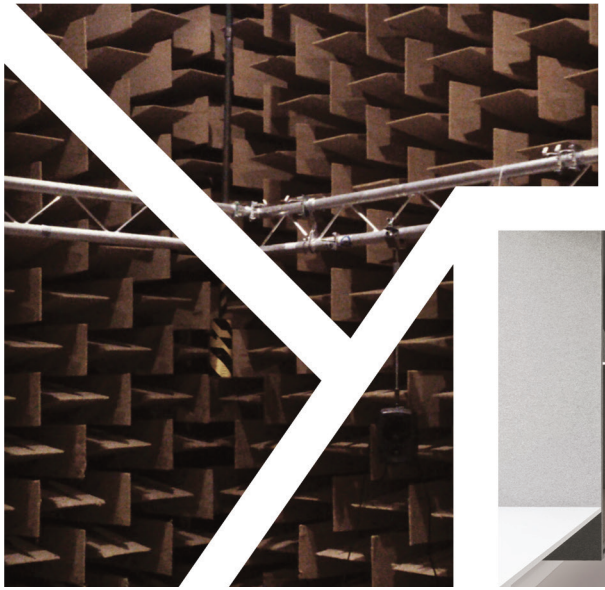
Figure 28. Principles of reverberation

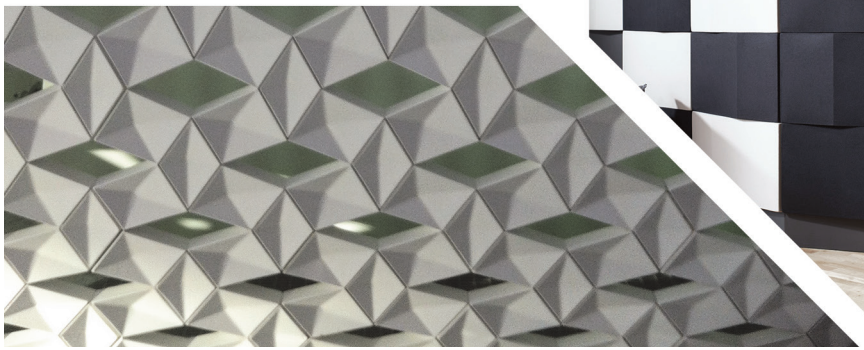
3.4.3 ANALYSIS OF EXISTING PRODUCTS

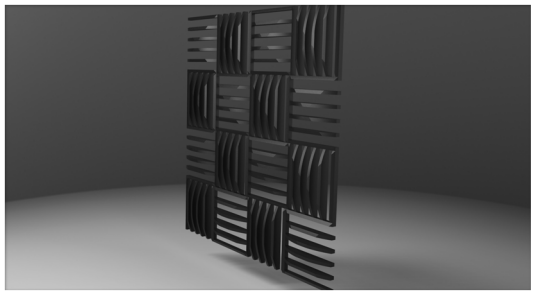
In addition to studying the basic principles of acoustics in commercial space, a product study of existing solutions was conducted. There are many inspiring ways for creating a good commercial environment with desireable acoustics performance. Many of which are using soft, porous and large coverage types of solutions. But what seems to be a challenge from the product study is how to create a good looking acoustic panel and manufacture it at an industrial scale without losing its functionalities.

What can be seen in many successful products is high visual novelty with some kind of ingenious functionality behind the visual aspect. Many of these products have also chosen to target a specific range of frequence. In general, current acoustic panels can be divided into two types. One where high speech privacy is sought after and one where absorption of ambient noise of lower frequency is targeted. The first one is usually implemented in office booths separation and the latter wall mounted solutions.

EXISTING PRODUCTS







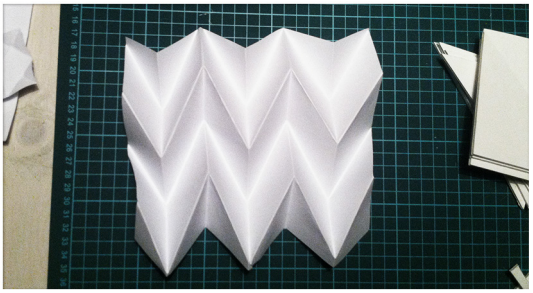
3.4.4 FORM DESIGN DEVELOPMENT

In order to find the desired combination of form and function an iterative process of digital mock-ups, physical mock-ups and testing was conducted. Many ideas were generated through various means with the purpose of finding how to incorporate the aforementioned acoustics theories into physical products. In general the guidelines for said process was to create a fair balance between aesthetic pleasure and function. This process resulted in mainly three different directions: blinds solutions, modular solutions and origamic structures. Result is described below .

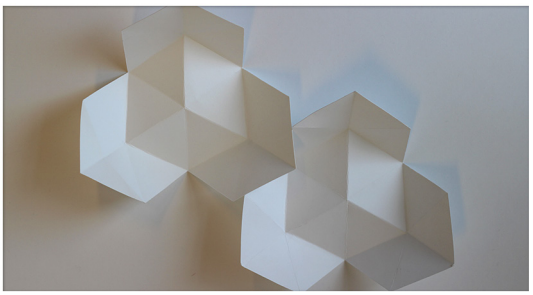
Blinds

Blinds solutions was one of the first things that came to mind, reason being that for optimal acoustic function are often covering the source very extensively. This affects the lighting environment in a commercial space and could be deemed one of the large downsides to acoustic products. Some ideas were generated with the principle of diffusing the sound by a large variety of reflective surfaces in different angles. The expectation was that, although unable to fully divide two acoustic environments, the sound would be diffused and create a more pleasant acoustic environment. Another aspect to this solution was that, by placing the product correctly, an aesthetically pleasing lighting could be created in the room through the use of shadows and daylight.

One of these concepts were turned into a physical mock-up for a quick test of acoustic performance, using a rough sound-tunnel with reflective walls. The sound tunnel consisted of 4 reflective surfaces, specific point of origin for sound source and specific point of reception for sound measurement. Recepticle and sound source were both



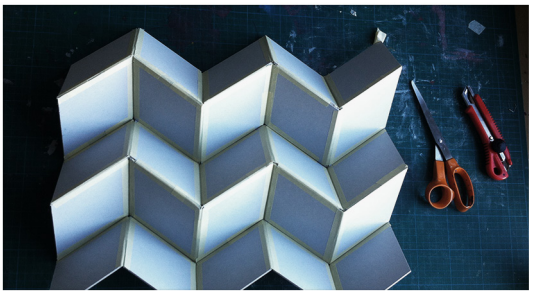
aimed perpendicularly to the mock-up surface. Unfortunately the blinds principle proved to be far too underperforming in regards to noise isolation, the diffusion of sound could simply not be expected to outweigh the value of isolating some of the noise.



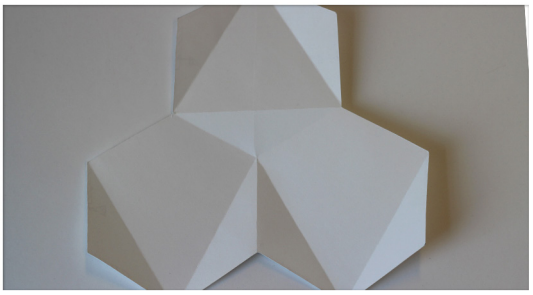
From these concepts one desired principle was extracted, using large variety of angles for high diffusion rate.

Origamic structures

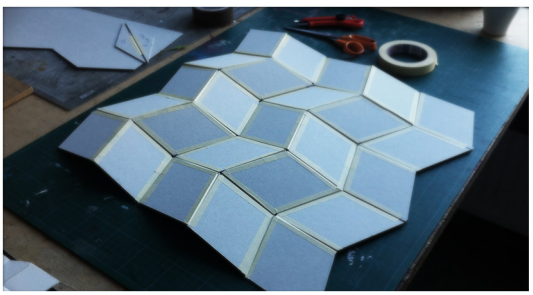
Along with the mock-ups for blinds solutions, many tests were performed with different origamic solutions. The idea of creating a more dynamic look to the product by using origamic structures was inspired by some existing products. Ideas of this sort were mainly generated using quick mock-ups and testing in the previously mentioned sound tunnel. The idea of using origamic structures could be described with two motivations: adjustable acoustic performance by folding and dynamic/high contrast look by extreme angles.

