A NEW CONNECTION

The use of used timber in the construction industry

Noud van Esseveld
A NEW CONNECTION
THE USE OF USED BUILDING MATERIALS IN THE CONSTRUCTION INDUSTRY

by

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Buurman, the collaborating organization, is a company that trades used building materials with both the trade and the public sector. They are located at the Keilewerf, a warehouse, that houses 45 different creative companies. The materials in which Buurman trades, originate from a wide variety of sources, so at the same time Buurman functions as a facility that transforms waste into new resources. By also functioning as such, Buurman breaks through the linear product process of these ‘products’ and gives them a second life. Figure 1 shows Buurman’s achievements in the year 2016.

Most of the materials/products at Buurman are a form of timber, but a variety of other materials can also be found in market.

Besides a market for used building materials, Buurman also is involved in construction projects, offers workbenches in their workshop for rent, sells DIY furniture sets, and offers a variety of building courses. All of which utilize the availability of used building materials.

With these activities Buurman is one of the companies in Rotterdam, that is helping in transforming the linear stream of resources into a more circular system. It is Buurman’s ambition to expand this impact and to expand the amount of material they are able to process.

Together with Buurman a graduation assignment was formulated in which the new ways were going to be explored to continue and increase this expansion.
Figure 1: Achievements of Buurman in the year 2016
1. INTRODUCTION

1.1 Aim of the thesis

The amount of used building material that is available in The Netherlands is extensive. It is so extensive that Buurman, the collaborating company, can only collect an insignificantly small percentage of what is available. And although the sales of the building materials are growing, the material market is not reaching its full potential by a long shot. This is a pity, because the quality of this material is perfectly fine. Buurman is constantly looking for application through which they can show this. Currently Buurman is primarily successful in the public sector, but they are aiming to become more attractive for the professional sector as well. They are especially interested in becoming more attractive for the construction sector.

This industry not only uses a lot of building materials, but is also one of the biggest producers of these materials. In contrast to what one might expect, these used building material are not produced through demolition, but completely arise during the process of construction.

The aim of this thesis is therefore to determine how Buurman can increase their material output, through the production of products, new materials or services. That being said, it is important to clarify the difference in aim of the analysis and the product development (synthesis and embodiment) in this thesis.

The analysis of this thesis aims to find out, how companies such as Buurman (CRRS Companies) in general can increase their output of used building materials to the construction industry, by means of new products, materials or services that incorporate these materials.

The aim of the product development (synthesis and embodiment) is to develop a product specifically for the collaborating company. It aims to incorporate the conclusions of the analysis, but has the priority of developing a product that fits the company and that increases their output of used building materials.

1.2 Research questions

The analysis of this thesis aims to answer the following question:

Main research question

“How can companies that collect, refurbish, re-use and sell used building materials, grow?”

The following sub questions were developed to address the main research question:

Sub question one

“What characterizes companies that collect, refurbish, re-use and sell used building materials?”

Sub question two

“How do companies that collect, refurbish, re-use and sell used building materials, select, collect and use their material?”

Sub questions three

“Which initiatives, that incorporate the re-use of building material, are feasible for medium sized construction companies to implement?”
1.3 Scope

Concerning the area on which this thesis will focus, the following is defined:

Buurman tries to expand the widespread availability of used building materials. Because the term ‘used building materials’ is quite broad, it is difficult to find a focus for the analysis. It will inevitably lead to the subject of secondary resources, a term that is simply too broad for the scope of this thesis. This thesis will therefore exclusively focus on used timber.

When used building materials are assessed as form of waste, it is often referred to as C&D (Construction and demolition) waste. Although the waste produced by the demolition industry has interesting characteristics it falls out of the scope of this thesis.

As mentioned, used building material are inseparable from the term secondary resources. The bigger picture of secondary resources is of big influence on the attitude of the industry towards the used building materials. One of the underlying reasons for this, is the price of labor versus the price of materials. Although, this lays at the heart of the problem used building materials, it exceeds the scope of this thesis.

Another big issue that is related to the use of used building material, is the role of the timber industry. Because this industry is so big, it likely that they are able to respond to any success in the used timber industry with their capital (e.g. dropping prices). Although relevant to the subject, this lays out of the scope of this thesis.

1.4 Relevance

In this day and age, it is becoming ever more evident how we as a society are depleting the world we are living in. Our way of using products has evolved into a habit in which we buy something new if it breaks down, throw stuff away when it is does not work and where new is always better. Fortunately, slowly but surely people are starting to see the impermanence of resources. The way resources and products are used is (very) slowly changing. Buurman tries to contribute this change by expanding the widespread availability of used building materials.

This change can also be seen in the way waste is managed. As is shown in Chapter 4: Literature, waste management in the Netherlands has been steadily improving in the last 20 years. Unfortunately, reuse still plays little to no part in this and most of the material is recycled. Although recycling is preferred above disposing materials, it would be even better if materials would be re-used (figure 2) (US EPA, 2017).

For this reason is important to contribute to improving the way resources and products are used. Projects like this thesis, albeit very little, contribute to this improvement. This is what makes this thesis relevant.
1. 5 Overview thesis

Figure 2 shows the overview of the complete thesis. It comprises of the following elements:

**Analysis of Buurman**
The information that was used to write the internal and external analysis was derived through the analysis of company documents, unstructured interviews, Internet research and literature research. The internal analysis of Buurman was used in the cross-case analysis between Buurman and Comparable companies.

**CRRS Companies**
To gain insight in the underlying reasoning and motivation of companies such as Buurman. In-depth interviews were conducted with companies comparable to Buurman. The information derived from these interviews, together with the information derived from the internal analysis of Buurman, were used in a multi-case analysis (study one). The conclusions from this multi-case analysis were used to answer sub question one.

**Construction companies**
Pilot interviews with Vorm and Era Contour were used to test sub question two and three on their relevance. Accordingly these questions were adjusted. These pilot interviews also served to gain general information on the company and to enable contact between the experts that were interviewed in the in-depth interviews.

The information that was derived from the in-depth interviews with Vorm and Era Contour, was used in a multi-case analysis (study two). The conclusions from this study were used to answer sub question two and three.

**Product**
With the help of the insights of the answers to subquestion one, two, three the design the product was developed. This phase consistent of an ideation phase, a conceptualization phase and a embodiment phase

**Validation**
By means of the prototypes of the developed product, the system was tested and validated
Figure 2: Overview Thesis
2. METHODOLOGY

2.1 Methodology study one

Process

The process of the qualitative study entailed the following steps:

1. Company selection
   The companies that were used in this study were selected on three criteria. The information needed to assess these criteria was derived from the websites of each of these companies. A detailed description of the selection criteria can be found under Samples.

2. Pilot study
   Following the process of the company selection, a pilot study was conducted with one of the selected companies (Jan van IJken oude bouwmaterialen). In this pilot study, the interview was conducted as it was intended for the official study. This interview was recorded.

3. Lessons learned
   After the pilot study, a list of lessons learned was formulated. This list was used to create additional questions, to remove questions and to create an overview on what to pay attention to in the official study.

4. Additional interview
   Because of time constraints, the company that was used for the pilot study, was contacted after the pilot to ask additional questions. These questions completed the information and made it usable for the analysis.

5. Official interviews
   Following the additional interview, the remaining interview was conducted. This interview was conducted over Skype with a company called Community Wood Recycling, based in Brighton, England. This interview was also recorded. The interview protocol, used for both interviews, can be found in Appendix E: Interview protocol in-depth interviews study one.

6. Transcription
   The recordings of both interviews were used to transcribe them. These transcriptions can be found in Appendix G: Transcriptions jan van Ijken and Appendix H: CWR.

7. Analysis
   The transcriptions were used to conduct a multi-case study with. A summary of this study can be found in chapter 9. The complete multi-case study can be found in Appendix E: Complete multi-case study one.

In short, this multi-case study comprised the following:

1. An introduction to the method behind the study
2. A case report of the interview with Jan van IJken
3. A case report of the interview with Community wood recycling
4. A case report of the analysis of Buurman
5. A list of the most important findings derived from the case report of the interview with Jan van IJken
6. A list of the most important findings derived from the case report of the interview with Community wood recycling
7. A list of the most important findings derived from the case report of the analysis of Buurman
8. A list of tentative assertions derived from the most important findings
9. An list of cross-case assertions
10. Conclusions
Assumptions

No companies could be found that operate exactly like Buurman. Nevertheless, a selection of companies was assessed on comparability and two of them were selected (see Samples). The assumption is made, that the level of comparability amongst this selection, enables the researcher to gain enough insight concerning such companies.

The companies were interviewed on the subjects: vision, mission, strategy, ambition, business-structure and products. It is assumed that together, these subjects enable the researcher to conduct the cross-case analysis on the companies.

Limitations

Quantity

As mentioned in the introduction, this qualitative study merely aims to understand the underlying reasons and motivations of companies such as Buurman. In other words, it serves to create insight, instead of supplying an actual unequivocal answer to the research question for the industry in general. How the evidence for certain conclusion in this study is interpreted, can be read in the conclusion of the complete study (Chapter 9: Study one).

Instruments

The following instruments were used in this study:

- Audio recorder
- A notebook and pen
- An interview protocol
- An interview guide
- Skype

Samples

In this cross-case analysis three cases are compared. These cases share a common characteristic or condition. In Multiple Case Study Analysis (Stake, 2006), the group that shares such characteristics is referred to as the ‘quintain’.

