New mounting solution for acoustic ceilings

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DIVISION OF PRODUCT DEVELOPMENT | DEPARTMENT OF DESIGN SCIENCES
FACULTY OF ENGINEERING LTH | LUND UNIVERSITY
2017

MASTER THESIS

Ecophon® SAINT-GOBAIN
A SOUND EFFECT ON PEOPLE

New mounting solution for acoustic ceilings

A case study of Focus DS

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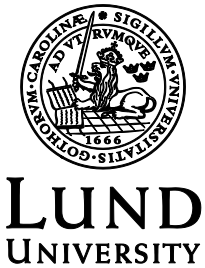

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Abstract

Acoustic ceilings in today's market has to be both functional and aesthetically pleasing. In order to fulfill those needs Saint-Gobain Ecophon has developed a product called Focus DS which is a demountable acoustic ceiling with a concealed grid system. Even though Focus DS fulfills the markets needs Ecophon has discovered that there are issues with the current design of Focus DS that often results in damages to the ceiling tiles. The objective of this master thesis was to investigate possible problems with the current Focus DS and generate new concepts based on the results from those investigations.

The project started with a problem analysis of the current design of Focus DS and was followed by interviews and observations in order to gather raw data for the identification of the consumer needs. Based on the consumer needs a concept generation was performed in two parts. The first part was an external search which included an investigation of what kind of products that where on the market (that fulfilled the consumer needs) as well as a patent search. The second part was an internal search were concepts were generated based on the findings from the external search as well as based on personal knowledge.

In the last part of the master thesis final concepts were chosen with the help of a decision matrix as well as with the help of intuition, two concepts were chosen. The first concept is to add grooves to the current design of Focus DS in order to stop the tiles from moving unwantedly. The second concept is a spring that you add to the grid system also in order to stop the tiles from moving unwantedly.

Keywords: *Acoustic ceilings, mounting solution for acoustic ceilings, Focus DS, demountable ceiling, concealed grid system.*

Sammanfattning

I dagens marknad måste akustiktak vara både funktionellt och estetiskt tilltalande. För att uppfylla de behoven har Saint-Gobain Ecophon utvecklat en produkt som heter Focus DS som är ett demonterbart akustiktak med dolt bärverk. Även om Focus DS uppfyller marknadsbehoven har Ecophon upptäckt att där är problem med den nuvarande designen av Focus DS som ofta leder till skador på takplattorna. Målet med detta examensarbete var att undersöka möjliga problem med den nuvarande Focus DS och generera nya koncept baserat på resultaten från undersökningen.

Projektet startades med en problemanalys av den nuvarande Focus DS designen och följdes av intervjuer och observationer för att samla rådata för identifieringen av kundbehoven. Baserat på kundbehoven genomfördes sedan en konceptgenerering i två steg. Det första steget var extern sökning som inkluderade en undersökning av vilka olika produkter som fanns på marknaden (som uppfyllde kundbehoven) såväl som en patentsökning. Den andra delen var en intern sökning där koncept genererades baserat på resultaten från den externa sökningen men även baserat på egen kunskap.

I den sista delen av examensarbetet valdes de slutgiltiga koncepten med hjälp intuition och en beslutsmatris, två koncept valdes. Det första konceptet är att lägga till en skåra i den befintliga designen av Focus DS för att förhindra oönskad rörelse hos plattorna. Det andra konceptet är en fjäder som man sätter på bärverket, också för att förhindra oönskad rörelse hos plattorna.

Nyckelord: *Akustiktak, monteringslösning för akustiktak, Focus DS, demonterbart tak, dolt bärverk.*

Preface

First I would like to thank Ecophon and the staff at Ecophon for enabling me to do my master thesis for them and helping me throughout the project. I would especially like to thank my supervisor Johan Gross for always taking the time to help me and answering my questions and also Peter Strandqvist for helping me with my interviews.

I would also like to thank my supervisor at LTH assistant professor Damien Motte for always helping me when help was needed and for giving me invaluable advices on my master thesis.

Lastly I would like to thank my family and friends for always supporting me.

Lund, March 2017

Alexandra Schönbeck

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1 Introduction

This chapter introduces the background and the essential features of the master thesis.

1.1 Background and objective

Acoustic ceilings has undergone a dramatic change the last decades. Primarily acoustic ceilings were used in order to enhance room acoustics and subsequently create a better working environment. In today's society products has to fulfill more criteria's than its core purpose and for acoustic ceilings that means being aesthetically pleasing as well as functional.

Saint-Gobain Ecophon (Ecophon) is a leading manufacturer of acoustic ceilings, as well as other acoustic products. They strive to develop products that fulfills the demands and needs of the market and have therefore come up with an acoustic ceiling called Focus DS, see figure 1.

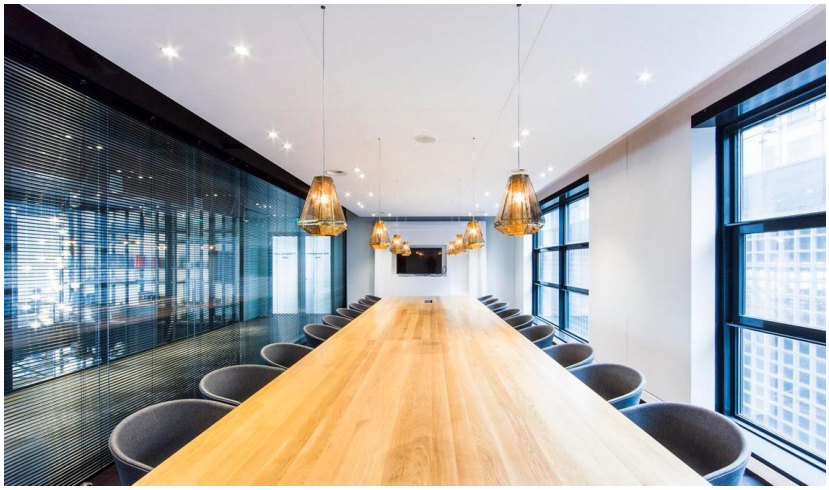

Figure 1 Focus DS visual appearance [3]

However (due to Ecophon's close contact with buyers etc.) they have realized that there are issues with the current design of Focus DS, issues that they believe often results in damages to the ceilings tiles. The objective of this master thesis is to

investigate possible problems with the current Focus DS. After that new concepts will be generated in order to solve the current problems.

1.2 Saint-Gobain Ecophon

Ecophon is a Swedish based company that manufactures acoustic products and systems. The company's aim is to create a good room acoustic in order to offer a better working environment for their customers. Ecophon operates in 14 countries and have representatives in further 30 countries. The main office of Ecophon is located in Hyllinge in the outskirts of Helsingborg. Ecophon has approximately 750 employees worldwide and is a subsidiary of the industrial group Saint-Gobain [4].

Saint-Gobain was founded 1665 by the French minister Jean-Baptiste Colbert and Ludwig XIV. Today Saint-Gobain is represented in more than 67 countries and have approximately 170 000 employees. The focus of Saint-Gobain lies in the manufacturing of construction materials and innovative materials, they also focus on the construction industry in general. For more information visit http://www.saint-gobain.se/om-saint-gobain/saint-gobain-v%C3%A4rlden-%C3%B6ver.

1.3 Method

This master thesis project follows a product development process described in the book *Product Design and Development* by Ulrich and Eppinger [1;2]. In short the method consists of a 4-step process:

1. Identify consumer needs
2. Product specifications
3. Concept generation
4. Choice of concept

Each part of the process consists of several sub-steps which has been suitably modified and in some cases removed in order to adapt the process to the master thesis. Due to these alterations it was decided not to include a more full description of the method since it was believed that this would only confuse the reader. Instead each chapter of this master thesis will start with a short description of how the chosen method has been used in order to gather and analyzing data.

Before the product development process started a Gantt-schedule and a problem analysis was performed in order to identify the different parts of the master thesis as well as to structuralize and identify the scope of the project.

1.4 Disposition

1.4.1 Chapter 1 – Introduction

Chapter 1 includes a general description of the method used in the master thesis as well as short background to the master thesis and the company.

1.4.2 Chapter 2 – Problem analysis

The different problems that Ecophons has discovered with Focus DS are described in this chapter. A thorough analysis of the current Focus DS is also performed, e.g. how installation and manufacturing is done. In the end of the chapter a mission statement is prepared based on information given in the chapter.

1.4.3 Chapter 3 – Consumer needs

The process of gathering raw-data and the translation of this in to consumer needs are described in chapter three. The identified consumer needs are also scored according to their perceived importance and final decision is made on which needs that will be the base for the concept generation.

1.4.4 Chapter 4 – Product specifications

A short account on the method and reason for translating consumer needs into products specifications is performed in this chapter. None of the consumer needs were however translated into product specifications due to their subjective nature.

1.4.5 Chapter 5 – Concept generation

In this chapter an external and internal search [1;2] was performed in order to generate concepts. The internal search was based on the chosen consumer needs and some inspiration for the internal search was also gained from the external search.

1.4.6 Chapter 6 – Choice of concept

During this chapter the different concepts are evaluated in an decision matrix [1;2]. Based on the results from the decision matrix as well as intuition different concepts

were chosen for further development and analysis. In the end of the chapter two concepts were chosen to be presented for the company.

1.4.7 **Chapter 7 – Final reflections**

Short personal reflection about the master thesis.

2 Problem analysis

The different problems that Ecophons has discovered with Focus DS are described in this chapter, a thorough analysis of the current Focus DS is also performed.

2.1 Focus DS

When an acoustic ceiling is mounted for the first time it is often done by tradesmen who knows how the mounting procedure work. Often, however, tiles has to be demounted after the primary installation in order to execute different maintenance- and/or installation- work, for example installing a projector in a classroom. Ecophon has discovered that this often constitutes a problem in regards to their acoustic ceiling called Focus DS (DS).

DS is a dropped acoustic ceiling (i.e. secondary ceiling that hangs below the main ceiling), consisting of tiles that are mounted on to a grid system. The grid system, in short, consists of t-beams (here meaning a thin sheet metal with a t-shaped cross section) which are mounted on to adjustable hangers which in turn are installed to the main ceiling.

A special edge design on DS enables the tiles to conceal the grid system, creating a more esthetically pleasing appearance, see figure 2.