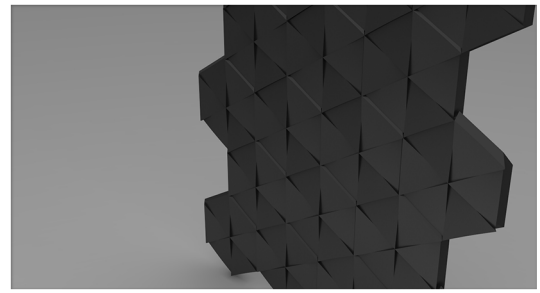


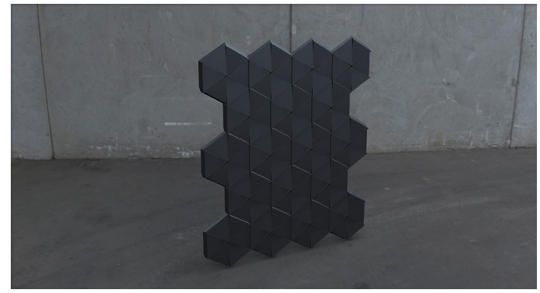
The adjustable acoustic performance proved to be an interesting idea to investigate since it created a new value to acoustic panels that many existing products lack. The principle behind this function is adjusting the diffusion rate of sound by altering the angles of reflective surfaces. Two challenges was discovered upon testing of the mock-ups, the coverage of the products decreased as they were folded and the weight of the material could be a potential problem for flexible structures.

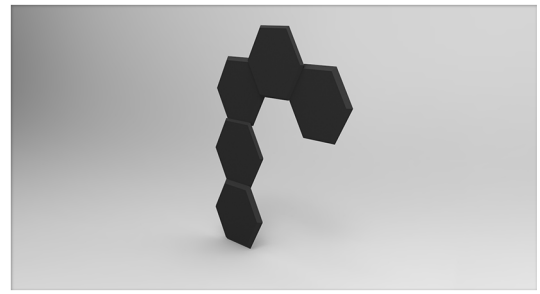


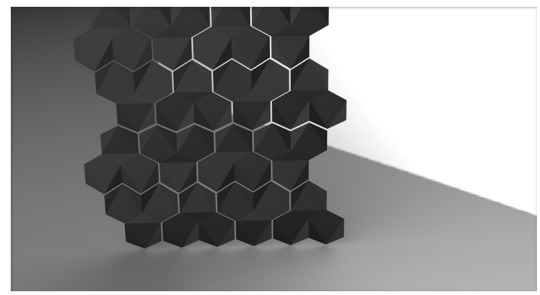
Since the total surface area is the same in an origramic structure, folded and unfolded, the covering area must decrease as the structure is folded together to create more extreme angles. In practice, as the diffusion rate increases (due to extreme angles in folded state) the noise isolation rate is decreased. This creates a dilemma as both of these functions are wanted in the product.











Foldable structure also comes with another dilemma due to the material properties. The density of PVC-cable sleeves is fairly high, setting a high demand on how much bearing force the structure should possess. Since the material itself is relatively flexible it also implies that there is a very limited potential for creating high bearing structure using only the material. Simply put the material cannot be expected to hold itself up without altering the material properties using more additives. Adding additives, in this case, is of course undesired since it would create a down-cycling effect which opposes the aim of this project. Using other material to hold the strucutre together would, logically, be the only alternative. But since the density is still high the supporting structure still need to have high bearing capabilities. A folded structure creates a demand on the structure both in bearing and abrasive resistance, compared to a static (non movable) solution which would set lower demands. Without going into calculations this difference may very well imply that different materials, for instance wooden or other organic material, could suffice for a static solution while it may not suffice for a foldable solution. This difference in material requirement implies that a origamic solution could be more expensive to manufacture as well as more difficult to recycle since it could require metallic supporting structure.

From these concepts two principles was extracted for the final concepts. The product could give the impression of a dynamic origamic like look but should remain static without moving components, and preferably the product should enable variation of its sound absorption qualities.

Modules

Modular solutions came to be while trying to solve the problems created by the blinds and origamic solutions. While the adjustable performance is

Analysis of Manufacturing methods

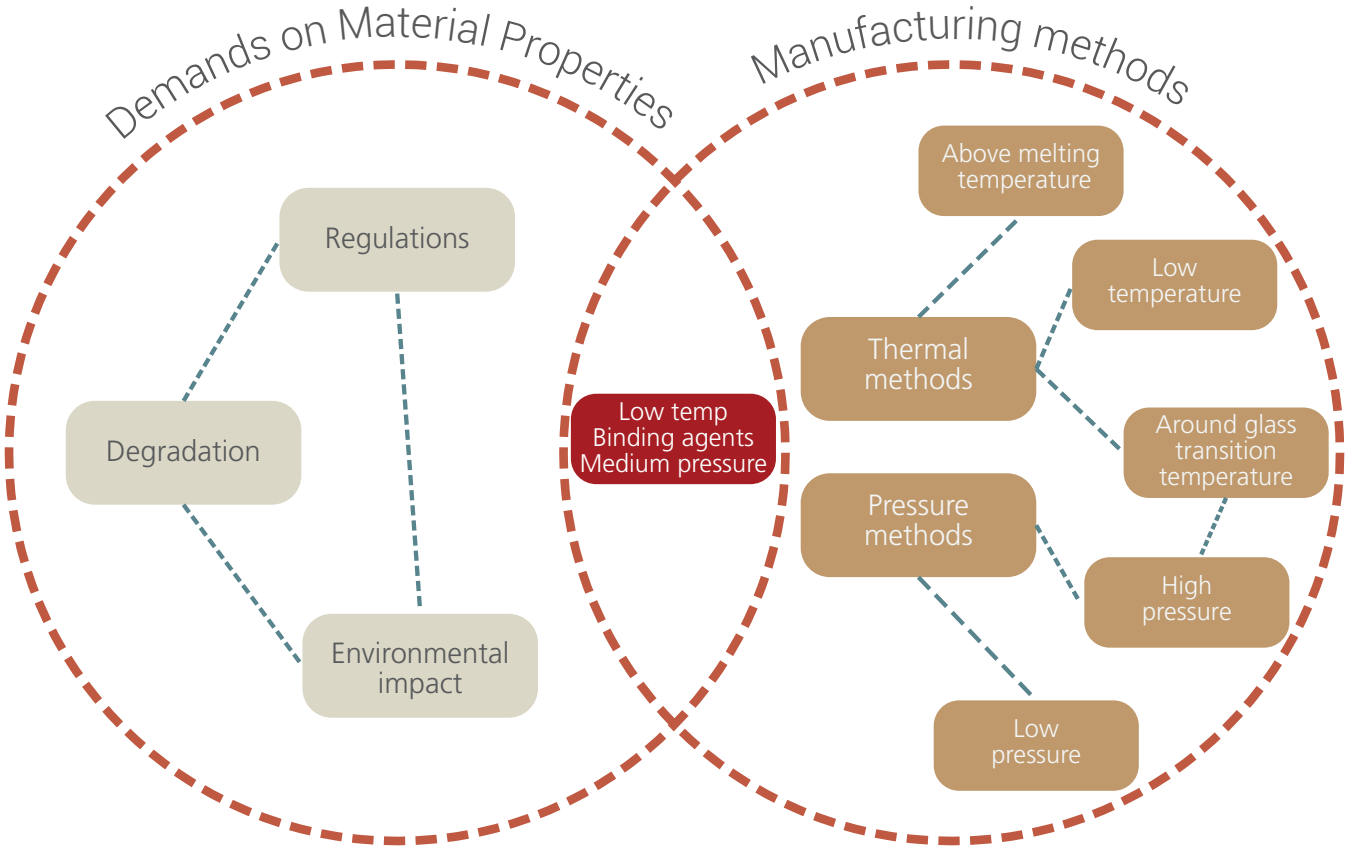


Figure 29. Testing of manufacturing methods

desired and could create a very competitive value in the product it should only be done in two dimensions, perpendicularly to the sound source and recipient. Instead of folding one big wall together, perhaps it is possible to create smaller modules that can be mounted together to create a wall with varying acoustic performance? Very quickly this was realized to be a viable solution since it also creates other desired properties, easy manufacturing and transportation. The challenge here is to how to create a structure that can implement all the aforementioned desired functions into one product and how to make it look good. Digital as well as physical tests were conducted and a large amount of ideas were expressed using simple mock-ups. Eventually one of these ideas were chosen as the final concept.

Analysis of manufacturing methods

figure 29. Testing of manufacturing methods

To identify a plausible way to manufacture the end product, a mapping of potential methods was nescessary. It was discovered that there are several factors at play when choosing manufacturing methods for this material, they can be divided into two simplified dimensions: demands imposed by the material properties and limitations of existing manufacturing methods.

In this project the demands imposed by material can be simplified to three different aspects:

- Existing regulations
- Degradation factors (functional declination)
- Environmental impact (produced by the manufacturing method)

Each of these aspects have separate demands on the material during manufacturing. Existing regulations demands a transparent documentation of substances in the material and prohibition of certain substances. In practice this limits the choice of waste fraction as well as the specific material properties (glass transition temperature, flexibility, strength etc.) Degradation factors demands, depending on the specific material properties, different treatment methods since the degradation will be affected differently. Environmental impact factors poses demands on low emission and release of undesired substances during manufacturing. For the up keep of material value in the recycled PVC granule, the added substances in the manufacturing methods should also be kept to a minimum.