There are not a lot of companies in The Netherlands that collect refurbish, re-use and sell used building materials (see chapter 3 in Phase One report). There are actually none like Buurman, the collaborating organization in this thesis. To be able to still conduct a multi-case study some abandonments were done concerning location and the origins of the utilized building materials. This led to the following list of required common characteristics:

- Collecting material from either the construction or the demolition industry
- To some extent refurbishing this material
- Selling building material that can be used by hobbyists in building projects. Companies that merely sell complete products (e.g. washbasins, furniture) were considered unsuitable for comparison.
- 5 to 40 employees
- Located in Europe

The following companies were selected:

- Jan van iijken Oude Bouwmaterialen
- Community wood Recycling

Time period

The data was collected over the period: 01-01-2017 to 01-02-2017
2.2 Methodology study two

Process

1. Company selection
The companies that were used in this study were found through the network of Buurman. Both of them are construction companies and comply with the proposed criteria. The information needed to assess these criteria was derived from the websites of each of these companies and from unstructured interviews with Buurman employees. A detailed description of the selection criteria can be found under Samples.

2. Pilot study
Prior to the official interviews, two pilot studies were conducted; one with each company. The contacts needed to conduct these interviews, were gathered through Buurman. For Era Contour the interviewee was E. Gathier a concept developer and for Vorm the interviewee was C. Jongenotter an innovation manager. The interview protocol and question list of both pilot interviews can be found in Appendix K: Interview Protocol pilot for study two.

These studies aimed to:
- Gain insight in the general working principles of the company
- Gain insight in what subjects needed to be addressed
- Gain insight in what questions needed to be asked
- Acquire contact information of relevant experts within the company, for future interviews

The summary of these pilot studies can be found in Appendix L: Summary pilot studies Era and Appendix M: Summary pilot studies Vorm.

3. Lessons learned
The pilot studies produced the insights needed to compose the tools needed for the official interviews. These insights and how these they influenced the official interviews can also be found in Appendix L: Summary pilot studies Era and Appendix M: Summary pilot studies Vorm.

4. In-depth Interviews
Based on the insights of the pilots studies a question list was composed that was going to be used for the in-depth interviews of both companies. The pilot studies also produced the connection to the relevant experts of each company. The reasoning behind the choice for these specific experts can be found in the lessons learned from the pilot interviews. The interview protocol and the question list, used for these interviews, can be found in Appendix N: interview protocol in-depth interviews.

Era Contour
The interview with Era Contour took place at the office of a construction site in Utrecht. The interviewee was O. Smit, the general foreman.

Vorm
The interview with Vorm took place at the office of Vorm. The interviewee was R. van Walsem. The head of sales.

5. Transcription
The recordings of both interviews were used to completely transcribe them. These transcriptions can be found in Appendix O: Transcription Era Contour, Appendix P: transcription Vorm.

6. Analysis
The transcriptions were used to conduct a multi-case study with. The complete multi case study can be found in Appendix I: Complete Multi case study two. In short, this multi-case comprised of the following:
- An introduction to the method behind the study
- A case report of the interview with Era Contour
- A case report of the interview with Vorm
- A list of the most important findings derived from the case report of the interview with Era Contour
- A list of the most important findings derived from the case report of the interview with Vorm
- A list of tentative assertions derived from the most important findings
- An adjusted list of cross-case assertions
- Conclusions
Assumptions

It is easier for medium size construction companies to adapt to sustainable initiatives than it is to big construction companies, still can have significant impact

Limitations

Quantity
As mentioned in the introduction, this qualitative study merely aims to understand the underlying reasons and motivations of companies such Era Contour and Vorm. In other words, it serves to create insight, instead of supplying an actual unequivocal answer to the research question for the industry in general. A more extensive list of cases to compare would have improved the study significantly

Quality
It is sincerely believed that the companies and experts, that were consulted in this study, were suited to be used in this research. Nevertheless, the companies that were used, were the companies that were at the disposal of the graduate at that time. This limits the quality of the study. A thorough review of a larger list of companies, before choosing them, would have improved the quality of the study significantly.

Time
In both quantity and quality limitations, time was the biggest factor. Unfortunately, due to time constrains everything in this research had to be devised to take as little time as possible.

How the evidence for certain conclusion in this study is interpreted, can be read in the conclusion of the complete study (Chapter 10: Study two)

Samples

In this multi-case analysis three cases are compared. These cases share a common characteristic or condition. In Multiple Case Study Analysis (Stake, 2006), the group that shares such characteristics is referred to as the ‘quintain’.

For this study the quintain was defined through cooperation with Buurman, the collaborating company in this thesis. In the years they have been active, they have build up an extensive network of construction companies, contractors and other corporations. Two of those construction companies, have been close partners of Buurman from the beginning. These are the companies Era Contour and Vorm

Era Contour and Vorm share common characteristics. These characteristics define the quintain:

- They are both of a middle large size (Era 285 employees, Vorm 235 employees). Although these companies are in the same order of magnitude, Era Contour officially is considered a ‘large’ enterprise, whereas Vorm medium sized enterprise (Eurostat, 2017)
- They are active in a large portion of the Randstad
- They both develop their own project as for other corporations
- They are both active in urban areas
- They both have the topic of sustainability as a high priority

Instruments

The following instruments were used in this study:

- Audio recorder
- A notebook and pen
- An interview protocol
- An interview guide
- Skype
PART 1: ANALYSIS
CHAPTER 3 INTERNAL ANALYSIS

In the internal analysis all the different segments of the company Buurman are analyzed. This includes an analysis of the mission, vision strategy and ambition of Buurman. This is followed by an overview of Buurman’s products, material and Business structure. Finally, the complete business model canvas is described. The chapter will be concluded with the strength and weaknesses of Buurman and the opportunities and threats of the market it operates in.

The information from the internal analysis will be used to serve as a case in the multi case analysis of study two.
3.1 STRATEGY OVERVIEW

In this overview of Buurman’s strategy, the mission, vision, strategy and ambitions of the company are described. The information derived here, is used in Chapter 7: Concept, to assess if the developed product adheres with the company’s strategies.

3.1.1 Vision

In a vision statement, a company expresses their vision of the ideal conditions for their community. In Buurman’s case, there is no such single statement.

Buurman’s vision focuses on the following principles:

- As effectively as possible, re-use as much material as possible
- Incorporate material driven design and inspire customers to incorporate this

3.1.2 Mission statement

In a mission statement, a company describes what the company is going to do and why this is the case. Buurman comprises of many elements; for each element there is a separate mission statement. The two mission statements that are the most relevant are:

**Lower the demand for primary resources from trade sector through the sale of fair products, produced with re-used building material.**

**Changing people their attitude from production-driven to material-driven through assistance in purchasing, assistance in design and assistance in building, through courses, workshops and the sales of fair products**

3.1.3 Strategy

Through a certain strategy a company tries to reach their mission. Buurman developed a regional oriented strategy that aims to be exploitable in every big city of The Netherlands. After a start in Rotterdam the blueprint for their business concept can be utilized to implement it in other area’s of The Netherlands. With this business concept Buurman wants to create impact in the following areas:

End-of-pipe material trade

Buurman has build up an extensive network of companies. These companies supply Buurman with the second hand building material they sell in their store. Amongst these companies are:

- Construction companies
- Creative sector
- Museums/art institutions

Although Buurman has important partnerships with certain suppliers, there are no specific companies to which Buurman is bound and the companies that can supply the material that is most suitable, get priority. An overview of these materials can be found on page 21.

Buurman is always trying find new and better material sources to optimize the amount of quality material they can sell. By doing so they hope to stimulate people to choose secondary material resources above a primary resources.

Reintegration to the labor market

The building orders that are executed through BuurmanBouwt, are build with the help of the BouwAkademie. The Bouwakademie is an initiative from Buurman which temporarily employs people with challenges of access to the labor market, in the workshop of the Bouwakademie. This aims to help them with their reintegration to the labor market.

Changing consuming attitude

Apart from the trade in secondary resources, Buurman also tries to inspirer the public sector to adapt a more material-driven way of consuming. They do this by:

- Teaching how to build products in a variety of workshops and carpentry courses.
- Showing the potential of the use of secondary resources, by assisting in the purchase off and building with, used building materials.

Product sales (furniture etc.)

Buurman also operates as a carpentry company for both the public as the private sector. Orders from these sectors comprise interior and exterior objects/furniture.
These objects are build with the help of the employees of the BouwAkademie and when necessary with help of companies at the Keilewerf. By delivering quality products made of secondary resources, Buurman hopes to promote to use such materials.

In the design process of these orders Buurman works as material-driven as possible and tries to produce the products with what is in store. This way of working, is shown and communicated to the client. By doing so, Buurman brings across the potential of secondary material sources to these clients.

3.1.4 Ambition

Buurman is growing in a steady pace and three options for the future are being considered. These three different option are:

Implement the Buurman concept throughout The Netherlands
In this scenario, Buurman stores will be opened in different places throughout The Netherlands. These stores will comprise of the same elements as the Buurman does now. The different elements will be kept approximately at the same size and no mayor changes in the concept will be made.

Separate the different elements
A second scenario for the future, is separating the different elements of Buurman. In this scenario, the different elements (See company overview on page 18) are developed individually on locations, that are best suitable for each specific element. This will mean that each element will grow in size significantly.

Choose the best element
In this final scenario the element that is performing the best, is chosen and further developed. The other elements are discarded. New venues are opened through The Netherlands, in which only this element is exploited. The size of these venues will have to grow significantly in with respect to the current size.
3.2 COMPANY OVERVIEW

3.2.1 Business structure

In the company overview, an overview is given that shows how Buurman operates (fig. 3). This overview is based on the flow of the building material from the sources, to the customers. A description is given of each element of this structure. Following the business structure, an overview of the products and materials available at Buurman is given.