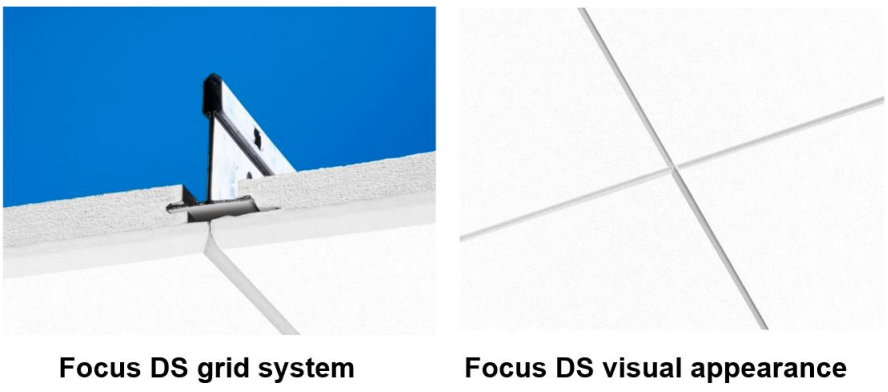

Figure 2 Visual appearance of DS [5]

The tiles are made from glass wool which has been cut into the right size, painted and lastly milled in order to create a special edge profile. The paint gives extra structural integrity to the tiles as well as an esthetically pleasing appearance. The milling is performed on two of the tiles edges in order to create the special edge profile. The two edges have different profiles and have been designed in order for the tiles to have no offset when mounted on to the grid system (this in order to simplify the installation of light armatures etc.). One of the edges (edge 1) has two deeper grooves while the second edge (edge 2) has one shallow groove, see figure 3 below.

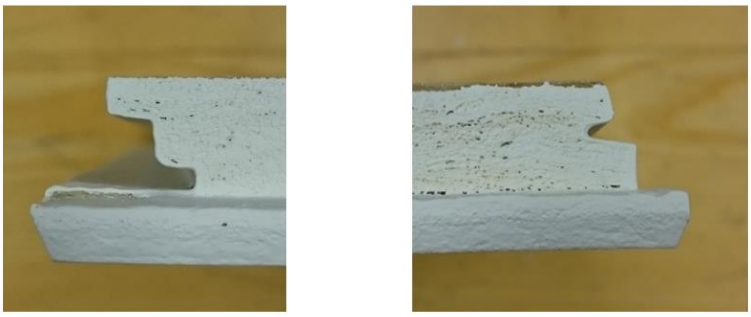

Figure 3 Picture depicting the two different edges of DS

The mounting of DS tiles can be described as a three-step procedure. The first step is to angle the tile and slide the deepest groove of edge 1 on to the t-beam. The next step is to lift the other side of the tile up to the t-beam in order to align edge 2 to the beam. The third step is to slide the tile in the opposite direction of step 1 in order to mount edge 2 on to the t-beam and also letting the shallow groove on edge 1 fall on to the t-beam. The reverse procedure is applied when one has to demount the tiles.

The problem Ecophon has identified with DS is that tradesmen that has to demount the tiles (after the preliminary installation) doesn't understand how to do it. This in turn often leads to the tradesmen having to use brute force in order to demount the tiles which results in damages to the tiles and the overall esthetical appearance. Since the esthetical appearance and demountability is a key selling argument for DS these kind of problems could affect sales since the consumers could feel misdirected about the products purpose, which includes esthetical appearance.

2.2 Mission statement

The goal with the master thesis is to investigate what kind of problems tradesmen have when demounting and mounting DS. Based on the result from those investigation DS will then be further developed in order to create a new mounting and demounting solution.

Considerations will only be taken to develop the mounting and demounting system of DS. No alterations will be done to the esthetical appearance of Focus DS nor to the grid system, based on the whishes from Ecophon. However if solutions are thought of that effects the appearance of Focus DS or the grid system they will be included in the work but excluded from further development.

Based on the above mentioned clarifications a mission statement was prepared, see table 1.

Table 1 Mission statement

Product description	-Demountable acoustic ceiling with a concealed grid system.
Possible advantages	-Easier mounting and demounting solution
Key target	-Increased sales
Primary market	-Assembly firms -Construction companies
Secondary market	-Schools, offices etc. -Private market
Assumptions and limitations	-No alterations to the grid system -No alterations to the esthetical appearance of DS. -Limited amount of time for the project. -The cost of alterations to current product is considered though not as important
Stakeholders	-Buyer and user -Manufacturing -Sales office

3 Consumer needs

The approach of deriving consumer needs and which needs that were identified is described below.

3.1 Method

In order to get a sturdy foundation for the consumer needs it was decided to use 2 methods in order to gather raw data, both described in chapter 5 in the book *Product Design and Development* [1;2]. The first chosen method was interviews and the second was to observe random people (with no or little experience regarding acoustic ceilings) interacting with Focus DS. The reason for wanting to observe random people interacting with Focus DS were in order to simulate how it could be when a craftsman (with no or little experience with acoustic ceilings) has to demount the tiles in reality. Furthermore it was decided that it would be easier to get a hold of random people that would be willing to partake in the observations than craftsmen. The hopes for the simulations were to get some insight into possible difficulties with the ceiling. Besides just observing the users it was also decided to let them fill in a questionnaire after they had interacted with Focus DS.

The interviews, 7 in total, were executed by contacting representatives from different assembly firms and other craftsmen or company representatives that *had knowledge* about Focus DS. Depending on their previous knowledge about Focus DS different types of questions were asked in the hopes of getting the best result. The questions can be seen in appendix A.1 and A.2.

In order to observe people using Focus DS a small scaffolding was built at Ingvar Kamprad Design Centre (IKDC), complete with a small grid system that could hold 4 Focus DS tiles, see figure 4 below.

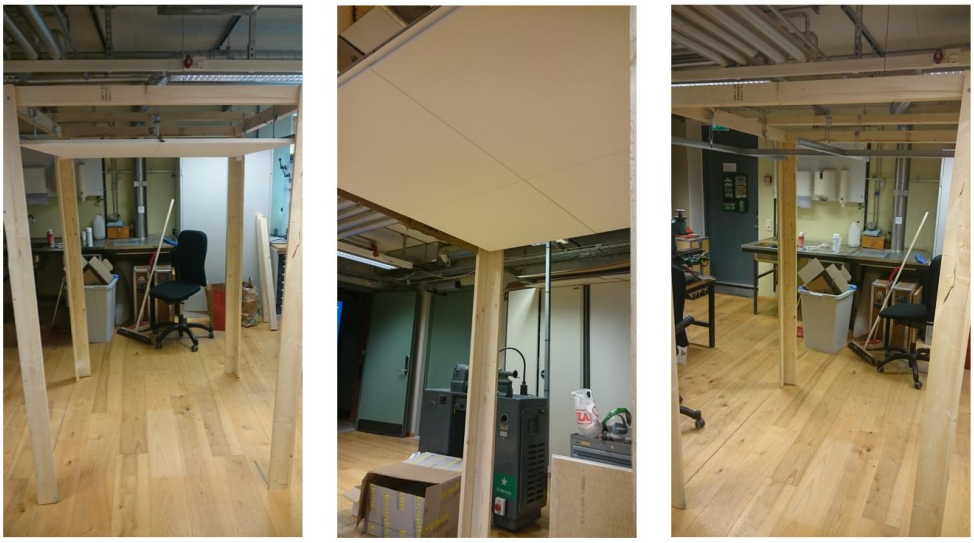

Figure 4 Three different views of the scaffolding that was built

People passing by would then be asked to try to demount and mount a Focus DS tile back up again while being observed. After that they would be asked some questions about their experience, see appendix A.3. The scaffolding was constructed to imitate reality, i.e. hiding the edges and grid system as much as possible. Otherwise there would be a risk that users could understand the demounting and mounting principle of the ceiling just by looking at the construction.

The results from the interviews and the observations was then interpreted in to consumer needs. The needs were then weighted according to their perceived significance in order to choose which consumer needs that would be the base for the product specifications. The chapter ends with a discussion about the results and the process.

3.2 Interviews

Many of the interviewees remarked that the cost of Focus DS was too high, the main reason for this was mainly due to the installation costs of the ceiling. They explained that for other types of acoustic ceilings such as the Focus A (see figure 5 below) the installation is straight forward and one does not have to align the tiles to one another in order to get straight lines. The interviewees gave an example that if they were to mount Focus DS in comparison to Focus A it would take almost 50 % longer time.

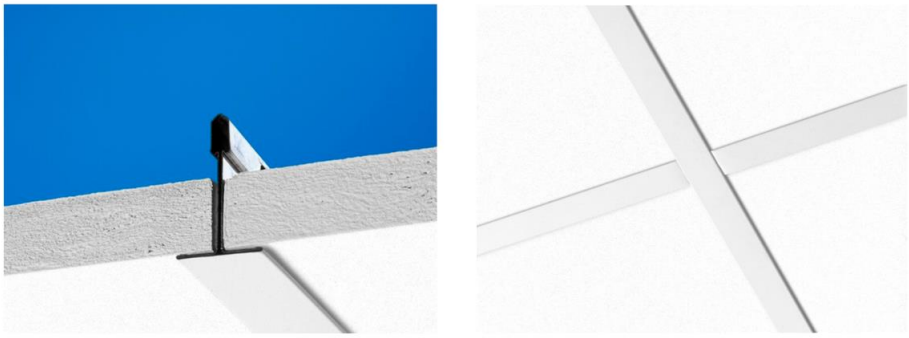

Figure 5 Visual appearance of Focus A [4]

The reason for not having to do any adjustments to Focus A is because of the fact the grid system conceals the tiles edges and therefore as long as the grid system is installed correctly there will be straight clean lines. Since Focus DS has a concealed grid system and due to the fact that the tiles can move or shift easily the assembly firms has to adjust the tiles continuously during the installation in order to get straight lines between the tiles.

Another issue that interviewees mentioned with Focus DS was regarding the compression springs that are mounted on to the ceiling where it meets the wall. The reason for needing these compression springs are in order to compress the tiles towards each other in order to prevent movement of the tiles and also to compensate for eventual movements of the wall. The interviewees said that this institutes a problem when a tile is removed (i.e. for maintenance work) since all of the other tiles will move because of the compression springs. This movement of the tiles will make it harder to put the removed tile up again and will also lead to a more instable ceiling system, according to the interviewees.