Manufacturing methods used for this type of material is typically divided into thermal, pressure and a combination inbetween, thusly these three were tested accordlingly for the mapping of possible manufacturing methods. As stated earlier, due to the functional demand of porous structure, the end product requires high porousity. therefore achieving high porousity was the main focus of the mapping. In order to achieve a structure with high porosity, the PVC granules need to be treated with low pressure and temperature to avoid melting and decrease of porousity.

As a result of the mapping method it can be concluded that the prefered manufacturing method for the end product should be of low temperature, medium pressure and binding agent for surface bonds between granules. As a suggestion these following steps should be taken during manufacturing:
• Compounding of binding agent and granules.
• Form press of the compound.

3.4.5 DECISION(RESULT)

Once the last remaining ideas were theoretically verified to be manufacturable at industrial scale, a concept was chosen due to its superior functions and ease of manufacturing. The exact details of how to potentiall mount the modules together, the form design as well as how to use the product was finalized.

As found to be desireable during the test of modular solutions (see 3.4.4), the product should incorporate the idea of adjustable acoustic performance while sustaining a high visual novelty. The acoustic performance should be easy for the user to adapt in accordance with their particular use environment. In practice this means a modular solution that can target different ranges of frequencies by altering direction or form. For instance if the use environment is an office space where speech privacy is desired the users should be able to move the product in a way that will block the source from the recipient. In a more industrial environment where ambient noise of lower frequency is causing problems the product should be able to absorb a reasonable amount of noise to create a desireable environment.

In order to create the aforementioned visual novelty and the commercial value that comes with it, few guidelines for design and expression were chosen. The chosen principle of high diffusion rate through large variety of angled surfaces aligned well with an "edgy" expression. The idea of the desired expression is thus high contrast surfaces through light and shadow, sharp edges between surfaces as well as a light/wooden look for the Scandinavian heritage. *(figure 30. Expression board)*

EXPRESSION BOARD

Figure 30. Expression board

Figure 31. Rekustik

3.5 FINAL CONCEPT

3.5.1 REKUSTIK

The final concept is named Rekustik. The word rekustik is a portmanteau of the English word ”recycled” and the Swedish word ”akustik” (“acoustics” in English). It refers to the fact that the desired acoustic qualities of the concept largely depend on the material properties of recycled PVC. The tagline “Used since 2003“ is a discrete way of implying that the concept only makes use of recycled cables with known content, which are allowed by current laws and regulation. Rekustik is aimed at, first and foremost, commercial buildings with large space that needs noise reduction with a visual twist. It has two primary uses, dividing large spaces for modest level of speech privacy and absorbing an adjustable range of noise frequencies in an open room. Typically the first application can be used for open landscape types of offices and the second in large industrial or commercial spaces, such as lobbies and halls.

Rekustik is a modular concept where each unit consists of two parts; a wooden part (*see figure 33*) and a part made from recycled PVC granule (*see figure 32*). The wooden part is a perforated spruce board used to stabilize the entire structure and at the same time enable variation of the product´s acoustic qualities. The PVC granule board can be manufactured by compressing PVC granule with a binder in a mold achieving a surface structure with the desired properties. The two parts are then fixed together creating a modular unit (*see figure 34*) that can be used to create sound absorbing structures of tailored size. The modular units are fixed together by metal plates and screws. (*see figure 35*) The structure can either be mounted directly to a wall or be hung by wires from the roof. To enable alteration of the side facing outwards when mounted to a wall a threaded distance is used (*see figure 36*). The mounting is done by first fixating the distance to a wall by means of a screw; the modular unit is then fixated to the threaded distance by means of a second screw. Depending on the strength of the wall new modules can be added either by fixating them to the mounted module by means of metal plates and screws or by mounting them directly to the wall by means of screws and distances.

In order to differentiate the product from similar products, each set of modules is delivered with a special module equipped with a tag made from discarded fabric provided with the Rekustik logotype. (*see figure 41*)

The dimensions of a modular unit are 440 x 440 x 41 mm. It weighs approximately 2,5 kg, based on the density of virgin PVC and spruce (virgin PVC 1.35-1.45 g/cm^3 and spruce 0.45 g/cm^3). The design of Rekustik facilitates easy transportation, as the units can be stacked together in a space saving manner. The dimensions have partly been determined with regards to efficient packaging and transportation on pallets (1200 x 800 mm, European-standard).

3.5.2 FUNCTIONALITY

The sound absorbing units have been designed with the word versatility in mind. Versatility in terms of users being able to alter the acoustic qualities of a room according to their own needs. This is possible thanks of the two-sided construction of each unit. The PVC granule side is designed to absorb high frequency sounds like human speech while the perforated wooden side is designed to absorb low frequency ambient sounds emitted by mechanical equipments. Sound absorption of low frequencies is often overlooked when trying to reduce noise pollution in a room. Often too much effort is put into reducing

higher frequencies, resulting in bad environments for conversation *(Everest, 2001)*, instead of trying to reduce lower frequencies, which are often the cause of noise induced fatigue *(Long, 2006)*. The Rekustik concept takes this into account. For example, if mounted to a wall the soundscape of a room can be altered simply by varying the amount of wooden sides versus PVC sides facing outwards. Versatility is also expressed in terms of users being able to adjust the size of the sound absorbing structure according to the size of the room and the need for noise reduction. Size adjustment is done simply by adjusting the amount of modules mounted onto the structure.

Due to the porous structure of the PVC granule board (*see figure 37*) the sound waves are able to travel through the material and thereby suffer from energy loss and a decrease in volume according to the principles of porous sound absorbers explained in the previous chapter. The overall angular shape of the PVC granulate board is meant to disseminate sound waves that are not absorbed by the material. This creates a more evenly distributed soundscape, which reduces stress caused by reverberations.

The perforated wooden side absorbs sound in a slightly different way. By using the principle of a perforated panel absorber backed by airspace, similar charactertistics to Heilmholtz resonator *(see 3.4.2 Resonant absorbers)* can be achieved. *(Long, 2006)* Specific lower frequencies can thus be targeted with appropriate dimensions of perforations and intermediate airspace between the wooden and PVC panel. In order to achieve this effect an airspace between the wooden and the PVC panel must be implemented.

3.5.3 DESIGN AND EXPRESSION

The design and expression of the final concept is inspired by its intended users and use contexts, the principles of sound absorption and acoustics, its Swedish heritage and of course the PVC material. The sought expression is presented in the Expression board in *figure 30*.

The overall expression can be deemed distinctive due to heavy use of contrasting shapes and materials like the rough, black and angular PVC in contrast to the smooth, white and plain spruce. Since many of the use contexts, large open areas, are rarely colored in dark colors and the PVC granule is dark grey or black by its nature there was never an option of trying to get the product to blend in. Instead the large contrasts was embraced and emphasized in the product.

Apart from creating contrasts the shape of the PVC is also meant to capture and conceptualize the principles of sound absorption and noise reduction. Angular shapes are often used to reduce noise pollution by scattering the sound and thereby decreasing concentrated reverberation. The final concept displays generous use of angularity, but does it in a controlled and balanced manner.

To capture the Swedish heritage the supporting structure of the concept is made of spruce. Spruce is the most common tree in Sweden, it is light weight but at the same time durable. Spruce will maintain its light color in a satisfactory way (in contrast to pine).

The concept is shown in two example contexts in *figure 38*, *figure 39* and *figure 40*.