The business structure of Buurman is not very complex and can be divided in five segments.

Phase 1: Material source and collection
Phase 1 shows how the materials get from the source to the material market. They get transported, sorted and processed by both Buurman and BouwAkademie employees. Once at the material market, they get sold as building material or get used by Buurman.

Phase 2: Use by Buurman
In phase 2, the materials get assigned to a certain branch of Buurman. This can mean that the material:

- Will be used in a course or workshop
- Will be used in the manufacturing of Furniture or other products (BuurmanBouwt)

In this phase the production plans are made and workshops plans are developed.

Phase 3: Production and sales
In the third phase the material is applied in the manufacturing of products (with or without the help of third parties and the BouwAkademie) or by participants in carpentry workshops and courses. The BouwAkademie helps in the manufacturing of the products.

Phase 4: Use by customers
In the final phase the destination of the material or product can be seen. Here, either the public sector:

- Builds products (with or without renting a workbench)
- Directly uses the products bought at Buurman (with or without renting a workbench)

Or the trade sector:

- Manufactures products
- Directly uses the products bought at Buurman
Figure 4: Business structure based on the material stream
3.2.2 Product analysis

Overview
Figure 1 till 12 on the next two pages show a selection of the products that are made by Buurman

1. Multiplex footstool
2. Wall Cabinet
3. Closet
4. Block toy
5. Balcony bench
6. Plant Cabinet
7. Footstool with felt sitting
8. Garden bench on wheels
9. Pick-nick bench

As can be seen, the products vary from inside furniture to outside object and are all produced with reclaimed wood or other re-used material.

Possibilities and restrictions
Buurman is always limited by the material they collect. This means that the production of products is currently restricted in its degree of precision. Most of the products therefore have a rudimentary appeal.
3.2.3 Material overview

Figure 1 till 9 show a selection of the material that is being sold at Buurman

1. Variety of wooden plates (big and small)
2. Variety of wooden beams
3. Wooden ‘Baddingen’
4. Variety of small wooden plates
5. Variety of wooden planks
6. Isolation wool
7. Collection of ironware
8. Electra
9. Ironware

As can be seen, the largest part of the available material is made up of timber. Besides timber, Buurman also sells other materials, but those are not as consistent in their availability. This is partially caused by the fact that the inflow of material is inconsistent, but also by the limited storage space. A lot of material is available for Buurman, but cannot be stored.

Standardization and common end-grain dimensions

All the material that gets collected, gets possessed by the BouwAkademie. They remove nails if his is necessary, and saw the timber in standard lengths of:

- 40 cm
- 80 cm
- 120 cm
- 250 cm

In principle all the sizes of end-grain can be collected by Buurman, but in practice certain sizes of end-grain are much more common than others.
The business model canvas of a company completely describes the rational of how an organization creates, delivers and captures value (Osterwalder, Pigneur, Clark, & Smith, 2010). In Buurman’s case each business element could be described with a separate business model. In figure 5 the business model is shown that takes into account the elements that are relevant for this thesis. This business model canvas is based on archive material (Rosen Jacobson, n.d.; Buurman Werkplaats en Materialen, n.d.). A complete description of the business model can be found in Appendix A Business model canvas.

### 3.3 BUSINESS MODEL CANVAS

#### 3.3.1 Customer segments

Personas of the different customers can be found in Appendix B: Personas.

**Do-it-yourself hobbyists**

An important part of the customer segment consists of do-it-yourself builders. This group visits Buurman to see if specific materials are in store. When this is not the case, they start looking at how they can work with what is in store at that moment.

**Small contractors**

The small contractor is a customer that purchases material in bigger quantities than the do-it-yourself builder. This group usually wishes to know what is in store before they visit Buurman.
Creative entrepreneurs: architects, interior designers
The third group that is considered a customer, is the creative entrepreneur. This group primarily consists of architects and interior designers.

Companies that supply used building materials (e.g. construction companies)
This customer segment can be seen as both a customer as a partner (see key partnerships). The former, because Buurman accommodates a medium that improves the corporate social responsibility (CSR) of this customer segment.

3.3.2 Value proposition
The value proposition of Buurman can be divided into three segments.

- Access to affordable used building materials (secondary resources)
- DIY Support and inspiration for material-driven production
- Unique and responsible, finished products
- A medium to improve corporate social responsibility
3.3.3 Channels

Material market at the Keilewerf
Because of the lack of an inventory, which customers can use before they visit the market, customers have to call and ask or have to come by to see what is in store. The material market is a channel that serves a different purpose for each customer segment.

Website
Buurman’s website serves to raise awareness amongst customers about the products and the services Buurman offers.

Mail
Each week Buurman sends out a mail that shows new interesting material available in the material market.

Phone
The first and third segments regularly need bigger quantities of material or multitudes of products, which require bigger quantities of material. It is therefore not unusual that Buurman communicates with these parties beforehand to confer about the materials available at Buurman.

Social Media (Facebook, Instagram)
Buurman is primarily active on Facebook. Through this medium they promote upcoming courses, workshops, show new materials and DIY projects of independent builders.

Flyers
This channel focuses on the DIY builder and primarily promotes new courses and workshops.

3.3.4 Key resources

Physical
Buurman’s most important resources are physical ones. Their material sales completely rely on the materials they collect, the means to transport these materials, the tools to process them and the space to store them.

Human
The human resources (Buurman employees, BouwAkademie employees, Course instructors) are almost as important as the physical ones. These resources utilize the physical resources and give them a purpose.

3.3.5 Key activities

Production: Collection, preparation, product development, production, sales, workshops and courses.
The core of the activities at Buurman revolve around the sales of used materials. These materials have to be collected and transported to Buurman, after which they get processed to be either sold in the material market or to be used in the production of products. Buurman also organizes a variety of carpentry workshops and courses.

Problem Solving: Product development and building advice
A differentiation between two sorts of product development can be made, based on the origin of the development. Production related product development originates from within the company, whereas problem solving related product development originates from a specific client.

3.3.6 Key Partnerships

Buurman is very dependent on the partnerships it has with different companies. A differentiation is made between three categories of partners.

Buyer-supplier relationships to assure reliable supplies
The most important from these partners are the ones that supply the used building materials. A differentiation can be made in the partners that supply on a regular basis and the ones that supply on an irregular basis.

Cooperation: strategic partnerships competitors
Buurman is surrounded by creative companies at the Keilewerf. Although there are no official agreements on it, companies try to stick to their trade and try not hinder other companies by taking on orders outside of their scope.

Strategic alliances between non-competitors
Buurman is owned by B. van den Berg, L. Vunderink and L. R. Jacobson. Van den Berg and Vunderink are also the owners of the Keilewerf. Although these companies are considered as being two completely separate enterprises, there are certain benefits to this relation. The Keilewerf and Buurman can therefore be considered partners.

Although no further official partnerships exist within the Keilewerf, it is noteworthy that Buurman profits from companies at the Keilewerf as these companies sometimes require the materials Buurman sells.
3.3.7 Customer relation

**Do-it-yourself (self-service)**
In the first place Buurman is a place where customers can find all the means to build their own projects.

**Purchasing assistance (personal assistance)**
This assistance starts with purchasing. The material available at Buurman varies a lot, customers therefore get personal assistance in the market when they need this.

**Design assistance/design (personal assistance)**
When customers (public sector) buy material and they need assistance with the design of the product, this can also be supplied.

**Building assistance/building (personal assistance)**
People who buy material and subsequently rent a working bench, can get personal assistance in building their project. This personal assistance is related to the use of tools and the treatment of material.

**Recycling (personal assistance)**
Construction companies offer certain building material to Buurman. The selection and collection is handled through personal assistance.

**Website (self-service)**
A final element that influences the relation between Buurman and its customer is the self-service element of the website. Here customers can book working benches or sign up for courses and workshops.

3.3.8 Cost structure

**Physical resources**

**Materials**
The materials that are collected are either free of charge or very low priced, so there are little costs associated to this. The only costs that are significant are those of the transport and the preparation of the material.

**Tools**
The tools that are used at Buurman are used intensively throughout the week. Consequently, these tools break down and need to be replaced or repaired once every so often.

**Storage**
Storing material and giving workbenches, tools etc. a place at Buurman costs money. Material needs to be sold within a certain time, otherwise the storage costs exceed the revenue the material creates.

**Human resources**
At Buurman nothing is mechanized. Most of the work that goes into development of the products, is done by hand. The employees that do so (all of which freelancers) need to be compensated.

**Marketing**
Although Buurman invests little in marketing, small costs are made through Facebook campaigns, Flyers and posters.

**Overhead**
As in every company there are overhead costs for small things that do not fit within the other cost segments. Such costs are: lighting, cleaning, office equipment etc.

3.3.9 Revenue streams

The revenue streams describe the cash a company generates through their customer segment. Buurman’s revenue is completely dependent on transaction revenues (one-time customer payment). No recurring revenues contribute to Buurman’s business model.

**Material**
The revenue streams that originate from the sales of used materials stand central in the business model of Buurman. Through all channels and via all the customer segments revenue is collected true the sales of used material.

**Workshops and courses**
The workshops that are organized by Buurman create a significant revenue stream (about 50%)

**Assistance**
Throughout Buurman’s business model, personal assistance comprises an important role. This is assistance is also an important source of revenue.

**Work benches**
A part of Buurman’s revenue is created through the rent of working benches in Buurman’s workshop. People rent these working benches per hour, per half a day or per day.