Another problem that the interviewees mentioned was that the tiles broke easily. Some of the assembly firm's representatives mentioned that the edges of Focus DS were very sensitive to any type of impact and the damages that arose could either be esthetical and/or structural (not being able to mount the tile on to the grid system). As soon as a tile had been through some sort of impact, for instance falling down during assembly, the result was often that the tile had to be thrown away.

Most of the interviewees also mentioned that they had seen or heard from other craftsmen (for instance electricians or ventilation installers) that damages often occurred to the tiles because of the use of brute force to demount and mount the tiles back up again.

The advantages mentioned regarding Focus DS was that it was a good ceiling to use if the space between the acoustic ceiling and the main ceiling was small and that it had a pleasing esthetical appearance.

When the interviewees were asked if they had any improvement ideas for Focus DS one answered that all of the edges should be identical so that one could mount the ceiling on to the grid system independent of the edges. Another interviewee wanted less sensitive edges and being able to mount Focus DS in patterns.

3.3 Observations

The result of the observations indicated that most of the test subjects had difficulties demounting the tile but not so much mounting it back up again. When they had demounted the tile almost all of them inspected the tile to see what it looked like underneath, presumably making it easier for them to understand the principle and mount the tile back up again.

Based on the information given by Ecophon it was thought that a majority of the participants would answer that it was hard to demount the tiles but easy to mount the tile back up again. The result from the questionnaires did not, however, correspond to the preliminary assumptions. Out of the 15 participants 53% percent answered that it was hard to demount the tile and only 40 % percent answered that it was easy to mount the tile back up again, see table 2 below.

Table 2 number of participants that found it easy/hard to demount/mount the tiles

	Easy		***Hard***	
	Percent	***Number of participants***	***Percent***	***Number of participants***
Demounting	47%	7	53%	8
Mounting	40 %	6	60%	9

One interesting answer from the questionnaire came from a person who had previous experience with dropped ceilings/acoustic ceilings. He/she answered that it was easy to demount/mount the tile but that it was hard to get straight lines with this kind of ceiling, much similar to what the representatives from the assembly firms had answered.

One of the questions in the questionnaire was how the users thought that they should demount/mount the tile just by looking at it. Most of the test subjects answered that they thought that they had to push the tile up somehow and angle it (more or less the current principle of Focus DS). Others answered that they thought that it would be sufficient to push the tile up for it to release and come down and some thought that the tiles were mounted on to specially designed clips or rails that would enable a “push-and-release” function. Some answered that they thought that the tile had to be shifted in one direction in order to release and be demounted.

Most of the participants didn't answer the question regarding improvement ideas for Focus DS, some did however. Suggestions that arose were to make it easier to understand which edge (edge 1 and 2) that would be mounted first on to the grid system or to have some sort of a push-and release system instead of the current mounting system. Other suggestions were to have some sort of indication one which side to push when demounting (by using colours, symbols or different weights on the tile) and having some sort of demounting/mounting instructions on the underside of the tile.

3.4 Consumer needs

Based on the result of the interviews and the observations the consumer needs were identified. In order to decrease the amount of data repetitive or similar answers were combined into one.

The first consumer needs to be identified were the one based on the interviews, see table 3.

Table 3 Interpreted consumer needs based on interviews

Question	*Answer*	*Interpreted need*
What kind of problems do you see with Focus DS?	-Sometimes the tiles will lift, due to pressure, and fall down.	-Focus DS tiles only moves if you want it to move.
	-It takes longer time to mount, both the grid system and the tiles since you have to be more thorough.	-Focus DS is easy to mount.
	-Notches can appear, sensitive when you demount in order to fix things, you should leave it as it is.	-Focus DS is impact resistant.
	-Springs from the wall molding's in order to pack the tiles closer. The smaller the room the more pressure – the tiles can skew.	- Focus DS tiles only moves if you want it to move.
	-Mounting of armatures and other installations is harder in a DS roof.	-It is easy to mount armatures and etc. with Focus DS.
Do you have any improvement ideas for Focus DS?	-Identical edges, be able to mount the tiles independent of the edges.	- Focus DS is easy to mount
	-Be able to mount Focus DS in patterns.	-Focus DS can be mounted in patterns.
What are the advantages with Focus DS compared to other modular ceilings?	-Easier to demount a DS roof if it is less than 100 mm suspended.	-Focus DS is easy to demount.

	-Look like plasterboard.	- Focus DS has an aesthetically pleasing appearance.
	-Esthetical.	-Focus DS has an aesthetically pleasing appearance.

The identified consumer needs from the observation questionnaires can be seen in table 4.

Table 4 Interpreted consumer needs based on questionnaires from observation trials

Question	*Answer*	*Interpreted need*
What could have been better in regards to demounting/mounting? Suggestions?	-Some simple indication on which side to push.	- It is easy to understand which side to push on the Focus DS tiles in order to demount them.
	-Some sort of push-and-release function.	-Focus DS can be demounted just by pushing the tile.

Notice that the needs were not organized hieratical, as suggested in the book *Product Design and Development* [1;2]. The reason for not doing so was because it was considered unnecessary based on the small amount of consumer needs that were interpreted. If a larger amount of consumer needs had been identified it would have been necessary to organize them hieratical.

The needs were weighted according to a point-system, were each need could be given 1-3 points. A larger point-scale could have been used but since there were so few identified needs it was decided to use a smaller scale. The points were given accordingly:

1 p = The function should not exist/is already fulfilled

2 p = The function is nice to have but not necessary

3 p = Critical function, necessary

It was decided to proceed with the needs that were given 3 points.

In table 5 one can see the identified consumer needs and their perceived importance, repetitive needs are only mentioned once in the table.

Table 5 Identified consumer needs

Identification	*Consumer need*	*Number of points*
A	-Focus DS tiles only moves if you want it to move.	3
B	-Focus DS is easy to mount.	3
C	-Focus DS is impact resistant.	2
D	-It is easy to mount armatures and etc. with Focus DS.	1

E	-Focus DS can be mounted in patterns.	2
F	-Focus DS is easy to demount.	3
G	- Focus DS has an aesthetically pleasing appearance.	1
H	- It is easy to understand which side to push on the Focus DS tiles in order to demount them.	2
I	-Focus DS can be demounted just by pushing the tile.	3

3.5 Discussion

It was hard to localize people with in-depth knowledge about acoustic ceilings and more importantly knowledge about Focus DS. Only four assembly firms and three persons with knowledge about Focus DS were interviewed. More time for the project and a greater insight into the acoustic ceiling industry would probably have helped in terms of knowing whom else to contact. Despite the small amount of interviewees is the result from the interviews considered representative for the product. The reason for this is mainly due to the fact that many of the interviewees answered the different questions similar to one another leading me to believe that the main issues with the product has been identified.

One noticeable thing with the interviews was that almost none of the interviewees had any improvement ideas for Focus DS. Even though it is hard to understand the real reason for this one explanation might be that the interviewees are so focused on the different problems with the product that they can't see beyond that. Another explanation could be that it is just hard to think of improvement ideas for the product. It would have been interesting to have some sort of focus group study with the interviewees were they could discuss the product with each other and then hopefully think of possible improvement ideas for Focus DS. Naturally it takes time to arrange such a meeting which is the main reason for not doing it during this master thesis. If more time had been available this might have been a good idea to implement further one in the project.

The observations was primarily done because of the lack of people to interview, the people that took part in the observation were mostly students. If craftsmen had been used in the observations (instead of students) this might have led to a better foundation for the consumer needs and a better understanding of the product. However because of the time-restriction of the master thesis it seemed difficult to organize for craftsmen to come to IKDC in order to take part in the observations. Furthermore since it was assumed that a random person with no previous experience with Focus DS would react to the ceiling much in the same way as a craftsman with

no previous experience with DS it was decided to do the observations without the help of craftsmen.

Even though the scaffolding was built with the aim of mimicking reality as much as possible one has to take into consideration that it wasn't an exact replica of reality. For instance when the tiles were mounted on to the scaffolding one could see the entire grid system, mainly due to the fact that the scaffolding wasn't that high (because of height restrictions of the room as well in order for people to be able to reach the tiles), see figure 6.

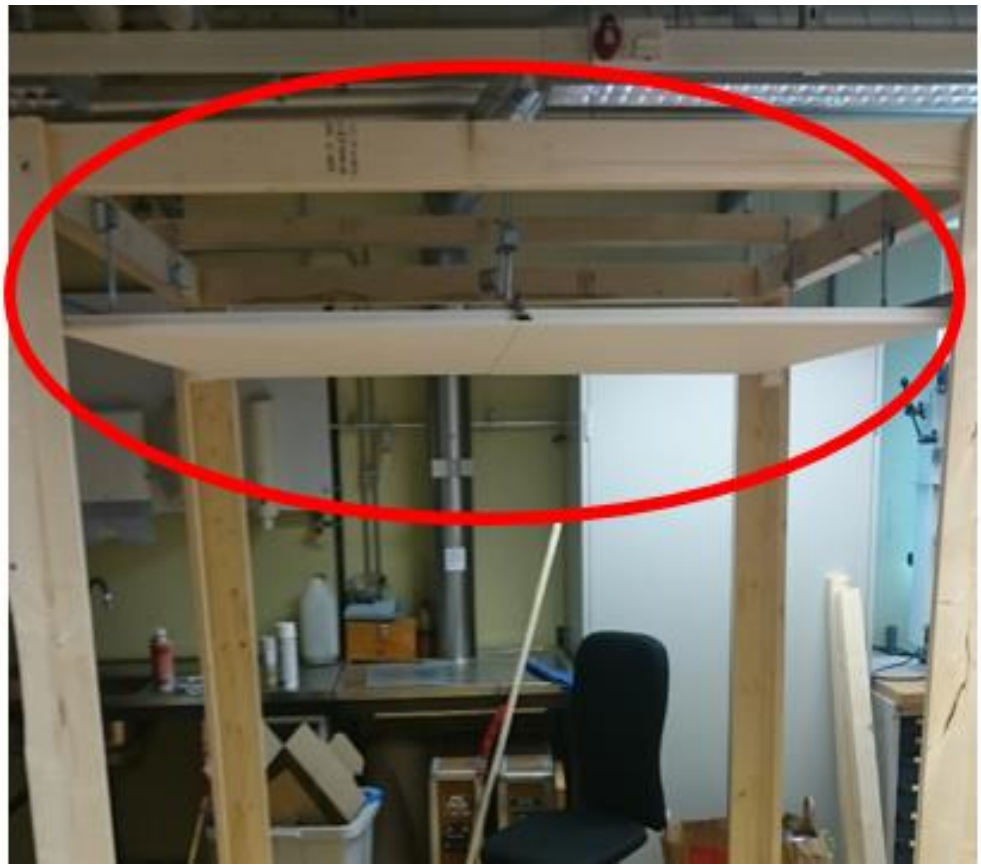

Figure 6 Visible grid system circled in red

In an attempt to hide the scaffolding pieces of corrugated paper was attached to the scaffolding in front of the grid system, see figure 7.