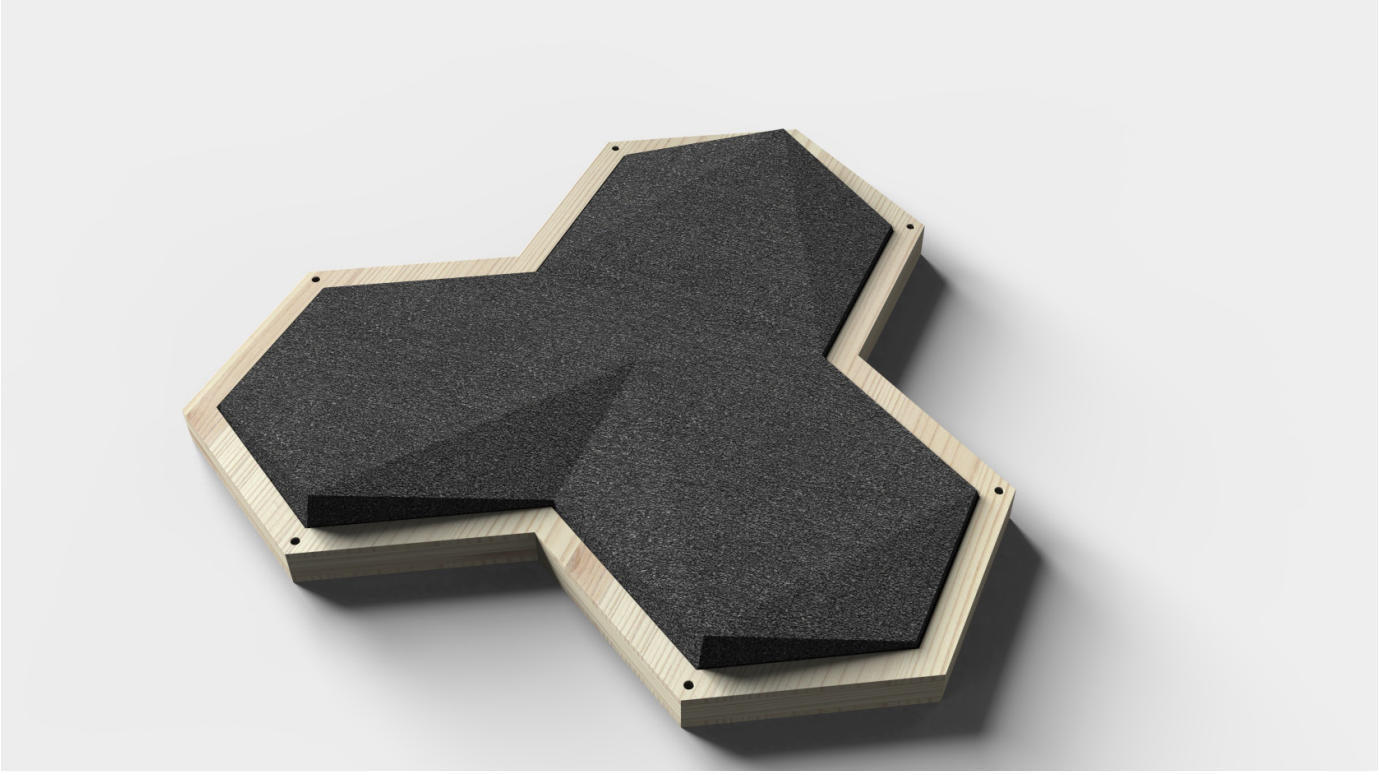


Figure 32. Rekustik PVC surface

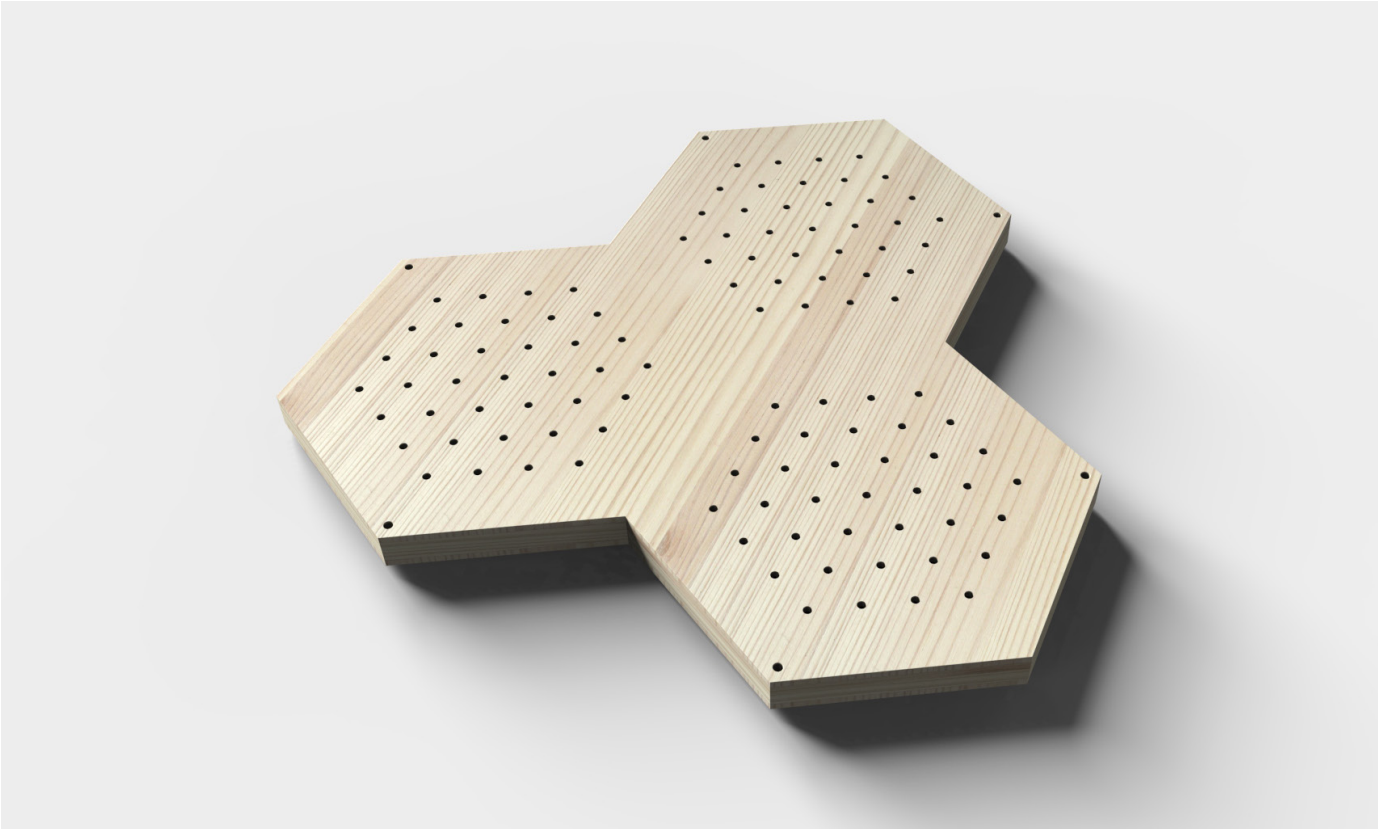


Figure 33. Rekustik wooden surface

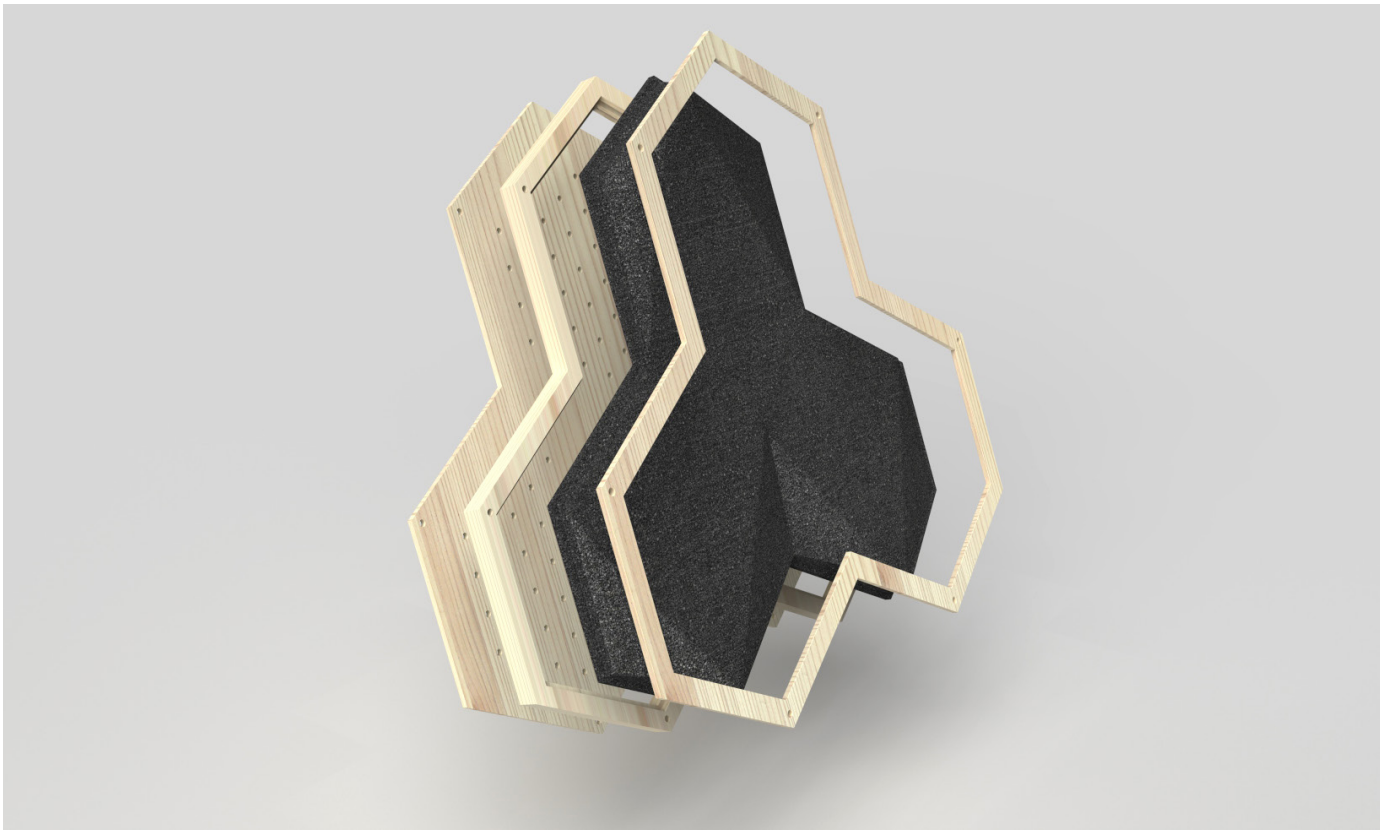


Figure 34. Exploded view of assembly

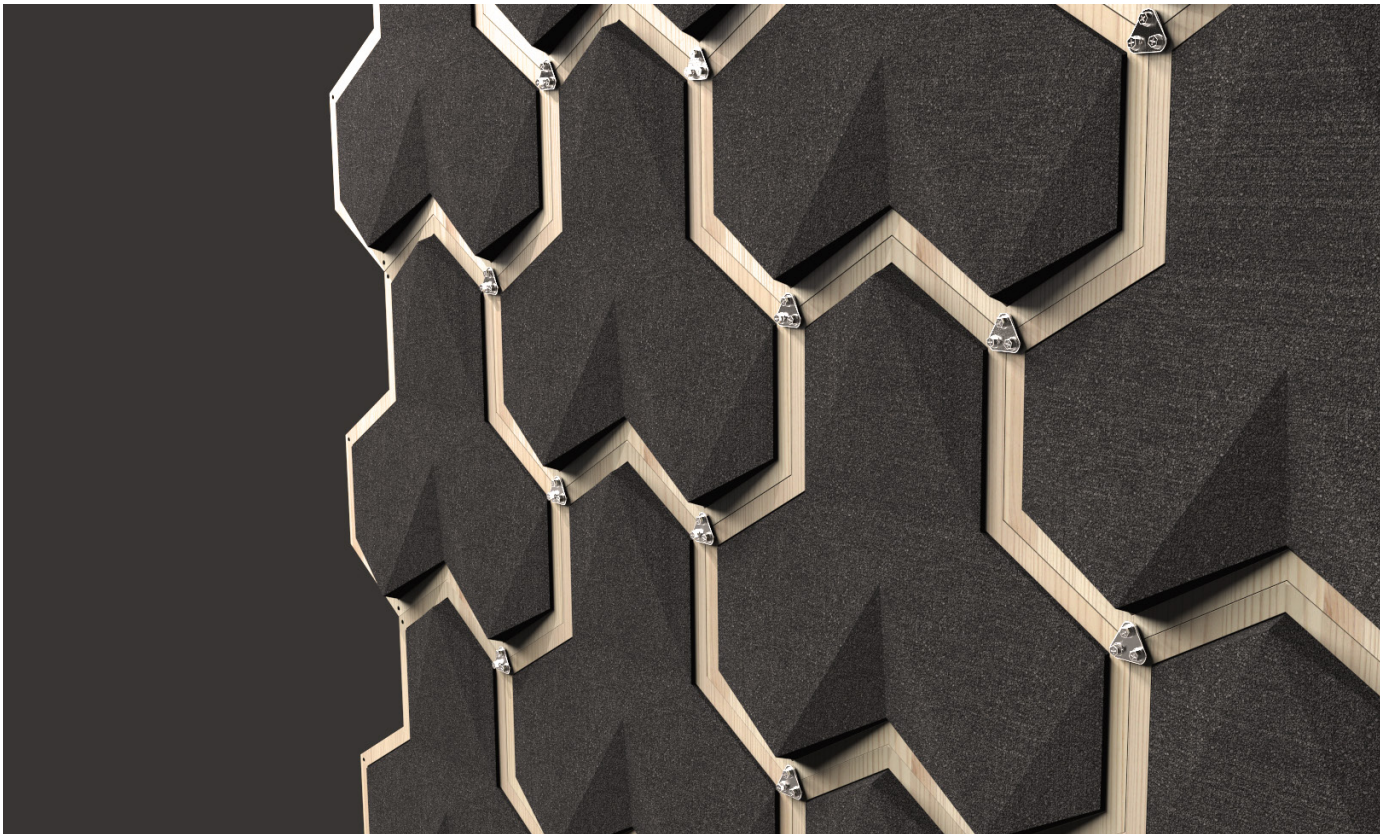


Figure 35. Modules mounted together

Figure 36. Module mounted to walls by distance screws

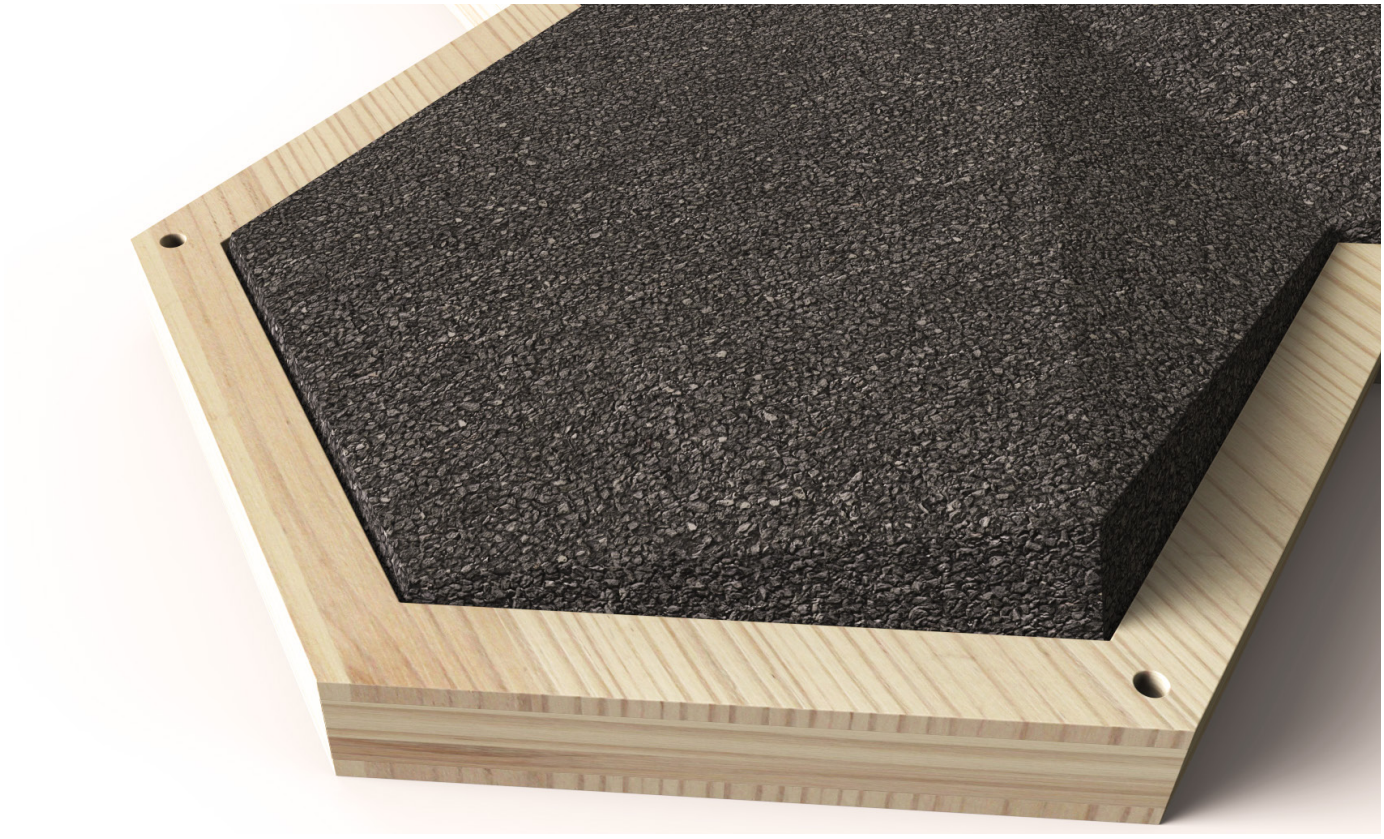


Figure 37. Porous Structure

Figure 38. Office context

Figure 39. Lobby context

Figure 40. Lobby context

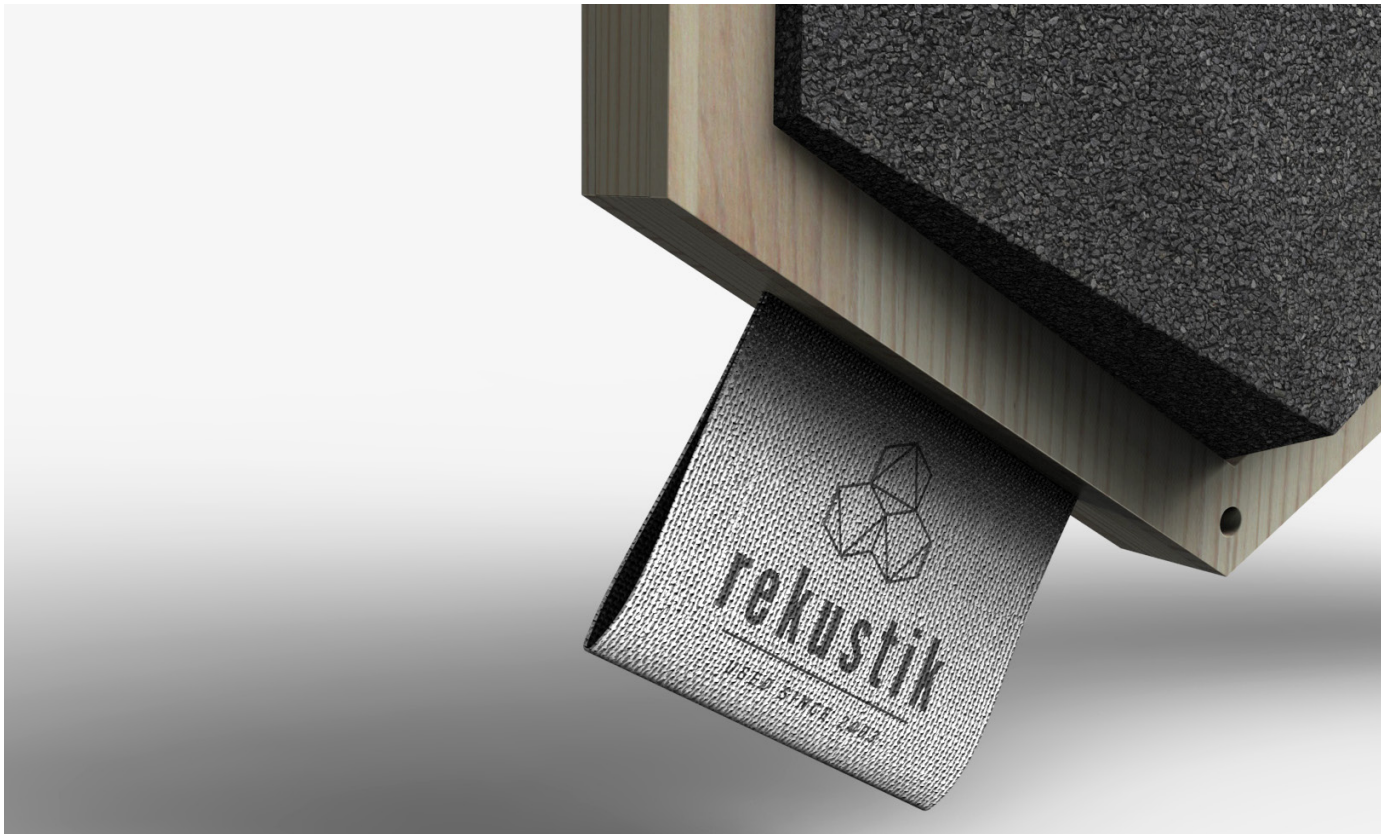


Figure 41. Trademark tag

4 DISCUSSION

4.1 METHODOLOGY DEVELOPMENT

The research method of the project was of an exploratory character and aimed at fulfilling the purpose of the methodology research - finding tools and methods to facilitate the creative processes of an IWtoPD project. Instead of trying to identify the ”optimal” way of addressing the challenges posed by IWtoPD projects through empirical methods, the approach used in this project was to identify a feasible, hypothetical solution and then test and verify it. The early selection of workshops as the feasible and appropriate method for IWtoPD projects is something that can be discussed. However, The decision to do so was based on recommendations found in recent literature and research in closely related fields. One may also argue that the initial testing of the workshop performance was a strong indicator that the chosen method was successful, thereby justifying the research method as well as the further development of the workshop format.

Furthermore, one might claim that this approach was necessary due to the fact that methodology development was conducted parallel to a product development phase that needed progress. In hindsight it can also be concluded that the components for workshop that were studied during the methodology development may very well be valuable for a more generalized ideation process in IWtoPD project. In which case the components can potentially be seen as key points for inducing and enhancing creativity that is the main challenge of the ideation phase in IWtoPD projects.

Because the methodology research was conducted concurrently with the ideation phase of an IWtoPD project, with the objective to produce a concept where the waste material is utilized, the methodology research did not reach the quantitative level needed to conclude the statistical significance of the results (due to limited resources). This, of course, questions the results and suggests that more research is needed on the subject. The relevance of the chosen criteria to describe workshop performance can also be questioned by this reasoning. The project and the evaluation criteria should however be considered a strong indicator that the suggested methodology works, considering the methodology research result and the project outcome.

The lack of statistical significance also affects the recommendations as they are derived from the research methodology. Still, the thorough documentation of the research methodology should facilitate further research on the subject based on its result.