**Products**
A final source of revenue, is that of the finished products Buurman sells. These products are either made in collaboration with customers or they are made exclusively by Buurman.
3.4 PORTER’S FIVE FORCES

To be able to make a statement about the long-term attractiveness of the business, Porter’s five forces analysis was conducted. This analysis aims to determine the attractiveness of a business in terms of overall profitability. It does this through analyzing five forces that influence a company’s ability to serve its customers. (Porter, 1997; Kotler & Armstrong, 2013). These forces are:

- Threat of intense segment rivalry
- Threat of new entrants
- Bargaining power of supplier
- Bargaining power of customer
- Threat of substitute products

Normally the results of such an analysis would form the basis of the strategic agenda of a company. In the creation of such strategy the underlying sources for each force would be researched and a plan would be devised. This plan would describe the best way of dealing with each force individually. In relation to this project, the approach of Porter’s analysis is less thorough and focuses on defining the influence of each force on Buurman. The information derived from this, will be used to define the opportunities and threats for the company.

Because Buurman consist of multiple segments, a complete analysis should actually comprise an analysis of each segment separately.
3.4.1 Material market

Instead, because of time constrains, the analysis is only conducted for the segments relevant to this project: The material market, BuurmanRecycles and BuurmanBouwt.

In figure 6, 7 and 8 an overview of the results of Porter’s five forces analysis can be seen; per force a short explanation is provided.

When analyzing porter’s different forces, it can be concluded that the material market in an attractive business to operate in. Beside the threat from possible new entrants, Buurman does not experience any significant threats from other directions.

**THREAT OF NEW ENTRANTS**

- Entering on a small scale is possible
- Large available market share
- High availability of resources (Durmisevic and Binnemans, 2014)
- Easy product differentiation
- Low capital requirements

**BARGAINING POWER OF SUPPLIER**

- There is no threat of forward integration by the supplier
- They do not need to contend with other companies in the industry
- Buurman is not an important customer

**THREAT OF RIVALRY**

The existing rivalry among competitors in Buurman's material market is relatively low. This is primarily caused by the fact that it is a relatively new kind of business. Because of this, there is little direct competition that is equal in size and power. Adding to this is the growing market that leads to lesser fighting over market share and decreases the thread of over-capacity and extreme diversity in rival strategies.

**BARGAINING POWER OF BUYER**

- The material Buurman sells forms a significant fraction of the cost of the total (final) product.
- Backwards integration by the customer is possible.
- There are no costs bound to switching to another company.

**THREAT OF SUBSTITUTE PRODUCTS**

- The products from the material market are hard to substitute by other products, because they are the waste of other industries. The price of this ‘waste’ is low, while the performance is relatively high. This makes finding a substitute product, which offers an attractive price-performance trade-off, a difficult task.

---

*Figure 6: Overview Porter’s five forces, material market*
3.4.2 BuurmanBouwt

Because of its maturity, this business element of Buurman is assessed as being the least attractive of the three elements. Nevertheless, this market is a relatively attractive one to operate in.

3.4.4 BuurmanRecycles

BuurmanRecycles, is assessed as performing slightly poorer on Porter’s different forces. This is caused by the high bargaining power of the construction companies as buyers.

In general, the outcome of Porter’s five forces analysis is very positive. Although the relevant elements of Buurman were assessed separately, they will ultimately function as one, creating a unique combination. In Chapter 7: Concept, the results of Porter’s five forces will be reviewed in relation to the developed product.

<table>
<thead>
<tr>
<th>+</th>
<th>THREAT OF NEW ENTRANTS</th>
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<tbody>
<tr>
<td></td>
<td>Entering on a small scale is possible</td>
</tr>
<tr>
<td></td>
<td>High availability of resources (Durmisevic and Binnemars, 2014)</td>
</tr>
<tr>
<td></td>
<td>Low capital requirements</td>
</tr>
<tr>
<td>-</td>
<td>A larger industry with more existing competition</td>
</tr>
<tr>
<td>-</td>
<td>Less available market share, because of more mature industry and a slower growing market (Social Enterprise, 2016)</td>
</tr>
<tr>
<td>-</td>
<td>Large product differentiation within the market</td>
</tr>
<tr>
<td>MODERATE</td>
<td></td>
</tr>
</tbody>
</table>

| - | BARGAINING POWER OF SUPPLIER |
| - | Suppliers do not need to contend with other companies in the industry |
| - | Buurman is not an important customer |
| - | The supplied product is not unique |
| - | The resource that is supplied is not dominated by a small group |
| - | There is no threat of forward integration by the supplier |
| MODERATE |  |

| + | THREAT OF RIVALRY |
| + | Because BuurmanBouwt is competing in another field, rivalry differs on some points. The major difference lies between the sales of materials and the sales of consumer products. The latter, is altogether, a much more saturated industry. This makes it growing much slower, with much fiercer fight over market share, thread of over-capacity and extreme diversity in rival strategies. |
| MODERATE/HIGH |  |

| + | BARGAINING POWER OF BUYER |
| + | Ironically, the only factor that supplies the customer with bargaining power is the threat of backwards integration. |
| | Customers of Buurmanbouwt do not purchase in large volumes (Buurman Werkplaats en Materialen, n.d.) |
| | The products Buurman sells are not standardized |
| | The quality of the product is of importance to the customer’s product/service |
| | The product saves the customer money |
| LOW |  |

| + | THREAT OF SUBSTITUTE PRODUCTS |
| + | There is little threat of a substitute products. The products that would have to be substituted are all variations on furniture made of used building material. There are no alternative products that offer an attractive price-performance trade-off. |
| LOW |  |

Figure 7 Overview Porter’s five forces, BuurmanRecycles
<table>
<thead>
<tr>
<th>Threat of New Entrants</th>
<th>Bargaining Power of Supplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ Entering on a small scale is possible</td>
<td>+ When BuurmanRecycles is taken into account, the relationship between the supplier and Buurman in general, changes. By supplying material, the construction companies also profits from the value proposition. For BuurmanRecycles specifically this means that the 'buyer' is also the supplier. For Buurman in general, this balances the relation between the construction company and Buurman.</td>
</tr>
<tr>
<td>- Large available market</td>
<td>-</td>
</tr>
<tr>
<td>+ High availability of resources (Durmisevic and Binnemans, 2014)</td>
<td>-</td>
</tr>
<tr>
<td>- Easy product differentiation</td>
<td>- Low capital requirements</td>
</tr>
<tr>
<td>- Low capital requirements</td>
<td>+</td>
</tr>
</tbody>
</table>

**Threat of Rivalry**

The existing rivalry among competitors in Buurman’s recycling business is relatively low. This is primarily caused by the fact that it is a relatively new kind of business. Because of this, there is little direct competition that is equal in size and power. Adding to this is the growing market that leads to lesser fighting over market share and decreases the thread of over-capacity and extreme diversity in rival strategies.

<table>
<thead>
<tr>
<th>Bargaining Power of Buyer</th>
<th>Threat of Substitute Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ The product’s quality (being that of a recycling service) is not of major importance to the construction company product/service. BuurmanRecycles does not save the construction company a significant amount of money. There are no costs bound to switching to another company</td>
<td>+ From a theoretical point of view, the threat of a substitute product for BuurmanRecycles, is big. There are no practical ties binding construction companies to Buurman and expressing a sustainability vision can be done in a variety of manners. If such an alternative manner is offered by another company, the threshold to switch is very low. Although this might be true, from a practical point of view the threat might not be as pressing. Construction companies can work with multiple companies at the time and every little bit helps. How construction companies view this, is something that will be researched in phase two</td>
</tr>
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<td>-</td>
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</tbody>
</table>

**Low**
STRENGTHS

- Wide network for resources
- Affordable labor
- Unique value proposition
- Wide range of product options
- Broad customer segment

WEAKNESSES

- Limited in-house skills
- Limited production capacity
- Resources require processing
- Inconsistent material dimensions
- Inconsistent material influx
- No inventory
Buurman is a company that operates in a market that is becoming more relevant each day. How they are functioning in this market is unique. There are companies that offer certain elements comparable to Buurman: Used building material markets, do-it-yourself workshops, furniture making courses, product development that incorporates used material, etc. However, there are no companies that offer a combination of these elements, like Buurman does. Concerning such a combination, Buurman is unique.

Through the internal analysis the strength weaknesses opportunities and threats were defined. The figures on this page show the ones that are most important with regard to this thesis. The complete list can be found in Appendix C: SWOT.
In chapter 4, the literature that was reviewed, is discussed. The information derived from this literature was used as comparison material in study one and study two. The chapter touches on three different subjects: The impact of the construction industry, Innovations in waste management and Waste management in The Netherlands. In this last subject a comparison is made between the waste production numbers of different construction companies and between the waste processing numbers of different CRRS companies. The chapter is finalized with conclusion on the derived information in relation to Buurman.


4.1 LITERATURE REVIEW

4.1.1 Introduction and justification

This thesis is finalized with a product. Possibly this product will be the answer to the main research question of this thesis:

‘How can companies that collect, refurbish, re-use and sell used building materials, grow?’

As can be read in this question, CRRS companies, and the use of used building materials are the most important subjects. Because of a lack of literature, information on CRRS companies is exclusively gathered through a multi-case study.

As explained in the methodology, the research aims to find out if CRRS companies can grow by expanding their sales to the construction industry. For this reason the first part of the literature review focuses on use of used building materials in the construction industry.

Because the use of used building materials is inseparable from the topic of sustainability, it is important to collect information on what motivates the construction industry to corporate sustainable construction. This is the first subject of this literature review. The subject of sustainable construction will also play a role in the study that will be conducted in relation to the construction industry. The information gathered through the literature review can be used as a comparison in this study.