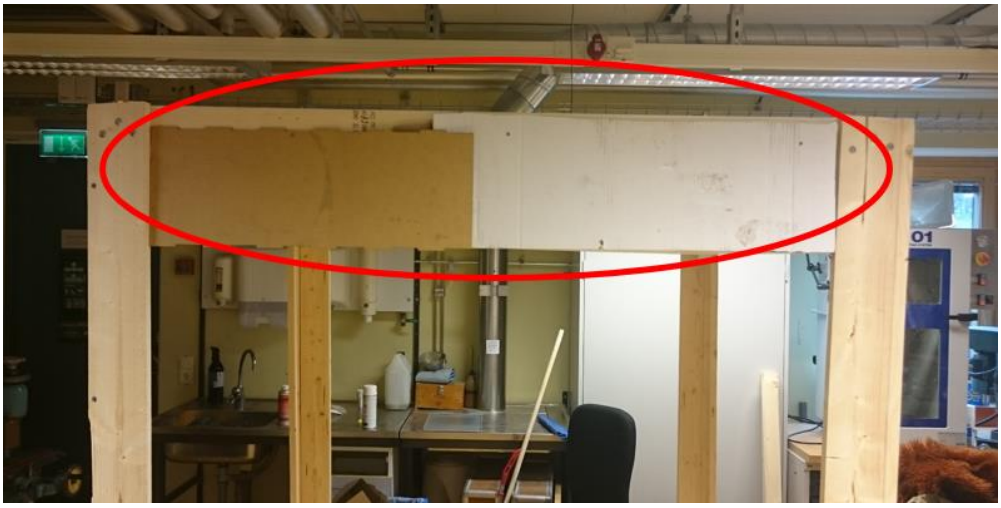

Figure 7 Grid system hidden with corrugated paper, circled in red

Though everything was done in order to hide the grid system there might have been instances during the observations where someone caught a glimpse of the grid system before trying to demount a tile. This could then have led to them getting a better understanding of the principle of the mounting/demounting procedure and consequently making it easier for them to demount a tile and then mount it back up again. Another problem with the way the scaffolding was built was that it didn't have any walls which again made it less similar to how it would have been in reality. Furthermore (due to the lack of walls) there were no springs pushing the tiles inwards from the wall. If there had been any springs it would undoubtedly have made it harder for the users to demount and mount the tiles back up again.

One interesting thing with the observations was that the perceived results didn't correspond to the results from the questionnaires (see table 2). Based on the initial information from Ecophon it was thought that a majority of the participants would find it harder to demount the tiles then to mount them back up again. However the results from the questionnaires revealed that only circa 50% of the participants found the demounting hard to do and only 40% of the participants found the mounting easy to do. This result neither affirms nor contradicts Ecophons suspicions since there are no clear tendencies in the result. For instance if Ecophons assumption is correct that a majority finds the demounting hard the result of the questionnaire would probably be in the region of 80-100 %. If their assumption is wrong the result would probably be in the region of 0-20 %. However since the result for both the demounting and mounting is in the region of 50 % it is hard to draw any conclusions.

There can be several reasons to why the results from the questionnaires does not correspond to Ecophons suspicions. One reason could simply be due to the previously stated restrictions and simplifications of the observations leading to a different experience for the participants than in real life. Even though this would account for some differences in the result it can't explain it all. Observation trials

with more participants and a better test environment would therefore have to be performed in order to affirm (or contradict) Ecophons suspicions.

It is believed that the small amount of consumer needs still represents the different problems of Focus DS in a conclusive way. More needs could have arisen if more interviews had been performed and if there had been more participants in the observation trials. But due to the previously mentioned difficulties finding people to interview and the time restrictions on finding participants for the observation trials I'm overall satisfied with the result.

4 Product specifications

Consumer needs are translated into product specifications in order to aid in the generation of concepts, see chapter below.

4.1 Method

Consumer needs are translated into product specifications, that is, measurable metrics, in order to move away from subjective interpretations of the needs, see chapter 6 in the book *Product Design and Development* [1;2]. However, if a need cannot be translated into a measurable quantity (generally the case for several needs early in the process or for new products), the metric will have the same formulation as the need and its evaluation will be subjective.

4.2 Discussion

During this part of the project it became evident that the needs would not be translated in to product specifications, there were two main reasons for this. The first reason was because most of the needs could not be translated into measurable quantities, the second reason was that it was deemed unnecessary.

The reason for why it was deemed unnecessary was because of the nature of the project. For instance if the project was about improving a specific thing e.g. Focus DS grid system it would be of great value to interpret the needs into product specifications. This would namely aid in the following concept generation in regards of setting target values for what the new improved grid system should accomplish for instance in comparison to the current grid system or competitors grid system. In this project, however, the aim is to improve the overall experience of the mounting and demounting of Focus DS (one could almost describe it as creating a completely new product). And because of this any kind of attempt to set target values or similar would be unnecessary since it would be a new product with no current equivalent and therefore any kind of evaluation would ultimately be subjective.

5 Concept generation

Method of generating concepts and the result of that is described below.

5.1 Method

It was decided to generate concepts based only on the consumer needs with the highest points as well as the demands and wishes given by Ecophon. The reason for this was in order to focus on the essential issues with Focus DS. A summary was done of the chosen consumer needs, demands and wishes see table 6.

Table 6 Summary of chosen consumer needs and the demands and wishes from Ecophon

Demands and wishes		*Consumer need*	
1.	Demountable	A.	Focus DS tiles only moves if you want it to move.
2.	No alterations to grid system.	B.	Focus DS is easy to mount.
3.	No alterations to the visual appearance of the tiles.	F.	Focus DS is easy to demount.
		I.	Focus DS can be demounted just by pushing the tile

In order to identify if there were any products on the market that fulfilled the chosen demands, wishes and consumer needs an external search was performed – for more information see chapter 7 in [1;2]. The external search was a combination of benchmarking[1] and patent searching. The internal search was done by generating ideas based on personal knowledge (gained through courses taken at the Faculty of Engineering LTH of Lund University LTH) as well as creativity. The external search was also a helpful tool in order to gain inspiration for the internal search. The chapter ends with a discussion regarding the process and the results.

[1] According to [1;2] benchmarking is when you gather information and get an understanding of competitive products on the market. Benchmarking can be used in several different parts of the product development process e.g. during the concept generation [1;2]

5.2 External search

The competitive products should fulfil the chosen consumer needs and demands and wishes from Ecophon. The products should also have a concealed grid system and be demountable. However if competitive products are found that only fulfils some of the requirements they might still be included in the benchmarking for inspirational purposes. Below are several different companies listed that produces acoustic products followed by a short account on what kind of interesting competitive products they have.

5.2.1 **Rockfon**

With Rockfons products one can choose between different appearances combined with different mounting systems. Since the mounting system is the main focus of this master thesis it was decided to look in to Rockfons different mounting systems.

One of their mounting systems is called Rockfon® System Swing A, E, C™. With this mounting solution the grid system is semi-concealed as well as being demountable, see figure 8 below.

Figure 8 Visual appearance of Rockfon® System Swing A, E, C™ [7]

The principle of the system is to lift one of the edges attached to the grid system, this will release the tile from the grid system. The tile can then swing down 90 degrees and hang vertically since the other edge still is attached to the grid system. This system is also very rigid when mounted i.e. the tiles doesn't move, see figure 9 below.

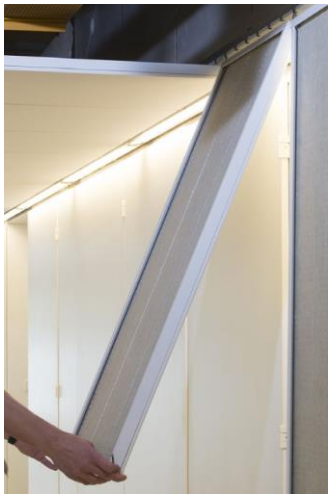

Figure 9 Demounted Rockfon® System Swing A, E, C™ [7]

5.2.2 **Armstrong ceiling solutions**

Armstrong ceiling solution (Armstrong) manufactures acoustic ceilings and acoustic wall panels. One can choose what kind of finish one wants for the ceiling and then choose from a variety of mounting alternatives and accessories.

In order to stop the tiles from moving Armstrong has developed a clip that is mounted on the T-bar and pushes the tile downwards to prevent it from moving, it is called retention clip, see figure 10 below:

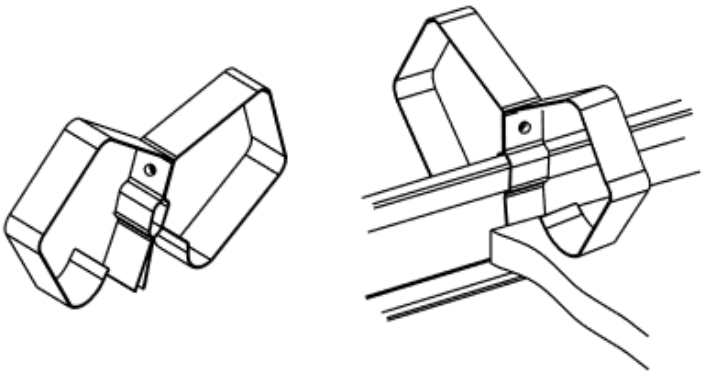

Figure 10 Retention clip not mounted to the left mounted to the right [8]

Armstrong also has a product called “universal hold down clip” which also pushes down on the tiles in order for them to be less sensitive to movement, see figure 11 below.