An IWtoPD project is characterized by an initial lack of direction compared to common PD projects. In common PD projects the design objectives are known while in IWtoPD projects they are unknown. This increases the solution space with the amount of design objectives permitted by the selected waste material. This starting point can be quite overwhelming for anyone taking on an IWtoPD project. By use of a controlled creative process provided by the workshop format initial doubts and hesitation should decrease and be replaced by a sense of direction. Judged by the final outcome of the project the approach is considered to be successful. However, other approaches may need to be considered and evaluated in order to reach a final conclusion.

Given it is a waste material, the potential of the material in an IWtoPD project is yet to be fully explored. In addition, the materials are often complex and sophisticated, which complicates

the situation even further. Thorough background studies have been used to solve this problem but the lack of material expertise has become evident during specific parts of the projects. Generally, during any large decision-making phase, e.g. screening and concept selection, material experts should be present. Material experts would facilitate the selection procedure and eliminate uncertainties regarding implementation of ideas. During this thesis these issues have been addressed by having material experts present at the creative workshops to increase the quality of the generated idea, something which has proven to be both successful and resource efficient.

In addition, an adapted form of PD process (IWtoPD) may not be the only way of solving the problems related to accumulated industrial waste. Perhaps there are other ways of solving the problems of waste materials or ways to facilitate utilization of it? Nevertheless, these types of projects will hopefully have a positive effect on these issues as they show the many economical and environmental benefits. A successful execution of an IWtoPD project creates incentives for other similar projects to follow.

4.2 PRODUCT DEVELOPMENT

The intricate web of background information gathered in this project, as seen in (chapter 3.1), presented a number of challenges to be overcome in the product development process. These challenges have caused many different practical, albeit sometimes impractical, implications for design. In particular where some information has been found to be conflicting with each other, a conscious decision had to be taken despite the fact that both sides of the conflict can be technically correct.