A second subject that will be covered, is that of innovation concerning the collection and re-use of building materials. The information, that is derived in relation to this subject, can serve as inspiration for the development of the product that will finalize this thesis. It can also provide information on learned lessons, from cases that show such innovations.

The information that is derived through the research of this thesis, will be used in the development of a product. Because this product will be applied in the context of the Netherlands, it is important that the overarching theme of this theses (Re-use of building material) is thoroughly researched in the relevant context. Waste management of building materials in The Netherlands will therefore be the third and final subject of this literature review. This subject will be divided in:

- Waste management in The Netherlands
- Waste management of the Dutch construction industry in numbers
- Waste management of the construction companies Vorm and Era Contour in numbers
- The management of building material of the CRRS companies Buurman and Community Wood Recycling in numbers

In this literature study, waste management is the overarching theme. Because this is so complex, the waste management hierarchy (figure 2) is used to prioritize the different practices of waste management. Companies such as Buurman operate in the middle of the hierarchy, whereas construction companies are able exercise influence in the top of the hierarchy. Strong collaboration between CRRS companies and construction companies can increase avoidance, reduction and re-use; and can decrease recycling, recover, treat and dispose.
4.1.2 Impact of the construction industry

In the last century it has become evident that the construction industry is a major contributor to environmental degradation. The evidence supporting this claim is widespread. Anink, Mak, & Boonstra (2004) show evidence that the construction industry accounts for more than 40% of the global consumption and natural resources. Furthermore, Hendriks & Pietersen (2017) show that, of all industrial waste in the world, 35% originates from the construction industry. In addition, the construction sector is responsible for 33% of the total emission of carbon dioxide (Baek, Park, Suzuki, & Lee, 2013). All these claims indicate that the construction industry in general has a lot to improve concerning waste reduction and reduction in resource excavation. An interesting phenomenon, since it has been shown that waste reduction can have both economical and environmental benefits for construction companies (Coventry & Guthrie, 1998).

When taking into account these numbers it becomes evident that the excessiveness in which construction waste is produced, is a serious problem that has a serious impact on the environment. Not only in depletion, but also in pollution. Handling this problem begins with changing the way construction companies are working. Among other things, this includes how the construction industry manages and salvages their waste. Managing and salvaging construction waste does not only reduce resource and energy use, land consumption, groundwater degradation and disposal costs (Ofori, 1992; Sjostrom and Bakens, 1999; Shen et al., 2007) but also creates jobs for low-skilled workers (Roper, 2006).

Roper (2006) also stresses the importance of quantifying and specifying when certain waste is generated, in relation to efficient and effective waste reduction. Only through such specification, cost-effective waste management techniques can be developed. The type of material, the quantity and the job site are, among other things, of big influence on what the options are for alternative waste management. Figure 10 shows a rough indication of what kind of materials arise in which kind of industries.

Figure 10: Impact of the global construction industry (Roper, 2006)
4.1.3 The barriers for sustainable construction

The previously mentioned change in waste management is just one of the aspects that need to change if the impact on the environment of the construction industry is to decrease. Construction that aims to have as little impact on the environment as possible is referred to as sustainable construction (SC). In the book Sustainable Construction, Kibert (2016) uses the definition of SC that was proposed by Conseil International du Batiment in 1994: ‘Creating and operating a healthy built environment based on resource efficiency and ecological design’. Successful full adoption of SC is dependent on implementation of all principles that define it, by every responsible stakeholder into all construction activities of the project life-cycle. (Matar, Georgy, & Ibrahim, 2008).

Although all stakeholders play an important role in the adoption of SC, the driving force behind it, are the owners of a projects (Pitt, Tucker, Riley, & Longden, 2009). This is primarily caused by the fact that the owners exercise influence in the start of a project. The earlier a construction project adopts SC, the bigger the changes are that it is adopted in the course of the entire project (Zainul Abidin, 2010). Unfortunately, the incentives for project owners to adopt SC are not as self-evident as one might expect. SC asks for integration of a variety of (new) methods, technologies and the full cooperation of stakeholders (Hill & Bowen, 1997), it requires higher investment with longer payback period and benefits are long term or intangible. This poses big barriers for owners. (Hwang & Ng, 2013). Furthermore, a certain level of consciousness is needed from the owner and other stakeholders, this consciousness is the starting points for the adoption of sustainable construction (Pitt, Tucker, Riley, & Longden, 2009). According to Sakr, Sherif, & El-Haggar (2010), one of the primary reasons for this low level of consciousness is the lack of related information.

To get an understanding of why companies do and do not adopt SC, Gan, Zuo, Ye, Skitmore, & Xiong (2015) propose a list of 25 critical factors that significantly affect the owners’ decision to adopt SC in their projects. These critical factors can be divided into five categories: Economic, Consciousness, Resources, Process and Policies & Regulations.

List of CF’s that influence the adoption of SC:

1. Consumer acceptance of SC
2. Information/knowledge of SC
3. Education and training of SC
4. Industrial culture
5. Initial investment
6. Payback Period
7. Support from financial institution
8. Affordable
9. Intangible benefits
10. Qualified workers and expertise
11. Time for SC practices
12. Risk of related technology
13. Related standard, code
14. Available of related technology
15. Support from professional institution
16. Cooperation of project stakeholder
17. Guidance of SC
18. Performance measurement
19. SC Commit for changing behavior
20. Project organization structure
21. Project procurement system
22. Policy implementation effort
23. Legal/regulatory framework
24. Realization of incentive policy
25. Policy monitoring system

The most relevant critical factors in relation to the use of used building materials are:

1. Industrial culture
2. Intangible benefits
3. Qualified workers and expertise
4. Time for SC practices
5. Risk of related technology
6. Related standard, code
7. Performance measurement
8. Project organization structure
9. Legal/regulatory framework

In contrast to Sakr, Sherif, & El-Haggar (2010), Hakinnen and Belonni (2011) state that SC is not hindered by a lack of information, assessment tools or technology, but rather by the difficulty of implementing these means. Through a literature review, they describe a list of barriers for sustainable construction in Finland based on a collection of themes. They combine the barriers through the literature review with case studies and interviews to define the issues that are of importance to sustainable construction. These issues are:
• The need to increase the expectation and demands of and awareness by, end users (both occupants and owners) about the potential of SC
• The adoption of methods for SC requirement management
• The mobilization of (integrated) SC tools
• The development of designer team working, competence and the role of chief designers
• The development of new concepts and services.

Although such issues might be similar for western countries in general, there is no literature to support this claim. To get a notion of what issues are the most important in the Netherlands, a multi-case study was conducted (Chapter 5: Research, study two).

This thesis primarily revolves around the use of secondary resources. Material selection in sustainable construction industry is therefore an important element in relation to this thesis. It is also seen as one of the most difficult tasks to undertake in a building project (Kibert, 2016). Akadiri (2015) identifies 13 barriers for the selection of sustainable materials. From these 13 barriers to following were defined as being relevant in relation to this project. When comparing these barriers to the critical factors proposed by Gan, Zuo, Ye, Skitmore, & Xiong (2015) many were found to overlap.

To get a complete insight on possible barriers, concerning the use of secondary resources in the construction industry, the overlapping critical factors were dropped and the ones that did not overlap, were translated to barriers:

List of barriers in sustainable material selection:

1. Lack of sustainable material information  
2. Uncertainty in liability of final work  
3. Building code restriction  
4. Lack of comprehensive tools and data to compare material alternatives  
5. Perception of extra cost being incurred  
6. Perception of extra time being incurred  
7. Perception that sustainable materials are low in quality  
8. Unwilling to change the conventional way of specifying  
9. Conservative industrial culture  
10. No tangible benefits  
11. Hierarchy of project organization structure

12. Lack of qualified workers and expertise

This list of barriers for sustainable material selection will be used in the multi-case analysis on the construction industry in Chapter 5: Research, study two. It can be used to compare what construction companies perceive as barriers and will give insight in possible barriers that are not indicated by the industry.

Conclusions and relation to the thesis

Sustainable construction is a subject on which literature can be found at length. A lot of this literature discusses the factors that influence how construction companies deal with SC. Although the different studies have slightly different approaches, the factors that are identified as influential on the decision making process all touch on the same subjects. It is interesting to see that the subject of re-use of building material has little part in all the literature found on the subjects of SC and when it is considered it is only done with respect to future re-use. The subject second life span or previous life span of a material/product is never considered as a factor. It is presumed that this absence, is characteristic for the Construction industry in general.

Based on the reviewed literature, a list of barriers for the selection of sustainable building materials was identified. In the multi-case analysis, this list can be used as a comparison. Besides confirming the literature through the similarities, it can put the roles of the interviewees in perspective through the contradictions concerning what they identify as barriers. After all, the function of the interviewee within the company, will most likely influence what he identifies as barriers of the selection of used building materials. The identified list of barriers can be used to shed light on this.

The comparison of the identified list of barriers and the results from the multi-case analysis, can also be used to confirm the presumption that the absence of considering re-use is characteristic for the construction industry in general.
4.1.4 Waste management in The Netherlands

Because this thesis revolves to re-use of building material in the Netherlands, it is important to gain insight in the policies for the management of construction waste, statistics concerning quantities and environmental impact, the statistics of construction companies and the statistics of CRRS companies.

Prior the analysis of the data, the following must be taken into consideration, concerning the sources of information:

- Not all the required data is publicly available, data therefore might be incomplete
- The required data is not per definition recorded annually, it might therefore be outdated
- There are a variety of sources for the required data. Results of these sources tend to vary.
- It is not always clear which source is most suitable to use

Because of these discrepancies, the analysis might not be as accurate as preferred. It must therefore be seen as a rough indication.