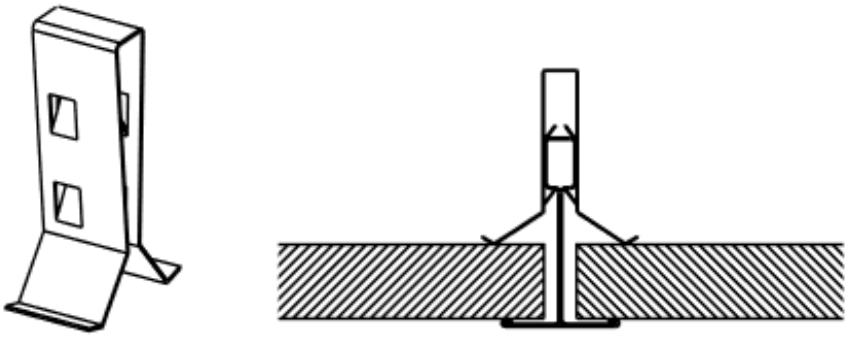

Figure 11 Universal hold down clip not mounted to the left mounted to the right [8]

It is unclear how the tiles are demounted when these kind of clips are on but since they fulfill one of the consumer needs they were included in the external search.

5.2.3 **Knauf Danoline**

Knauf Danoline (Knauf) manufactures a product called Contur that has an edge design called “edge D”, see figure 12.

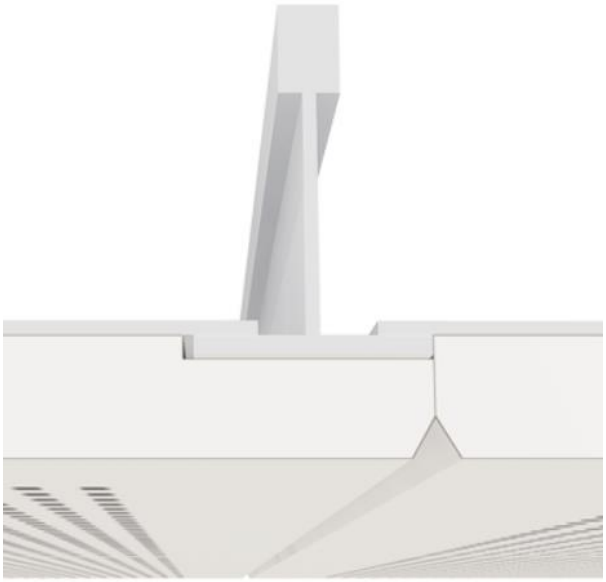

Figure 12 Contur with edge design D mounted on to grid system [9]

This design constitutes of two plates that has been added on to the tiles thus creating the overall edge design. The tiles are mounted on to the T-bar much in the same way as for DS. In figure 13 one can see how it looks when the tiles are mounted on to the T-bars, in the picture it also becomes clearer on how the edge design looks.

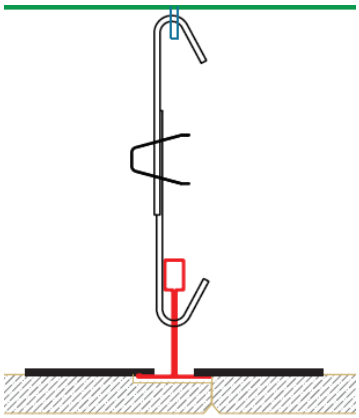

Figure 13 Contur with edge design D fully assembled [10]

5.2.4 itaab

itaab produces a ceiling were one uses narrow elongated tiles in order to create a different aesthetic appearance, the product name is Luxalon see figure 14.

Figure 14 Visual appearance of Luxalon [11]

The grid system is semi-concealed (there has to be a small gap between the tiles in order to be able grab the tiles for demounting) and demountable, the tiles are snapped on and off the grid system with the use of snap joints, see figure 15.

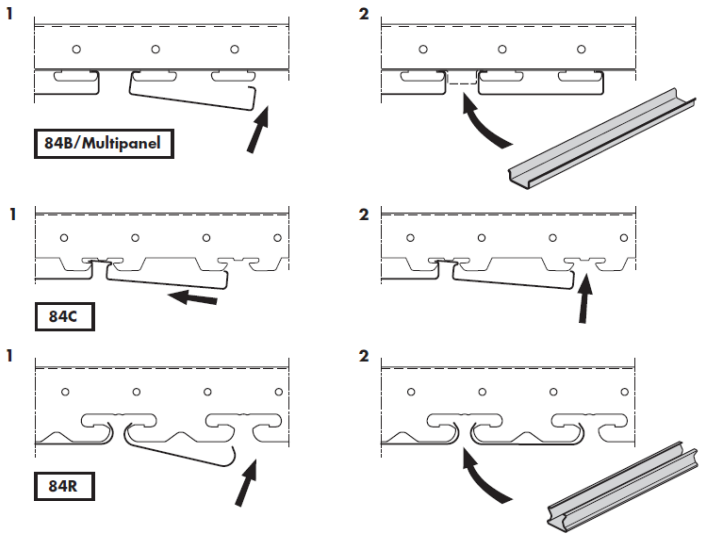

Figure 15 Mounting system of Luxalon [12]

5.2.5 **Paroc**

Has a products called Parafon Wall Absorber Classic. This is a wall tile but has an interesting mounting system. The tiles are mounted on to the wall by hanging them on to nails. The mounting on to the nails is performed by a so called “key-hole-attachment” on the backside of the tile. In figure 16 one can see an example of how a key-hole-attachment can look like.

Figure 16 Example of how a key-hole-attachment can look like [13]

5.2.6 **Zilenzio**

Zilenzio produces different types of wall panels that are all mounted on to the wall by using Velcro. A Velcro tile is screwed on to the wall, after that one can just mount the tile on to the Velcro (this is possible due to the material that the tiles are made of). An example of their wall panels (called Fazett) can be seen in figure 17.

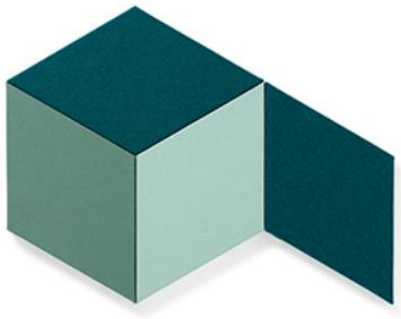

Figure 17 Visual appearance of the wall panel Fazett [14]

5.3 Summary of the external search

In order to summarize the findings from the external search a table (see table 7) was prepared where each product was evaluated based on which demands, wishes and needs that they fulfilled. The purpose of the summary was to aid in the ideation process in the following internal search.

Table 7 Summary of external search

Product name	***Rockfon® System Swing A, E, C™***	***Retention clip***	***Universal hold down clip***	***Contur***	***Luxalon***	***Parafon Wall Absorber Classic***	***Fazett***
Demands and wishes							
Demountable	✓	✓	✓	✓	✓	✓	✓
No alterations to grid system.		✓	✓	✓			
No alterations to the visual appearance of the tiles.		✓	✓	✓	✓	✓	
Consumer need							

Tile only moves if you want it to move.	✓	✓	✓		✓	✓	
Easy to mount.	✓	✓	✓	✓	✓	✓	✓
Easy to demount.	✓	✓	✓	✓	✓	✓	✓
Demounted just by pushing the tile							

A patent search was also performed (during the external search) on the different companies. The search was done mainly on three different websites: the Swedish patent base (PRV), the European patent base (Espacenet) and the United States Patent and Trademark Office (USPTO). For more information on PRV see: http://was.prv.se/spd/search?lang=en&tab=1 for Espacenet see: https://worldwide.espacenet.com/ and for USPTO see: https://www.uspto.gov/.

The purpose of the patent search was to see if the companies had any current patents for their products, to act as a source of inspiration for the internal search and also to research if there were any patents for the generated concepts. Only one patent [17] was found for Armstrong regarding a special way of mounting tiles with the use of clips placed in grooves in the tiles and then clicked on to the grid system. Because of the lack of patents for the different companies and since no patents were found for the generated ideas this was not included in the result. Further investigations has to be done however when and if Ecophon decides to develop one of the concepts.

5.4 Internal search

Any idea that fulfilled one or more of the consumer needs were included in the internal search – even if they didn't satisfy the demands and wishes of the company.

5.4.1 **Concept 1**

Add a strip that increases the friction between the T-bars and the tiles. The increased friction would make the tiles less sensitive to changes in pressure etc. so as to stop the tiles from moving unwantedly. The lists could be made of some sort of rubber or thermoplastic elastomer. This concept could be implemented in the current design of Focus DS, see figure 18.

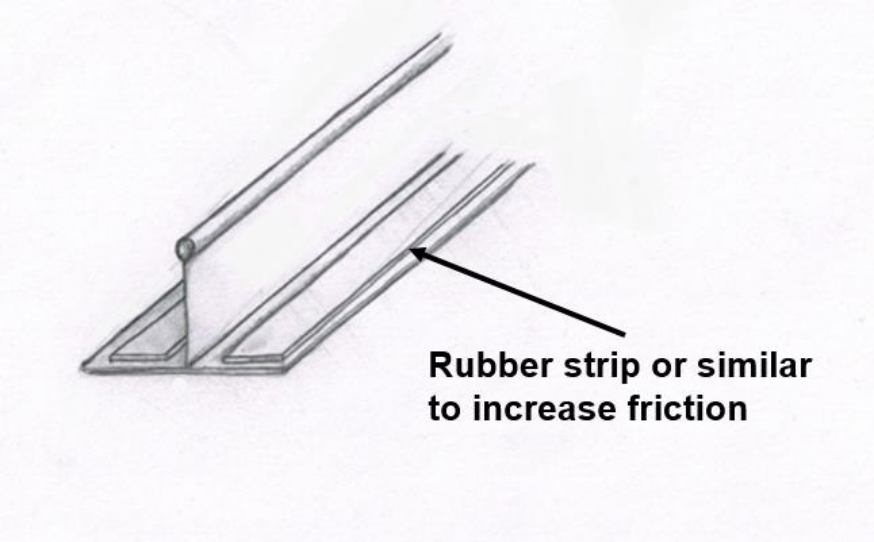

Figure 18 Illustration of concept 1

5.4.2 **Concept 2**

Use magnetic paint on the tiles and/or T-bars, the magnetic paint (figure 19) would make the tiles less sensitive to changes in pressure etc. so as to stop the tiles from moving unwantedly.