One of the most severe conflicts was caused by the difference in industrial drive for reapplication of PVC cable sleeves and what is actually allowed by regulations. The current industrial drive for reapplying PVC cable sleeves could be described as very high for low purity material. Low purity materials can be considered the critical area of reapplication of PVC cable sleeves. The lower the purity the more interesting it is to identify a reapplication area for the waste material due to the growing costs of taking care of the material. Reapplication of low purity PVC fractions conflicts heavily with the current regulations and will most likely be even more regulated in the near future due to an update of REACH. In general the current regulations focus strictly on the amount of certain substances and the identification of these. There are no signs of this type of regulations decreasing in number or level of strictness. In general, in order to identify how much of certain substances a product contains, the manufacturers need to know exactly what is in the raw material and how much of said sub- stances every delivery of raw material contains. This poses a two sided challenge for the manufacturing; transparent and precise documentation of contents and low variation of quality/content between deliveries; none of which the least pure fraction of PVC cable sleeves can provide. Currently there is also a lack of method for separating the well-documented fractions from the poorly documented, which means a large of amount of potentially reusable material are wasted in its current state. The implication these factors had on the design work was that a sustainable solution would not be drawn from the fractions without existing documentation of its source and content. Currently this eliminates all fractions with lowest purity, rendering these fractions undesired for a sustainable reapplication. For further research on how to reapply PVC cable sleeves, development in separation and source tracing technologies is recommended. Until then the IWtoPD goal should be

to reapply as much of the content aware fractions as possible.

Another conflict identified during the project was the directions in which additives and regulations are developing. These two industries have two different perspectives and entirely different set of goals. Where as additives are developed to avoid or follow regulations and create functional material properties, regulations are aimed at prohibiting harmful substances in regards to human health and environment. Regulations do not necessarily take into account the functional value of substances and additives the effect on health and environment. This conflict presented two sides that are both important, causing the project to take a aim further into the future with one question in focus: what will be regulated in the near future and how will it be regulated? While the industry may further develop more and more sophisticated forms of additives, one thing is certain, they will be subjected to the regulations none the less. From discussions with researchers at Swerea and what can be seen in the recent developments in regulations one trend is apparent, more substances will be regulated and more demands will be placed on simply knowing exactly what products contain. Since the demand of documentation will most likely persist, it would be less frugal to plan solutions using undocumented waste since the solution may very well be prohibited in the near future.