**National Waste Management Plan (NL: Landelijk afvalbeheerplan (LAP))**

The waste management policy of the Netherlands is recorded in what is called the Landelijk Afvalbeheerplan (LAP). Among other things, this waste management plan covers traditional items like: collection, separation, useful application, incineration, landfill, but also covers general subjects like, scenario monitoring and enforcement. (Ministerie van Infrastructuur en Milieu, 2017, p. 7 - 15)

Since 1985 the amount of waste that was produced in The Netherlands increased from 47 Mton to 60 Mton in 2010. Until 2000 this increase could be linked to the increase in the GDP of The Netherlands. However, from 2000 forth, the GDP has been increasing and the amount of produced waste has been decreasing. This change is owed to a shift in waste management policy in the Netherlands, that shifted from a ‘abolition’ focus to a ‘useful application’ focus. Although this is a very positive change, in the current state of affairs, the pressure from waste disposal on the environment is much to high to call it sustainable. (Ministerie van Infrastructuur en Milieu, 2017, p. 7 - 15)

The waste that was previously ended up in landfill, is now used in what is called ‘useful applications’ (NL: Nuttige toepassingen). Useful applications can mean the following (in order of preference according to aricle 10.4 from the Wet Mileubeheer)

- Product re-use: After use, materials and other products are again used as such.
- Material re-use: The materials that make up a product are re-used after the product’s life-cycle
- Fuel: Waste is applied as fuel or other form of power generation. (Ministerie van Infrastructuur en Milieu, 2017, p. 170 - 178)

The shift from landfill to useful application is without a doubt an improvement and a step in the right direction. However, when comparing the preferred order of useful applications (which complies with the waste management hierarchy (figure 9)) with the distribution among the actual applications (table 1) it becomes evident that the preferred and most sustainable option (re-use) is an underdeveloped application.
Waste management of the Dutch construction industry in numbers

After consulting a variety of report and databases, a selection was made concerning which data, about the Dutch construction industry, would be relevant. As previously mentioned, not all the required data is publicly available, recorded annually and is per definition complete. For this reason, the most recent year that could supply the most complete data was chosen to serve as an example. This was the year 2010. In the data sets that did not cover the year 2010, the average of the available years was used.

<table>
<thead>
<tr>
<th>Processing route</th>
<th>Share (%)</th>
<th>With this is saved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recycling</td>
<td>61</td>
<td>Virgin Wood fiber plywood</td>
</tr>
<tr>
<td>Biomass energy</td>
<td>36</td>
<td>Energy</td>
</tr>
<tr>
<td>Secondary fuel</td>
<td>2</td>
<td>Heat</td>
</tr>
<tr>
<td>Burning in waste incineration plant</td>
<td>1</td>
<td>Energy</td>
</tr>
</tbody>
</table>

Table 1: Wood: processing route and shares (CE Delft, 2017, p. 102)

Figure 11: Produced waste in the Netherlands 1985-2005 (Rijkswaterstaat Leefomgeving, 2017)
The following observation can be made based on the collected data:

Table 3 shows the amounts of waste, from the construction industry, that was processed between 2006 and 2010. In 2010 this was 23.75 Mton of which 22.439 Mton (about 94.4%) was recycled and 0.845 Mton (about 3.6%) was used in another form of useful application. Only 4% was ‘removed’.

As can be seen in table 1, 3.106 m3 of wood was used in the complete construction industry in the Netherlands (table 2). When the average density is assumed to be that of pine wood (0.51*10^3 kg/m3), this amounts to 1.530 Mton (1.53*10^9 kg). This is roughly 1% of the total construction waste that was produced in The Netherlands in 2010 (see table 4 & table 3) and 13.6% of all the material that was sorted (table 1).

The numbers for the year 2010 concerning the amount of ‘final products’ from sorting process could not be found. For this reason the average of the 2002 till 2009 was calculated (table 1).

### Table 1: Amount of final products from sorting process 2002-2009 (Durmisevic & Binnemars, 2014, p. 81)

<table>
<thead>
<tr>
<th>End Product</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood (A + B)</td>
<td>0.37</td>
<td>0.42</td>
<td>0.42</td>
<td>0.52</td>
<td>0.35</td>
<td>0.39</td>
<td>0.31</td>
<td>0.29</td>
</tr>
<tr>
<td>Wood (C)</td>
<td>0.02</td>
<td>0.03</td>
<td>0.01</td>
<td>0.02</td>
<td>0.02</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Metals</td>
<td>0.13</td>
<td>0.12</td>
<td>0.07</td>
<td>0.09</td>
<td>0.06</td>
<td>0.07</td>
<td>0.09</td>
<td>0.08</td>
</tr>
<tr>
<td>Paper and Cardboard</td>
<td>0.02</td>
<td>0.02</td>
<td>0.00</td>
<td>0.00</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Plastics</td>
<td>0.01</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Secondary-fuels</td>
<td>0.03</td>
<td>0.04</td>
<td>0.11</td>
<td>0.08</td>
<td>0.03</td>
<td>0.03</td>
<td>0.05</td>
<td>0.07</td>
</tr>
<tr>
<td>Debris (to crusher)</td>
<td>0.46</td>
<td>0.48</td>
<td>0.42</td>
<td>0.47</td>
<td>0.67</td>
<td>0.95</td>
<td>0.51</td>
<td>0.49</td>
</tr>
<tr>
<td>Unwashed sorting sieve sand</td>
<td>0.34</td>
<td>0.40</td>
<td>0.34</td>
<td>0.42</td>
<td>0.31</td>
<td>0.32</td>
<td>0.45</td>
<td>0.45</td>
</tr>
<tr>
<td>Washing sorting sieve sand</td>
<td>0.18</td>
<td>0.20</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Plaster, gas - /cell concrete</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.02</td>
<td>0.02</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>Plaster, gas - /cell concrete export</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.01</td>
<td>0.01</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>Monoflows</td>
<td>0.00</td>
<td>0.01</td>
<td>0.02</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Roof covering material</td>
<td>0.01</td>
<td>0.01</td>
<td>0.02</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Sorting NL</td>
<td>0.04</td>
<td>0.03</td>
<td>0.05</td>
<td>0.06</td>
<td>0.12</td>
<td>0.09</td>
<td>0.00</td>
<td>0.01</td>
</tr>
<tr>
<td>Export for removal</td>
<td>0.02</td>
<td>0.02</td>
<td>0.13</td>
<td>0.07</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Export for sorting</td>
<td>0.06</td>
<td>0.70</td>
<td>0.47</td>
<td>0.32</td>
<td>0.08</td>
<td>0.23</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Residue to dump</td>
<td>0.10</td>
<td>0.06</td>
<td>0.10</td>
<td>0.25</td>
<td>0.24</td>
<td>0.23</td>
<td>0.11</td>
<td>0.08</td>
</tr>
<tr>
<td>Residue to energy recovery</td>
<td>0.06</td>
<td>0.05</td>
<td>0.05</td>
<td>0.06</td>
<td>0.14</td>
<td>0.23</td>
<td>0.71</td>
<td>0.65</td>
</tr>
<tr>
<td>Total (in Mton)</td>
<td>2.40</td>
<td>2.60</td>
<td>2.20</td>
<td>2.40</td>
<td>2.10</td>
<td>2.70</td>
<td>2.30</td>
<td>2.20</td>
</tr>
</tbody>
</table>

The total amount of sorted ‘final products’ from sorting process (this is again the average) amounted to 2.36 Mton (see table 1). Of this 2.36 Mton 1.915 originated from the construction industry (see table 5).

Of the total C&D waste that was collected in 2010 (22.4 Mton), 21.5 Mton was stone or asphalt and only 0.3 Mton was wood (see table 4).

In 2010 3.106 m3 timber was used in the construction industry. When the average density is assumed to be that of pine wood (0.51*10^3 kg/m3), this amounts to 1.53 Mton. Since 0.3 Mton of timber was produced as waste. This means that the timber waste that was produced, amounts to almost 20% of what gets used. See table 4 and table 5.
### Table 5 Origin of construction waste (Durmisevic & Binnemars, 2014, p. 82)

<table>
<thead>
<tr>
<th>Origin</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction industry</td>
<td>2.14</td>
<td>2.36</td>
<td>1.88</td>
<td>2.02</td>
<td>1.68</td>
<td>2.10</td>
<td>1.53</td>
<td>1.61</td>
</tr>
<tr>
<td>Road construction</td>
<td>0.03</td>
<td>2.36</td>
<td>0.07</td>
<td>0.08</td>
<td>0.02</td>
<td>0.03</td>
<td>0.14</td>
<td>0.10</td>
</tr>
<tr>
<td>Building material inc.</td>
<td>0.04</td>
<td>0.04</td>
<td>0.03</td>
<td>0.04</td>
<td>0.03</td>
<td>0.04</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Other sorting organisation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Municipalities</td>
<td>0.13</td>
<td>0.11</td>
<td>0.11</td>
<td>0.11</td>
<td>0.09</td>
<td>0.10</td>
<td>0.21</td>
<td>0.22</td>
</tr>
<tr>
<td>Private persons</td>
<td>0.05</td>
<td>0.06</td>
<td>0.10</td>
<td>0.13</td>
<td>0.06</td>
<td>0.08</td>
<td>0.25</td>
<td>0.21</td>
</tr>
<tr>
<td>Import from foreign countries</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other Origin</td>
<td>0.00</td>
<td>0.00</td>
<td>0.02</td>
<td>0.02</td>
<td>0.00</td>
<td>0.00</td>
<td>0.08</td>
<td>0.06</td>
</tr>
<tr>
<td>Total (in Mton)</td>
<td>2.40</td>
<td>2.60</td>
<td>2.20</td>
<td>2.40</td>
<td>2.10</td>
<td>2.70</td>
<td>2.30</td>
<td>2.20</td>
</tr>
</tbody>
</table>
The following environmental impact results of the Dutch C&D activities were seen as relevant in relation to this thesis:

At the current rate, the demolition and construction waste is predicted to grow, from 23 Mton in 2006 to 31 Mton in 2021. In the current scenario, the level of recycling (95%) is expected to be maintained. Again, this means that re-use will not play a significant role. (Ministerie van Infrastructuur en Milieu, 2017).