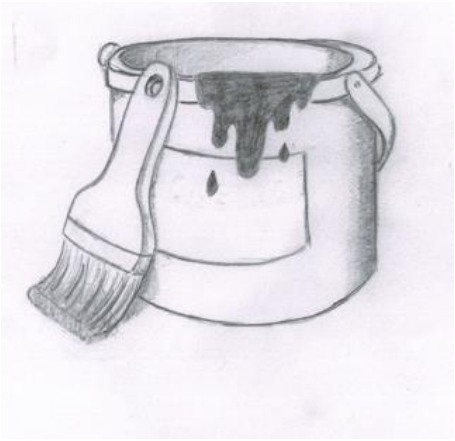

Figure 19 Illustration of a magnetic paint bucket

5.4.3 **Concept 3**

Use snap joints for easy mounting and also in order to stop unwanted movement of the tiles. The snap joint may be accomplished by applying a new edge design or by adding on snap joint to the tiles, see figure 20.

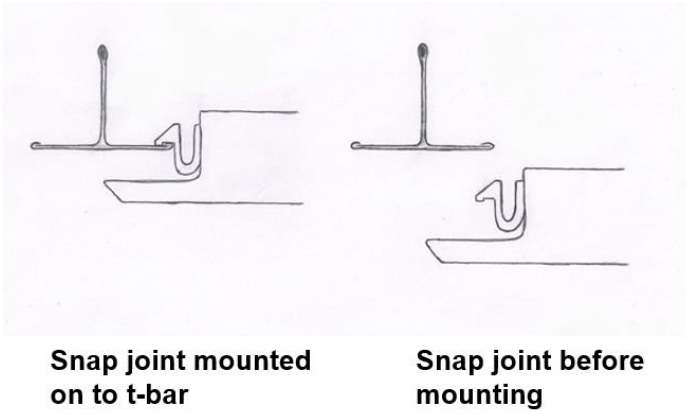

Figure 20 Illustration of concept 3, mounted and not mounted

5.4.4 **Concept 4**

Clips that you put on to the T-bar, before the tile is on the clip is open, you then mount the tile on to the T-bar and then push the clip down from above the tile. The clip would add pressure on the tile and consequently make the tile less prone to move unwantedly. This idea is based on the same principal as the retention clip and the universal hold down clip that Armstrong manufactures. The concept can be seen in figure 21.

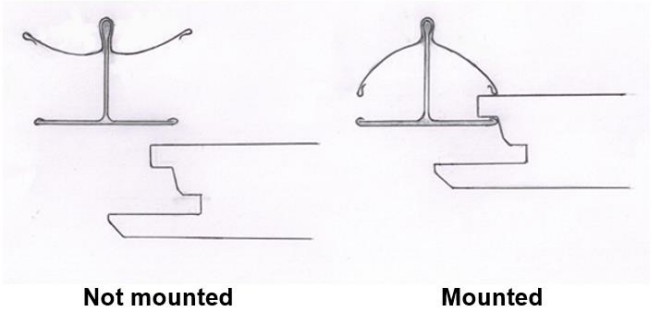

Figure 21 Illustration of concept 4, mounted and not mounted

5.4.5 **Concept 5**

Add a clip to the tiles edges before mounting it. The clip would snap on to the T-bar when one pushes the tile up towards the T-bar. If one pushes the tile more the clip would retract enabling the tile to fall down, a so called push-and release function, see figure 22.

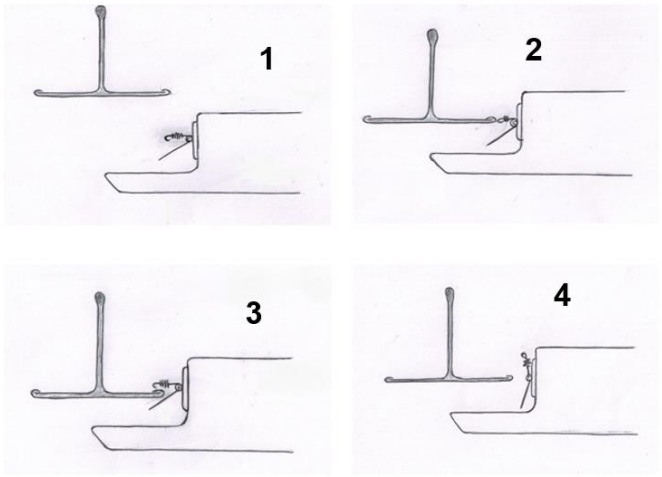

Figure 22 Illustration of concept 5 in it is different mounting steps

5.4.6 **Concept 6**

The same principle as the current Focus DS design but with the difference that the tiles doesn't just lay on the T-bar but are hooked on to holes in the T-bar. The "hooking" feature is accomplished by milled pegs on the tiles, see figure 23.

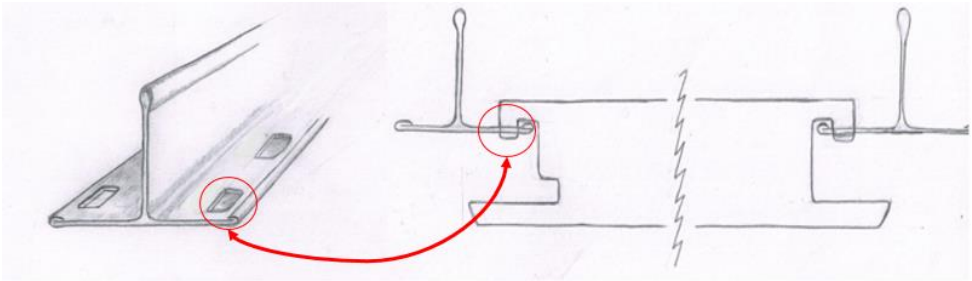

Figure 23 Illustration of concept 6

5.4.7 **Concept 7**

In order to make the tiles less prone to move unwantedly the tiles can be mounted with aid of hooks that are attached to the tiles and then hanged on to the T-bar, see figure 24.

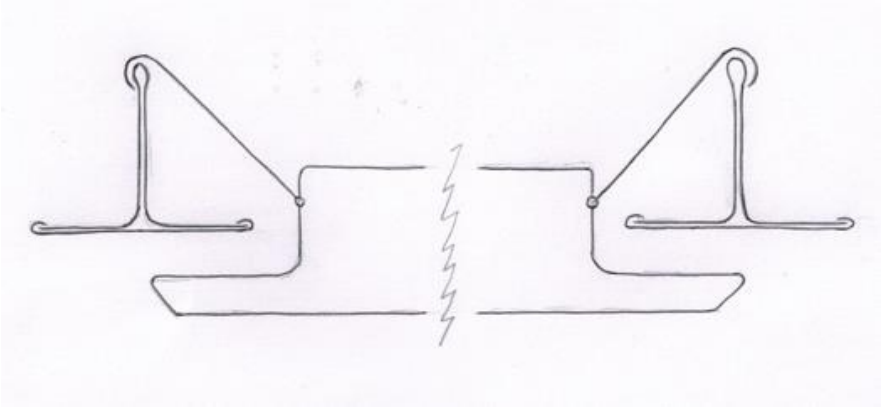

Figure 24 Illustration of concept 7

5.4.8 **Concept 8**

I-bars with shorter elongated scores that runs the entire length of the bar. The tiles has been milled so as to fit (and go through) the scores and consequently make the tiles less prone to move unwantedly, see figure 25.

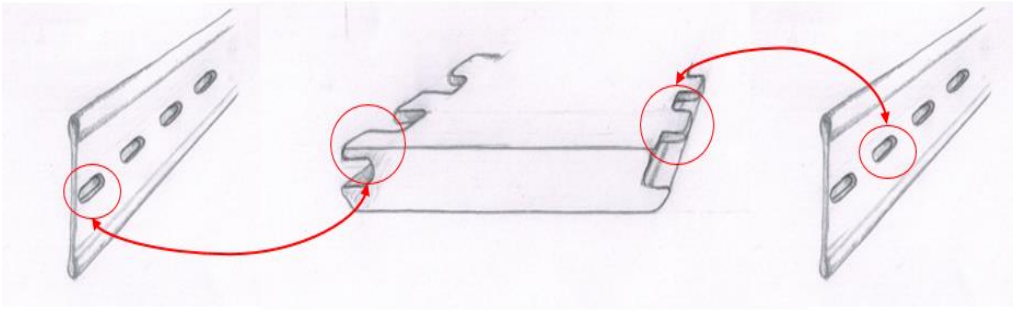

Figure 25 Illustration of concept 8

This concept would mean that the grid system of DS would have to be altered significantly.

5.4.9 **Concept 9**

In order to stop any unwanted movement of the tiles one could use the current design of DS but add grooves that “latches” on to the T-bars edge, figure 26.

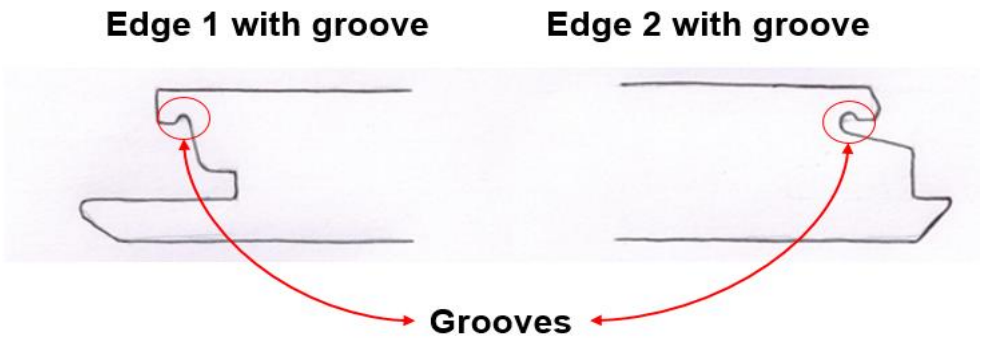

Figure 26 Illustration of concept 9

5.4.10 **Concept 10**

Use indicators on the current DS tiles in order to aid in demounting. Examples of indicators are indentations on the tiles surface, use of different colors on the surface or on the edges or maybe add instructions underneath the tiles.