Due to the limited choice of usable fractions, there are also a few visual and functional implications. Without adding additional pigments, which is not desired in this project as it would most likely cause a down-cycling of the material, the material will be in a consistent grey to black tone. In the final concept however, this property was intentionally incorporated into the design and variations of the tone of grey would not be harmful to the design due to the many different shades already caused by lighting.

The format in which the PVC cable sleeves are delivered are also incorporated into the design, but in order to be able to make a consistent use of the varying quality one measure had to be taken. Surface bonding between the granules are preferred as melting of the material would cause degradation; this is achieved through binders (adhesive additives). As to exactly what the optimal binder could be, no suggestions are able to be given at this junction. More research should be put into this aspect to identify and specify what binder should be used to achieve the following properties:

- high adhesive strength between granules
- high porosity in the end product, possibly with a blowing agent
- separable from PVC
- faster degradation rate than PVC
- slow enough degradation rate to survive the expected length of usage
- can be used for production at an industrial scale

Each of these properties should be assessed in further development of concept in order to realize the full potential of the concept.

The degree of effectiveness for sound absorption in the final product will depend on how well the aforementioned properties are achieved. With the properties achieved this concept will most likely have a reasonable level of sound absorption capability for its price. Whereas the competitive edge will be in the price of the material, the products versatility in regards to sound absorption, and the visual design that helps promoting the ideal of reusing industrial waste and an industrial scale. It is recommended that the sound absorption capability is tested properly using acoustic simulations and similar tools. According to literature used in this project, the weight of the material in the porous structure will contribute more to absorp-

tion of lower frequencies. In comparison with existing porous products, mostly consisting of absorption of higher frequencies, the final concept in this thesis can potentially be more beneficial for creating a pleasant commercial acoustic environment.

Since the PVC waste is expected to degrade drastically for each time it is put through thermal processing methods, the final concept has the additional value in that it only uses the waste once but the product itself has a long life span so the long lasting stability of PVC is utilized to a large extent. The product should be relatively easy to disassemble using crushing and separation just as today. The wooden granules weigh considerably less and can be easily extracted and taken to other recycling processes which should facilitate an easy recycling process of the product using existing techniques.

The final concept should reflect a market potential, identified during earlier investigation (see screening process), which can obviously be further assessed and properly addressed in accordance with how much more work should be put into increasing the profitability of the concept. At this point, with the result from earlier investigation, the trend of displaying recycling tendencies in architectural designs and the lack of industrialized good looking acoustic solutions is a positive sign for the final concept to become a successful product. What the analysis of existing products have shown is mainly products that are either good looking but not industrialized, or industrialized and functional but not aesthetically pleasing.

Since the raw material used for the final product is recycled material the cost of the production could be lower than using virgin PVC (or perhaps other materials). The profitability of the product can thus be expected to be higher than similar acoustic panels. In addition, the exposure of recycled material in a commercial space can have positive effects on the value of the space thus increasing the profitability even further.

The final concept also increases the value of the virgin PVC since the waste is recycled into other products in an open loop fashion. The value lies in the product having a long life span, taking advantage of the long life spans of PVC.

The development process itself also had its compromises due to different reasons in this project. Mainly this was an expected effect of placing the project's focus on methodology development and in latter phase focus on achieving one single concept with high technical level, innovation level and realizability. A conscious choice was made to apply a simplified, resource efficient screening process to quickly identify one application area with the highest potential for IWtoPD process. In retrospect the speed in which the screening process was carried out could have compromised and allowed many valuable ideas go to waste, despite it being effective in reaching the goal of finding one idea with high potential for further development. While acoustic panels can be concluded to be a good application area, there are also a lot of potentially equally valuable ideas that were not chosen during the screening process. Despite that, one may argue that the value of the idea is not simply in the idea itself but in developing the idea. With more resources more development projects could be found or in the very least benefit from a more thorough screening process. During the screening process there was also a slight lack of, though gradually improving, knowledge of the material and all the relevant background information (i.e. regulations and treatment process). Which in retrospect could have affected some of the judgements made during the screening process, based on the competence available at that particular time.

It was also discovered during the development process that IWtoPD is but one of many ways to address the accumulating amount of waste material. There are other ways to address this problem and these could, combined with IWtoPD projects, be beneficial to each other. For instance an improvement of the current recycling process, in particular identification of contents, would increase effectiveness of future IWtoPD projects. Lower amount of low purity material would in this particular case cause lower dependency on the previously mentioned conflicts.

5 CONCLUSIONS

As previously mentioned, the choice of workshop as potential methodology has affected the character of the methodology research as well as the outcome of the product development process greatly. While the value of the method may not lie in being the optimal methodology, it can be concluded that it has worked sufficiently in this instance. The reason is the extremely limited resources and time frame given in this project to perform both tasks concurrently. As a development method the cross-disciplinary workshops have provided a very concentrated form of ideation, swiftly moving the project from lack of definition to a clear and innovative product definition. In addition, with the extensive documentation and participants' own evaluation it made the screening process fairly painless and swift. The concurrent process in this project also allowed for an extensive period of time for studying the relevant theories and background information. In retrospect this opportunity was a necessity for creating the much needed depth in the project. In particular in the product development process where the lack of in depth knowledge of the material, and later on in acoustics, proved to be big challenges in this project the extensive background studies were crucial to the success and proceeding of the project.

The outcome of the product development part of this project reached the initial aim of the project, and then some. It could be concluded that the value of the final concept lies in the visual presentation of the material, where the industrial waste material is displayed in an uninhibited fashion. Another strength of the concept is the way the seemingly ugly material is transformed into a modern product that fits in most modern environments. The final concept can be concluded to have fulfilled the initial goal of reapplying a large amount of waste material as well as possessing a potential marketting value as promotion of the material.

For further development of the product, more research needs to be conducted in optimal binding agent and blowing agents to achieve the desired properties described in discussion. This development is best done in manufacturing industry where there are more economical incentives for perfecting the concept.

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APPENDIX A

Specification of demands

Priority	Specification
2	the product should not release any hazarduos material or additives
1	the source material can not be burned
1	the product may not contain more than 0.1% of DEHP (phthalate) substance if used in toys and childcare articles
3	the product should not contain a mix of phthalates
1	the product may not contain more than 0.1% of DBP (phthalate) substance if used in toys and childcare articles
1	the product may not contain more than 0.1% of BBP (phthalate) substance if used in toys and childcare articles
1	the product may not contain more than 0.1% of DINP (phthalate) substance if used in toys and childcare articles that children can put in their mouths
1	the product may not contain more than 0.1% of DIDP (phthalate) substance if used in toys and childcare articles that children can put in their mouths
1	the product may not contain more than 0.1% of DNOP (phthalate) substance if used in toys and childcare articles that children can put in their mouths
1	the product may not contain more than 0.1% of Dialkylftalater
1	the product may not contain more than 0.1% of Di(2-metoxietyl)ftalat
1	the product may not contain more than 0.1% of 4,4'-Bis(dimetylamino)benzofenon (pigment)
1	the product may not contain more than 0.1% of 4,4'-Bis(dimetylamino)difenylmetan (pigment)
1	the product may not contain more than 0.1% of a,a-Bis[4-(dimetylamino)fenyl]-4-fenylamino (pigment)
1	the product may not contain more than 0.1% of CI Solvent blue 4 (pigment)
1	the product may not contain more than 0.1% of TBTO (pigment)
1	the product may not contain more than 0.1% of CI pigments (pigment)
1	the product may not contain more than 0.1% of 2-metoxi-bensenamin (pigment)
1	the product may not contain more than 0.1% of Diaminodifenylmetan (curing agent)
1	the product may not contain more than 0.1% of MOCA (curing agent)
1	the product may not contain more than 0.1% of HBCDD (flamskydd)
1	the product may not contain more than 0.1% of Alkaner (flamskydd)
2	The product may not contain rest metals on its surfaces
2	The source of the material should be known or the quantity of contained substances should be measured
2	The material should be easily implemented into new "cradle-to-cradle" cycle
2	the material should be easily recollected as whole
1	The product should not be produced in temperature above 210 Celsius
2	Production should not contain other materials

APPENDIX B

Materialworkshop

Workshop 9:30-12:00

Kvantitet före kvalitet 15 min
Cue cards 20 min
Flip it 30 min
Evaluering & presentation 1h

Kvantitet före kvalitet – 15 min

I denna övningen gäller det att komma på så många idéer som möjligt under en given tid. Ingen idé är för liten och alla idéer räknas.