Timber, scores second highest on profit that was gained on environmental impact through waste processing in 2010 (-190 kton CO2-eq.) (figure 12).

The environmental impact of the entire Dutch construction industry in 2010 (this includes resources extraction and production outside of the Netherlands) amounts to 9,5 Mton CO2-eq. This is about 5% of the national emission.

Material use is responsible for the largest contribution on environmental impact and amounts to 70% of the total emission (figure 14). Applying construction waste in ‘useful applications’ compensates 9% of this emission. Transport of building material contributes around 18% of the total environmental impact (figure 14).

The Dutch construction and demolition activities together (this includes resources extraction and production outside of the Netherlands) consume 4,5% of the Dutch energy. This amounted to 170 PJ in 2010 (Centraal Bureau voor de Statistiek, 2017)

In the report Meten is Weten, CE Delft (2015) proposes that preventing illegal lumber by choosing products with a sustainable certificate, is the most important mean to decrease the environmental impact of timber use.

Conclusions the Dutch construction industry in numbers

It can be concluded that the Dutch waste disposal industry has significantly improved over the last three decades. This improvement can also be seen in the waste management of the construction industry. Around 98% of the material that originates from this industry is used in useful applications. Unfortunately, no data could be found on how the waste is distributed between the different forms of useful application. Since most of the impact is caused by material use, the effect of the shift, to applying waste in useful applications, has had a positive effect on the environmental impact of the
construction industry. The overall processing C&D waste has had an effect of -0.8 Mton CO2-eq. in 2010 (See figure 13). This roughly 8.5% of the total and 16% of the CO2 emission caused by material use (figure 14).

With -0.19 Mton, the processing of timber has had the second highest negative effect on CO2 emission in 2010 (3.8% of the emission caused by material use). Although this might have been true then, According to both Era Contour and Vorm, the market for the re-use of timber waste, appears to be collapsed. This means that timber possibly cannot be recycled as efficient and the effect of the processing of timber waste might therefore have a much less positive effect on CO2 emissions.

Because it is currently hard to find any information concerning this subject, additional research is required.

The data also shows that, in contrast to recycling, re-use is a phenomenon that is not yet embedded in the process of waste management The Netherlands. It is seldom included in reports and if it is, it amounts to insignificant numbers.
4.1.5 Waste management of Vorm and Era Contour in numbers

The following observation can be made based on the collected data on Era Contour's and Vorm's waste management:

- Vorm (together with its waste disposal company) has an elaborate and precise waste management system. They document their waste sorting into 32 categories, whereas Era Contour document their waste into 13 categories.

- Vorm produces 56% of the waste, Era Contour produces (the missing month has been taken into account).

- Vorm produces 606.9 tons of timber waste, Era Contour produces 607.4 tons of timber waste.

- 2.27% of the timber waste produced by Era Contour is class A timber. The remaining timber is class B timber.

- 4.33% of the timber waste produced by Vorm is class A timber. The remaining timber is class B timber.

- At both Vorm and Era Contour timber waste is produced consistently throughout the year. This is primarily class B timber.
### Table 6: Waste produced from Jan. - Nov. in the construction projects of Era Contour (Era Contour, 2017)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste type</td>
<td></td>
<td></td>
<td>5,950</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5,950</td>
</tr>
<tr>
<td>Construction and Demolition waste (sorted)</td>
<td>24,080</td>
<td>36,400</td>
<td>29,020</td>
<td>43,370</td>
<td>60,080</td>
<td>64,740</td>
<td>54,220</td>
<td>32,060</td>
<td>42,345</td>
<td>44,945</td>
<td>46,020</td>
<td>26,010</td>
</tr>
<tr>
<td>Construction and Demolition waste (not recyclable)</td>
<td>0,060</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0,060</td>
</tr>
<tr>
<td>Isolation material (stone-/Glass)</td>
<td>0,100</td>
<td>0,380</td>
<td>0,140</td>
<td>1,660</td>
<td>1,120</td>
<td>3,400</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3,600</td>
</tr>
<tr>
<td>Isolation material (remaining)</td>
<td>3,210</td>
<td>2,560</td>
<td>1,580</td>
<td>2,700</td>
<td>1,700</td>
<td>3,000</td>
<td>1,000</td>
<td>1,100</td>
<td>1,200</td>
<td>1,300</td>
<td>1,900</td>
<td>27,000</td>
</tr>
<tr>
<td>Gypsum chunks</td>
<td>5,660</td>
<td>3,200</td>
<td>3,040</td>
<td>3,120</td>
<td>3,120</td>
<td>3,120</td>
<td>3,120</td>
<td>3,120</td>
<td>3,120</td>
<td>3,120</td>
<td>3,120</td>
<td>3,120</td>
</tr>
<tr>
<td>Gypsum/Cellular concrete</td>
<td>4,300</td>
<td>9,400</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>13,700</td>
</tr>
<tr>
<td>Obscruible</td>
<td>137,330</td>
<td>303,900</td>
<td>292,900</td>
<td>292,900</td>
<td>132,080</td>
<td>148,830</td>
<td>60,730</td>
<td>41,630</td>
<td>149,630</td>
<td>75,450</td>
<td>102,930</td>
<td>60,280</td>
</tr>
<tr>
<td>Contaminated rubble</td>
<td>4,000</td>
<td>6,800</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10,800</td>
</tr>
<tr>
<td>Timber (A)</td>
<td>0,170</td>
<td>4,530</td>
<td>1,340</td>
<td>2,360</td>
<td>5,020</td>
<td>3,240</td>
<td>0,220</td>
<td>0,800</td>
<td>0,800</td>
<td>0,800</td>
<td>0,800</td>
<td>1,200</td>
</tr>
<tr>
<td>Timber (B)</td>
<td>34,310</td>
<td>70,760</td>
<td>63,014</td>
<td>57,930</td>
<td>42,940</td>
<td>31,440</td>
<td>46,000</td>
<td>16,000</td>
<td>21,200</td>
<td>17,000</td>
<td>51,000</td>
<td>632,944</td>
</tr>
<tr>
<td>Timber (B), Contaminated</td>
<td>1,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,000</td>
</tr>
<tr>
<td>Iron (bars)</td>
<td>1,180</td>
<td>1,040</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2,220</td>
</tr>
<tr>
<td>Iron marten</td>
<td>0,750</td>
<td>0,530</td>
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<td></td>
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<td></td>
<td></td>
<td>1,280</td>
</tr>
<tr>
<td>Industrial waste (inflammable)</td>
<td>1,000</td>
<td>3,200</td>
<td>9,420</td>
<td>7,410</td>
<td>7,540</td>
<td>16,920</td>
<td>15,020</td>
<td>0,200</td>
<td>10,200</td>
<td>3,420</td>
<td>2,200</td>
<td>0,360</td>
</tr>
<tr>
<td>Floor Covering waste</td>
<td>1,000</td>
<td>1,480</td>
<td>1,145</td>
<td>0,740</td>
<td>0,000</td>
<td>0,360</td>
<td>1,200</td>
<td>0,420</td>
<td>0,150</td>
<td>8,560</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardboard</td>
<td>0,440</td>
<td>0,290</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0,730</td>
</tr>
<tr>
<td>Paper/Cardboard</td>
<td>2,520</td>
<td>2,600</td>
<td>2,500</td>
<td>5,580</td>
<td>1,800</td>
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<td>3,780</td>
<td>0,520</td>
<td>2,400</td>
<td>3,010</td>
<td>2,400</td>
<td>4,840</td>
</tr>
<tr>
<td>Mixed sheet glass</td>
<td>0,200</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0,200</td>
</tr>
<tr>
<td>Green (Garden waste)</td>
<td>2,420</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2,420</td>
</tr>
<tr>
<td>Plastic (mixed)</td>
<td>0,000</td>
<td>2,060</td>
<td>2,000</td>
<td>1,940</td>
<td>0,400</td>
<td>0,710</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2,280</td>
</tr>
<tr>
<td>Foils</td>
<td>2,460</td>
<td>6,080</td>
<td>5,120</td>
<td>3,220</td>
<td>4,000</td>
<td>3,020</td>
<td>2,240</td>
<td>2,840</td>
<td>2,840</td>
<td>4,000</td>
<td>4,000</td>
<td>13,480</td>
</tr>
<tr>
<td>PVC</td>
<td>0,700</td>
<td>0,300</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,000</td>
</tr>
<tr>
<td>EPS</td>
<td>0,160</td>
<td>0,980</td>
<td></td>
<td></td>
<td>0,040</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,180</td>
</tr>
<tr>
<td>Hard plastic (mixed)</td>
<td>0,620</td>
<td>1,980</td>
<td>1,400</td>
<td>0,940</td>
<td>2,800</td>
<td>1,240</td>
<td>0,940</td>
<td>1,440</td>
<td>0,940</td>
<td>9,890</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PE building foil</td>
<td>0,160</td>
<td>0,320</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0,480</td>
</tr>
<tr>
<td>Soldering and cutting oil</td>
<td>0,048</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0,048</td>
</tr>
<tr>
<td>Vertical in plastic and steel packaging</td>
<td>0,242</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0,242</td>
</tr>
<tr>
<td>CIT cases</td>
<td>0,076</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0,076</td>
</tr>
<tr>
<td>KGA from construction and demolition waste</td>
<td>0,312</td>
<td>3,380</td>
<td>0,230</td>
<td>0,230</td>
<td>0,230</td>
<td>0,230</td>
<td>0,230</td>
<td>0,230</td>
<td>0,230</td>
<td>0,230</td>
<td>0,230</td>
<td></td>
</tr>
<tr>
<td>Lid batteries</td>
<td>0,100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0,100</td>
</tr>
<tr>
<td>Lighting containing dangerous materials</td>
<td>0,040</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0,040</td>
</tr>
<tr>
<td>Paint cans</td>
<td>0,024</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0,024</td>
</tr>
<tr>
<td>Total</td>
<td>228,680</td>
<td>354,030</td>
<td>332,836</td>
<td>317,100</td>
<td>231,780</td>
<td>325,215</td>
<td>164,618</td>
<td>97,040</td>
<td>276,610</td>
<td>162,785</td>
<td>250,560</td>
<td>154,790</td>
</tr>
</tbody>
</table>
4.1.6 The CRRS companies Buurman and Community Wood Recycling in numbers