5.4.11 **Concept 11**

Springs on the T-bars that adds pressure on the tiles in order to remove unwanted movement of the tiles, see figure 27.

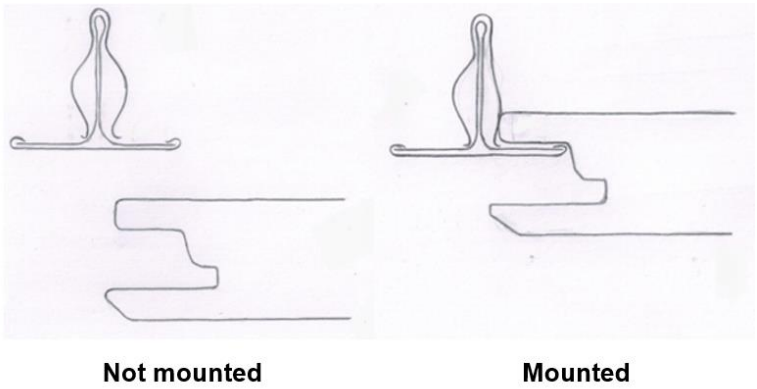

Figure 27 Illustration of concept 11, a tile is mounted on the grid system to the right

5.4.12 **Concept 12**

Use a prefabricated push-and-release lock. There are different types of push-and-release locks on the market. One of the most common types is the magnet push-and-release lock, see figure 28.

Figure 28 Picture of a magnet push-and-release lock [15]

There are also other types of push-and-release locks such as the "non-magnetic touch latch", see figure 29.

Figure 29 Picture of a non-magnetic touch latch [16]

5.4.13 **Concept 13**

Use tiles with sharply cut edges that are mounted on to triangular shaped bars. The tiles would stay on the bars due to friction and forces normal to the surface which would be achieved due to the bars pushing inwards towards the tiles, see figure 30.

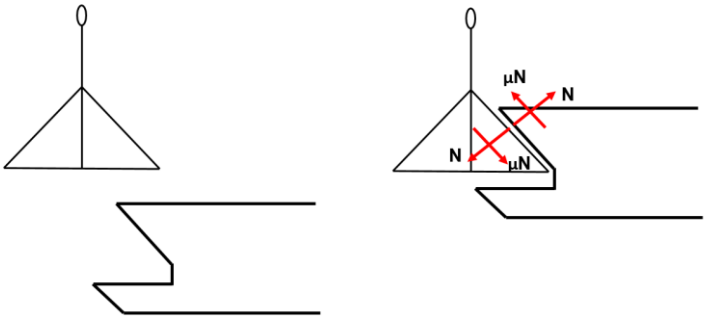

Figure 30 Illustration of concept 13

The tiles would be mounted and demounted in the same way as the current DS, i.e. by angling the tiles on side at a time.

5.5 Discussion

During the external search it became evident that most of the companies that manufactures acoustic ceilings have the same or similar products. For instance almost all of the companies that were included in the external search had a product similar or almost identical to the mounting system of DS. A short summary of similar products to DS on the market and which company that has them can be seen in table 8.

Table 8 Examples of similar products to DS

Company	*Similar product to DS*
Rockfon	Edge profile M
	Edge profile X
	Edge profile Z
Armstrong	Optima vector
	Square Tegular
Paroc	Edge profile D2

There are differences between the companies, mainly regarding which kind of materials they use to manufacture the tiles with but even so it became clear that Ecophon really has to stand out with DS in order to gain the largest share of the market with this type of ceiling.

The similarities between the companies weren't, however, just in regards to DS but as a whole most of the companies had very similar product ranges, to name an example: the "swing" ceiling. Most of the companies had a products similar to the previously mentioned Rockfon® System Swing A, E, C™ were one "swings" the

tiles down from one side while the other side remains attached to the grid system. Due to these very similar products ranges it was hard to find mounting systems that differed from another amongst the different companies, including Ecophon. Therefore the products presented for the different companies are the ones that were found to be the most interesting and inspirational from that company's product range.

It was hard to generate concepts for DS with the restrictions and limitations that were at hand. Only thirteen ideas were thought of which probably could have been higher if there weren't so many restrictions to take into account. Furthermore because of the difficulties of generating concepts this part of the project took much longer time to do then what was originally planned in the beginning of the master thesis. However based on the above mentioned difficulties I'm overall happy with the result.

6 Choice of concept

In this chapter previously generated concepts will be evaluated and in the end final concepts will be chosen in order to be presented to Ecophon.

6.1 Method

Several different ways of choosing a concept is presented in chapter 7 in the book *Product Design and Development* [1;2], e.g. external decision, intuition, decision matrix and so on and so forth. In this work a combination of intuition and decision matrix will be used. The decision matrix will evaluate each concept in relation to the different criteria's. The best concepts from the evaluation will then be developed further and/or combined with other concept in order to improve them. After further improvements a final concept will be chosen and presented to the company. The chapter will end with a short discussion on the work.

6.2 Preliminary screening

The decision matrix can be seen in table 9 were the concepts were ranked against the original Focus DS. The grading system used in the decision matrix is similar to the one used in chapter 7 in the book *Product Design and Development* [1;2]. The grading system that was used in the decision matrix is:

"+" = better than current product

0 = Equal to current product

"-"= worse than current product.

Concept	*C1*	*C2*	*C3*	*C4*	*C5*	*C6*	*C7*	*C8*	*C9*	*C10*	*C11*	*C12*	*C13*
Demands and whishes													
Demountable	0	0	-	0	0	0	0	-	0	0	0	0	0
No alterations to grid system	0	0	0	0	0	-	0	-	0	0	0	-	-
No alterations to visual apperance of the tiles	0	0	0	0	0	0	0	0	0	0	0	0	0
Consumer need													
Focus DS tiles only moves if you want it to move	+	+	+	+	+	+	+	+	+	0	+	+	+
Focus DS is easy to mount	0	0	+	0	+	0	0	0	0	0	0	0	0
Focus DS is easy to demount	0	0	-	0	+	0	+	0	0	+	0	+	+
Focus DS can be demounted just by pushing the tile	0	0	0	0	+	0	0	0	0	0	0	+	0
Nr. of "+"	1	1	2	1	4	1	1	1	1	1	1	3	2
Nr. of 0	6	6	3	6	3	5	6	4	6	6	6	3	4
Nr. of "-"	0	0	2	0	0	1	0	2	0	0	0	1	1
Sum	1	1	0	1	4	0	1	-1	1	1	1	2	1
Ranking	3	3	4	3	1	4	3	5	3	3	3	2	3

Table 9 Decision matrix

The concepts with the highest ranking are concept 5 and 12, the concepts with the lowest rankings are concepts 3, 6 and 8.

Concept 12 (magnet push-and-release lock) got very high scores in the matrix however this idea would have to be outsourced by Ecophon which would increase the production costs significantly for Focus DS. Other issues with the concept is that it would alter both the tiles and the T-bar (since the lock consists of two parts) and since one of the demands from Ecophon is to not to alter the tiles this idea is discarded.

Concept 5 is also a push-and-release lock but with the difference that it only consist of one part and is not a current product on the market. The mechanics of the concept is not yet finalized but will continue on for further development.

Concepts 3, 6 and 8 are excluded from further development since they don't fulfill all of Ecophons demands and due to the fact that they have the lowest rankings.

From the remaining concepts (all ranked 3) it was decided to continue with concepts 4, 9 and 11. The reason for this was that they were considered better ideas, especially regarding the consumer need "the tiles only moves if you want it to move". These concepts were therefore chosen mainly based on intuition.

A summary of which of the concepts that were chosen and which that were not can be seen in table 10.

Table 10 Summary of the which concepts that were chosen and which that were not

Concept	*C1*	*C2*	*C3*	*C4*	*C5*	*C6*	*C7*
Continue?	No	No	No	Yes	Yes	No	No
Concept	*C8*	*C9*	*C10*	*C11*	*C12*	*C13*	
Continue?	No	Yes	No	Yes	No	No	

6.3 Further development and final decision

Concept number 4 (i.e. the hold-down-clip) is very good idea for solving the consumer need "the tiles only moves if you want it to move". However after further investigation it was found that Ecophon has similar products already in their range, for instance the "Connect clips DS" and the "Connect clips universal", see figure 31.

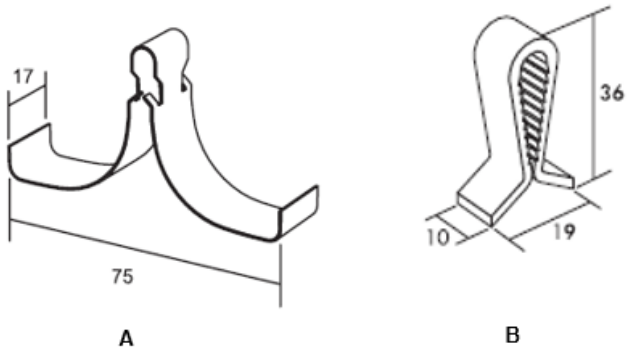

Figure 31 Visual appearance of Ecophons Connect clips DS to the left and Connect clips universal to the right [18]

Concept number 5 (i.e. push-and-release lock) is a very god concept since it fulfills all of the consumer needs as well as the demands and wishes from Ecophon. This concept would have to be mounted on to the tiles by the assembly firms which would add on time to the assembly. It is thought however that the overall mounting time would be significantly reduced even if it takes some time to mount the lock on to the tiles. Furthermore if the installation time is reduced this will lead to decreased mounting costs.

The exact mechanisms of concept 5 is not finalized and in order to do this more time and expertise help is needed. In order to aid eventual further development the concept is divided into its different parts, in short the concept consists of two parts. The first part latches on to the T-bar and prevents the tile from unnecessary movement. This part can for instance be a snap-joint of some sort or (as illustrated in figure 22) a small hook combined with a spring. The second part of the "lock" controls the first part, meaning that when pressure is added on to this part (when the tiles is pushed upwards) it will at *a certain point* retract and forcing the first part to retract as well. The mechanism can almost compared to that of a Suisse army knife, were the blade (at a certain point when you pull it out) will spring open by itself. One possible issue with concept 5 could be the costs associated with developing this idea as well as the manufacturing costs.