Instruktioner

• Arbeta enskilt och skriv ner så många idéer som möjligt på ett papper. *2 minuter*
• Välj tre intressanta idéer, skriv ner var och en på en postit-lapp och berätta sedan för varandra om de idéer ni har valt. (Var noga med att notera på postit-lapparna om diskussioner leder till nya idéer eller att idéerna utvecklas)
• Arbeta återigen enskilt och skriv ner så många nya idéer som möjligt på ett papper. Målet är att försöka dubbla antalet idéer från första omgången. *3 minuter*
• Välj på nytt tre intressanta idéer, skriv ner var och en på en postit-lapp och berätta sedan för varandra om de idéer ni valt. (Var noga med att notera på postit-lapparna om diskussioner leder till nya idéer eller att idéerna utvecklas)

Cue cards – 20 min

Den här övningen går ut på att man via användningen av, så kallade, Cue Cards får lite extra hjälp att komma på nya idéer. Diskussioner kring idéerna uppmuntras.

Instruktioner

• Varje deltagare drar ett kort ur Cue Cards-högen och följer instruktionerna på kortet. Obs: korten kan innehålla uppmaningar som involverar andra deltagare i gruppen så vänta med att idespåna tills alla känner sig redo. *1 minut*
• Använd uppmaningarna på korten för att komma på en eller flera nya idéer. *1-2 minuter*
• Berätta för varandra vilka instruktioner ni fick på era Cue Cards och vilka nya idéer det resulterade i. (Var noga med att notera på postit-lapparna om diskussioner leder till nya idéer eller att idéerna utvecklas) *godtycklig tidsram*
• Upprepa ovanstående steg tills den för övningen avsatta tiden är slut.

Flip it – 30 min

Nu är det dags att tänka annorlunda. Vi ska satsa på att skapa nya innovativa idéer ur till synes värdelösa idéer.

Instruktioner

• Varje deltagare försöker komma på den värsta tänkbara idén och skriver ner den på en postit-lapp. *1 minut*
• Gruppens lappar samlas ihop och ges till en annan grupp.
• Gruppen drar sedan gemensamt en dålig idé ur högen och läser den högt. Gruppen ska sedan, genom diskussion, försöka omvandla den dåliga idén till en bra.
• När en möjlig lösning har diskuterats fram förs den ner på en postit-lapp och en ny dålig idé dras ur högen.
• Forsätt dra nya lappar tills högen med dåliga idéer är slut eller tills det att den för övningen avsatta tiden är slut.

Bra gjort! Nu är det dags för evaluering.

APPENDIX C

	Metod
kruka	QbQ
balkonglåda	QbQ
rabattavgränsning	QbQ
växtlådor	QbQ
krukfat	QbQ
bordsben	QbQ
stolram	QbQ
sängstomme	QbQ
lampfot	QbQ
grytlapp	QbQ
lysrörslampa	QbQ
omslag på glas/mugg mot värme	QbQ
parkbänk	QbQ
klättergrepp	QbQ
matta	QbQ
underlägg	QbQ
väg	QbQ
brygga	QbQ
bro	QbQ
ramp	QbQ
lekpark	QbQ
möbler	QbQ
väggar	QbQ
tak	QbQ
stora rör som grävs ner	QbQ
balkar	QbQ
isolering till produkter	QbQ
tätningslister till ytterdörrar	QbQ
armering till kompositmaterial	QbQ
grepptag kring saker	QbQ
skrivbordsunderlägg i superanpassad form	QbQ
avfärgning i pennor tex	QbQ
"playmobil" typ lera leksaker	QbQ
Akustik	QbQ
Gardin	QbQ
tyg	QbQ
armering	QbQ
bord	QbQ
golv	QbQ
pacemaker	QbQ
hammare	QbQ
handtag	QbQ
tandskena	QbQ
fasadmaterial	QbQ
isolering	QbQ

vas	QbQ
eluttagshölje	QbQ
muggar	QbQ
inramningar	QbQ
halkskydd	QbQ
Fyllnadsmaterial (schaktning, trafikobjekt, boxningssäckar)	QbQ
dämpningsmaterial	QbQ
värmeresistent	QbQ
golv	QbQ
verktyg	QbQ
ljudisolering	QbQ
lekparker	QbQ
sulor till skor	QbQ
suddgummi	QbQ
knäskydd	QbQ
hjälm	QbQ
tandskydd	QbQ
suspensoar	QbQ
arbågsskydd	QbQ
frisbee	QbQ
hantlar	QbQ
viktskivor	QbQ
gångstavar	QbQ
bollar	QbQ
stötdämpare	QbQ
smycken	QbQ
västskydd	QbQ
stekspade	QbQ
konstgräsgummi	QbQ
däckleksakbilar	QbQ
Pedagogiskt hjälpmedel för valar i syfte att motvera monokulturer	CC
Stickor	CC
sykorg	CC
underlägg	CC
handarbeteslåda	CC
bricka	CC
skiva	CC
bord att rulla in	CC
strykbräda	CC
bakbord	CC
Modeartiklar	CC
anslagstavla	CC
stötdämpare kring båtar	CC
Resväska hårt skal	CC
stolpar till volleybollsnät	CC
fyllning till planer	CC

vikter	CC
klackskor	CC
smycken	CC
catwalkgolv	CC
stötskydd	CC
golv för kö	CC
termos	CC
lysrörskåpa	CC
högtalare	CC
klädhängare	CC
formbar bergochdalbana	CC
Tråd i tjockform	BB
Band runt stolpar eller liknande skydd	BB
Skydd för prylar	BB
stolpar i bilbanor	BB
kassaband	BB
Skrapa för att ta bort tuggummi	BB
Trasslingsmotsåndiga kablar	BB
Skrapa för att ta bort is	BB
mindre giftig elcigg	BB
lastpall - eu pall	BB
hylla affär	BB
ask	BB
låda - kista	BB
spänne	BB
Ekologiska smakförstärkare, färgämnen	BB

30 bra ideer 117 (25,6%)
Fluency= ideer/tid = 2,13 ideer/minut

	Metod
Rekvisiita/scenmöbler	MN
Möbler för utomhusteater	MN
scenkläder	MN
tysta golv för publikdel	MN
Hängmattor i stadsmljö, vävt	MN
Skosulor	MN
Isolering (för att det är kallt i alaska)	MN
Mattor för offentliga sammanhang	MN
underlägg till mattor, halksydd	MN
Förpackning till elektronik för att skydda prylar	MN
Kuddar under stolar för att inte repa	MN
Gardiner	MN
tallrikar	MN
muggar	MN

glasspinnar	MN
tavelram	MN
utegrillar	MN
handdukar	MN
örngott	MN
uppbykggnader/talarstol	MN
golv i stall	MN
hopphinder	MN
ljuddämpare på vägg	MN
Skydd - skottdämpande	MN
batong	MN
pengabössa	MN
gummi i konstrgräs	MN
saker som är användbara i staden	MN
utegym	MN
lekpark/gungbräda	MN
produkt att torka av skorna på	MN
planer till warhammer etc bygga kullar hus etc	MN
Material till 3D-modulering	MN
Bodyarmour mot splitter	MN
skejtskkydd	MN
garderobslapp	MN
galge	MN
golv bakom bar/halksydd	MN
vägbeläggning	MN
kajak	MN
forsränningskajak	MN
Däck	Flip it
bärande material (stommar etc)	Flip it
skottsäker väst	Flip it
gummibåt	Flip it
flytväst	Flip it
gummiband	Flip it
airbag	Flip it
hjälm	Flip it
hjul till rullskidor	Flip it
Kallpressa materialet för att få en "ekoreko"-look	Flip it
stativ	RP
möbler	RP
rumsavskiljare	RP
pekpinne	RP
skapa former	RP
Stafli, tillbehör till ritningar, typ underlägg	RP
Byggmaterial till modeller	RP
portföljer	RP
förvaringsutrymmen	RP

bära ritningar till byggen	RP
byggmaterial	RP
mätinstrument för att mäta avstånd och höjd	RP
rör	RP
Billiga tegelpannor	RP
tätningsskikt	RP
mjuka golv under trägolv	RP
ljudisolering	RP
Kanske går att göra poröst - isolering bra för husgrunder	RP
sporthallar - ytor	RP
tysta vägbanor	RP
vägspärrar	RP
räcken stötdämpande	RP
översvämningsskydd	RP
nygamla kablar	RP
musmattor	RP
gamingkonsoler	RP
3d simuleringsmaskiner	RP
tangentbord	RP
musar som formas lite efter handen	RP
stötdämpning i dator så de inte går sönder lika lätt	RP
snyggare rundare yttre former (it, dator)	RP
datormus	RP
tangenter datorbord	RP
headset	RP
stötskydd till ipad/hårddisk	RP
hjul till datorstol	RP
lampa	RP
kontroller till tv-spel	RP
Skal (temp OBS!)	RP

26 bra ideer av 90 (28,9%)
fluency: 90/45= 2 ideer/minut