Concept 9 is a very straight forward concept that would only mean minor alterations to the current DS. The hope of the concept is that the tiles won't move unwantedly thus decreasing the installation costs. Possible problems with this concept is that the edge where the groove would be might be too thin for a groove in order to maintain a sufficient carrying capacity for the tile. Another possible problem is if this new geometry would be able to be milled or if the geometry is too complex for milling? And if the geometry can be milled this would mean that new milling tools would have to be designed which would mean a significant investment cost for the company. However since this cost would be a one-time cost and since no other

investments would have to be done the cost is negligible if it would mean increased sales of DS. In figure 32 one can see a CAD-rendering of the concept (on edge 1).

Figure 32 CAD-illustration of concept 9, not to scale!

The last concept that was chosen was number 11, i.e. springs on the T-bars. This concept is thought to be a very inexpensive way of removing any unwanted movement of the tiles – thus reducing installation time and costs. The springs can't be too rigid nor to springy since this would make the system instable and create a similar problem to what the current compression springs do (described in chapter 3.2). The purpose of the springs is to add just enough pressure on the tiles so that they won't move unwantedly and hopefully make the current compression springs redundant.

One way that the springs could look like can be seen in figure 33 (which is a CAD-rendering).

Figure 33 CAD-rendering of concept 11, not to scale!

The associated costs of producing a spring like this is thought to be very small since it can be made out of one piece of sheet metal. The problem with the concept lies in

testing it to ensure that it works and doesn't create the same problems that the current compression spring does.

Based on the above mentioned it was decided that two concepts were chosen to be presented for Ecophon. The two concepts are concept number 9 and concept number 11. The reason for choosing them both was because they were considered to be equally good in terms of fulfilling the consumer need "the tiles only move if you want them to move". Furthermore since they were both considered to be quite inexpensive solutions to produce it was considered as a good idea to make Ecophon decide which one of the ideas they liked the most.

6.4 Discussion

The choice of concept could have been performed in many different ways. For instance a very common way of choosing concepts is with the use of a weighted decision matrix were each consumer need gets a weight factor. The sum of the different weight factors should be equal to 1 and the final score that each concept gets for a consumer need is the weight factor multiplied with the score that you gave the concept for that need, see chapter 7 in [1;2]. However since there were so few needs and due to the fact that the project is based on a current product (DS) it felt logical to use the chosen decision matrix were each concept is compared to the current one.

Intuition was also used in order to choose which concepts that would go on, the reason for using intuition became evident when there were several concepts that had the same ranking in the decision matrix. In this case it would not have been effective to choose every concepts that had a ranking of 3 (which was a majority of the concepts). Therefore in order to decrease the number of chosen concepts intuition was used.

When regarding table 9 it becomes evident that many of the concepts solved the need "Focus DS tiles only moves if you want it to move". The only reason I have for this is that I found it hard to generate concepts that solved the other needs. If there had been two persons writing this master thesis there might have been a greater variation of the generated concepts.

After the preliminary concepts had been chosen it was my intent to develop all of the concepts further and create prototypes. However when this process started it became evident that it wasn't easy to do. When I realized that Ecophon already had similar products to concept number 4 it was decided not to make any prototypes of this concept since that would be redundant.

I worked quite some time trying to figure out a viable mechanism for concept 5; visiting toy-shops, hardware stores, furniture stores etc. in order to find a product similar to what I wanted to accomplish with concept number 5. When I didn't find

any product that worked in the same manner I came to the conclusion that in order to make a prototype of this concept I would need more time and expertise help, things that I didn't have. The time issue was also a problem that occurred with concept 9 and 11 which is why no prototypes were made.

Since the concept generation took longer time than I anticipated this meant that I had less time to invest in the choice of concept and prototyping. If I had had more time at my disposal I might have been able to produce prototypes for the different concepts.

Despite the problems with managing my time efficiently I'm overall happy with the chosen concepts. I believe that both of the concepts could be implemented in Ecophons product range quickly and also increase the sales of DS. The reason why I believe that the concepts could increase sales is because they would hopefully reduce the installation time of the ceiling. This in turn would hopefully mean that the assembly firms would be more prone to recommend the product for possible costumers.

7 Personal reflections

A short personal reflection on the master thesis.

Overall I feel that I have fulfilled the goal with the master thesis, i.e. to investigate what kind of problems tradesmen have when demounting and mounting DS and based on the result from those investigation develop a new mounting and demounting solution. However if I compare my master thesis to other product development projects that I have done during my time at LTH I would say that this project separates itself from everything else. In previous projects the emphasis has been on generating concepts and not so much on analyzing a current product and identifying consumer needs. A significant amount of time was invested during this master thesis in order to identify what kind of problems there are with Focus DS as well as to identify the consumer needs (i.e. the interviews and the observations). The observations in particular is something that I'm very proud to have done since this is something I believe companies do in reality when analyzing their products.

As stated in previous chapters the concept generation took much longer time than anticipated. The reason for this was simply because I struggled to find concepts that would fulfill the consumer needs and at the same time take the demands and wishes of Ecophon into account. And since the concept generation was delayed it meant that I had less time to evaluate and develop my chosen concepts.

If I were to do a similar project again (were a thorough investigation of a current product has to be done) I would invest more time for concept generation and evaluation.

In appendix B.1 one can see the preliminary time-frame for my master thesis, in appendix B.2 one can see how my time during the master thesis actually was used.

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Appendix A

The different questions used to derive consumer needs

A.1 Questions for assembly firms

1. How often do you install modular ceilings from Ecophon?
2. How often are you hired to repair damages to modular ceilings?
3. How easy do you experience it is to mount and demount Focus DS?
4. What kind of problems do you see with Focus DS?
5. Have you heard from other craftsmen that they experience it to be hard to mount and demount Focus DS?
6. Do you believe that it takes longer time to mount and demount Focus DS than other modular ceilings?
7. Do you have any improvement ideas for Focus DS?
8. What are the advantages with Focus DS compared to other modular ceilings?

A.2 Questions for craftsmen or company representatives with knowledge about Focus DS

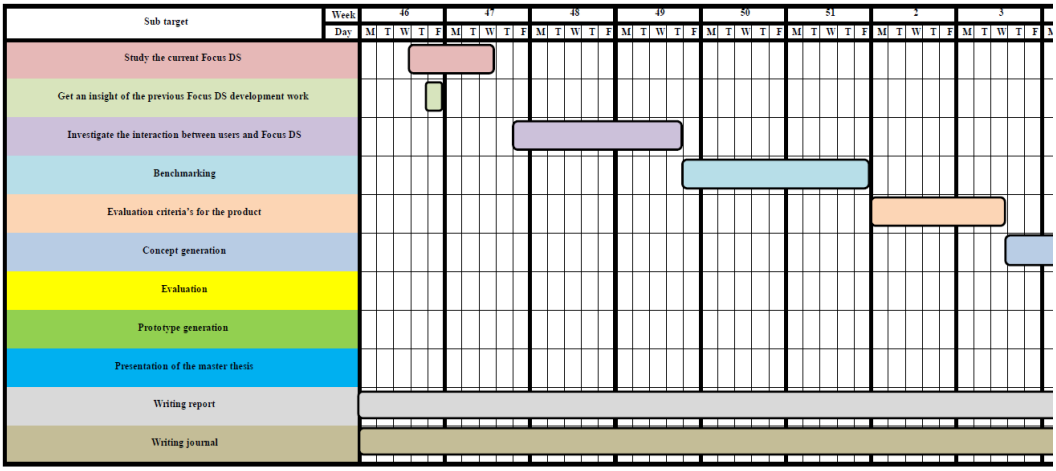
1. What kind of experience do you have with Focus DS?
2. What kind of problems do you see with Focus DS?
3. Have you heard from other craftsmen that they experience it to be hard to mount and demount Focus DS?
4. Do you believe that it takes longer time to mount and demount Focus DS than other modular ceilings?
5. Do you have any improvement ideas for Focus DS?
6. What are the advantages with Focus DS compared to other modular ceilings?

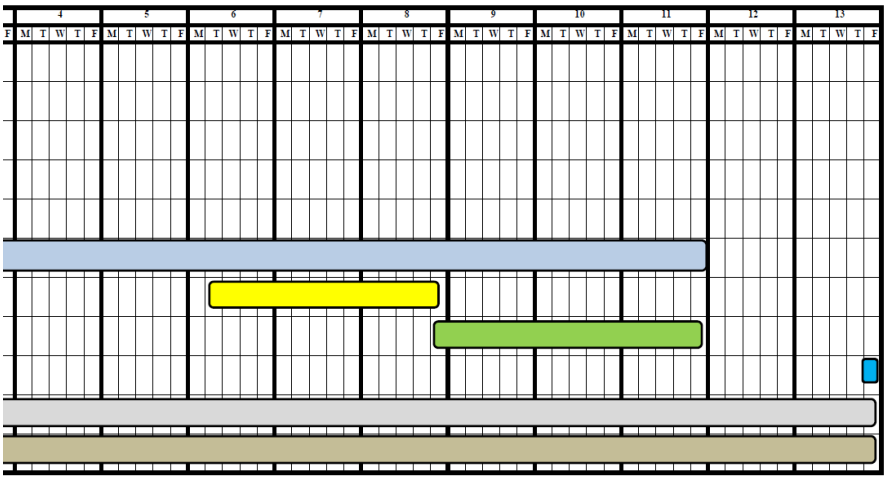
A.3 Questions for the observation trials

1. Do you have any previous experience of handling dropped ceilings/acoustic ceilings?
    a. Yes
    b. No
2. If your answer to question 1 was “yes” please describe your previous experience.
3. How did you think that the tiles would demount/mount just by looking at it?
4. Describe your thoughts about demounting and mounting Focus DS, was it easy/hard?
5. What could have been better in regards to demounting/mounting? Suggestions?
6. Other thoughts that you would like to add?

Appendix B Work distribution and time frame

B.1 Preliminary Gantt-schedule





B.2 Actual Gantt-schedule of work distribution