In study one (Chapter 5: Research), the multi case analysis on three CRRS companies will be explained. One of these companies is Community Wood Recycling (CWR). Subsequently to the in-depth interview on which this analysis was based, CWR and Buurman were requested to supply information on the amounts of materials they process (Jan van IJken was not able to supply this data). The following observation can be made based on the collected data on Buurman’s and Community Wood Recycling’s material management:

As can be seen in table 8, Buurman processes a variety of materials. It is therefore difficult to make an estimate on the weight of the material Buurman processed in the 2016. Comparing Buurman’s data with the numbers of the national construction waste management also has its limitations, because Buurman was not active in the year 2010. Furthermore, making an estimate per material category can only be done roughly, because a lot of the batches comprised of different materials and were documented as ‘variable’ and in m³. The 552 m³ Buurman processed, therefore comprises all the materials together.

The Community Wood Recycling network as a whole, collected an estimated 17,000 tonnes (roughly 12997 m³) of wood in 2016 and reused about 46% of it. Discounting enterprises that were just starting up or otherwise not running at capacity, enterprises collected between 50 and 2,400 tonnes each.

<table>
<thead>
<tr>
<th>Supplier</th>
<th>Material</th>
<th>Amounts</th>
<th>Units</th>
<th>Cubic meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERA</td>
<td>Doors</td>
<td>150</td>
<td>Pieces</td>
<td>10</td>
</tr>
<tr>
<td>Accenta</td>
<td>Wooden screens</td>
<td>16</td>
<td>1m x 2.4 x 1.50</td>
<td>38</td>
</tr>
<tr>
<td>Dino show</td>
<td>Fences</td>
<td>3</td>
<td>Vans</td>
<td>12</td>
</tr>
<tr>
<td>Frank</td>
<td>Variable</td>
<td>1</td>
<td>Van + Truck</td>
<td>3</td>
</tr>
<tr>
<td>CT theater</td>
<td>Wooden screens</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IABR</td>
<td>Variable</td>
<td>1</td>
<td>Truck</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>Vans</td>
<td>4</td>
</tr>
<tr>
<td>Sprong polder</td>
<td>Line reel</td>
<td></td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Rdam viert de stad</td>
<td>Baggyhead</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ERA</td>
<td>Construction yard material</td>
<td>3</td>
<td>Vans</td>
<td>12</td>
</tr>
<tr>
<td>HEMA</td>
<td>Pallets</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dominexes</td>
<td>Y long</td>
<td>6000</td>
<td>Pieces</td>
<td>72</td>
</tr>
<tr>
<td>VORM</td>
<td>Wooden beams</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heuvelman</td>
<td>Wood</td>
<td>6</td>
<td>Trucks</td>
<td>240</td>
</tr>
<tr>
<td>VORM</td>
<td>variable</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>particulier</td>
<td>Glass, perspex</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nakaartshoorn</td>
<td>Glase, perspex</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ERA Vlaardingen</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VORM</td>
<td>Ahoy Offshore Fair</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>552</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 8: Materials processed in 2016 by Buurman
(Buurman Materialen en Werkplaats, 2017)

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Collection and re-use Community Wood Recycling

[Graph showing estimated tonnes of recycling and re-use from 2010 to 2016]
4.1.7 Conclusions

As previously mentioned, the data made available for this research shows the numbers of 2016 for both Era Contour, Vorm and Buurman. This enables a comparison between these companies, but makes a comparison between the national construction waste production less valuable (2010). Nevertheless, this comparison is still made, because the amount of construction waste that is produced in The Netherlands is consistent, up to the year of which the data was available.

When the collected data on the national construction waste, the construction companies Era Contour and Vorm and the CRRS companies Buurman and Community Wood Recycling, is compared, the following can be concluded:

Impact of Era Contour and Vorm
When comparing the construction waste Era Contour and Vorm produced, with the complete Dutch construction waste production, it becomes evident that the contribution of these medium sized construction company, is minimal. The waste Vorm en Era Contour produced, amounts to respectively 0,024% and 0,012% of all the construction waste produced in the Netherlands in 2010. Currently the impact Buurman has had on the waste disposal of Vorm and Era Contour is insignificant.

Impact of Buurman
Of the total amount of material Buurman processed, between 300 and 400 m3 consisted of timber. When the average density is assumed to be that of pine wood (51 ton/m3), this amounts to 0,232 kton of timber. This is between 0,024% and 0,012% of all the construction waste produced in the Netherlands in 2010. Currently the impact Buurman has had on the waste disposal of Vorm and Era Contour is insignificant.

Impact CWR
The construction industry of the UK annually produces 120 000 kton of construction waste ("Waste | UK Green Building Council", 2017). 1185 kton of this waste is wood waste (table 9), which is roughly 1% of all the waste produced by the construction industry in the UK. In 2016 CWR collected 17 kton of wood of which 7,99 kton (47%) was re-used and the remaining 9,01 kton (53%) was re-cycled. This means that CWR collects roughly 1,5% of the wood waste in UK.

With 1,5% of the total timber waste processed, Community Wood Recycling has significant impact on the total waste production of the UK. This is spread over their enterprises and averages at 600 ton per enterprise (458 m³). Buurman’s complete volume of processed timber in 2016, amounted to 400 m³ and comes close to the average of CWR. If Buurman wants to reach a similar impact concerning waste processing, they would need roughly 21 Buurman enterprises. Although 21 enterprises might sound excessive, on the long term this might not be as improbable as it seems. However, it is very important to consider a couple of things concerning the growth of CRRS companies.

In its current size, the amount of sorted timber (300 kton/year) in The Netherlands would allow for 1428 CRRS companies that process 400 m³ timber each. However:

- Not all the timber is suitable to re-used. CWR reaches a 47% re-use percentage
- Not all sources of timber waste from the construction industry can be reached

Nevertheless, there is still a lot of timber that is not sorted, the 300 kton of timber that is sorted does not include this unsorted timber. The amount of usable timber might there fore be higher.

How much CRRS companies The Netherlands can take is depended a high variety of factors and an exclusive answer needs considerable more research. Furthermore, it is highly dependent on the form of the CRRS companies (complete waste management vs cherry picking). Although, the amount of CRRS companies ultimately is limited, there is currently enough timber waste to go around.

<table>
<thead>
<tr>
<th>Region</th>
<th>Packaging</th>
<th>Industrial</th>
<th>Construction</th>
<th>Demolition</th>
<th>Municipal</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entire UK</td>
<td>1,170</td>
<td>0,463</td>
<td>1,185</td>
<td>1,137</td>
<td>0,619</td>
<td>4,573</td>
</tr>
</tbody>
</table>

Table 9: Wood waste in the UK (Pöyry Forest Industry Consulting, 2009)
CHAPTER 5 RESEARCH

The research chapter discusses the research that has been conducted. This research accounts for the biggest part of the analysis and consists of two studies.

Study one
The information derived from the internal analysis of Buurman is very case specific and only says something about the company Buurman. To be able draw conclusions about CRRS companies general, additional information on such companies needed to be gathered. This was done through in-depth interviews with such companies. Following these interviews, a multi-case analysis was conducted that was aimed to provide insight with regards to sub question one.

Study two
This second study, revolves around the construction industry. It aims to gives answer to the sub questions two and three. To answer these questions, in-depth interviews were conducted with two medium sized construction companies. The results from these interviews were used in a multi case analysis.

This chapter gives a summary of the process of both studies and elaborates on the conclusions and insight that were derived from the results. The complete multi case study can be found in Appendix D: Complete multi case study one and Appendix I: Multi case study two.
5.1 STUDY ONE: CRRS COMPANIES

5.1.1 Introduction and Justification

Buurman is a company that collects, refurbishes, re-uses and sells used building materials. Prior to study one, an internal analysis of Buurman has been conducted that aimed at identifying Buurman’s strengths and weaknesses and the possible opportunities and threats in Buurman’s market. The information derived from the internal analysis is very case specific and only says something about the company Buurman. To be able draw conclusions about companies, that collect, refurbish, re-use and sells used building materials in general, additional information on such companies needed to be gathered. This was done through in-depth interviews with two comparable companies. Following these interviews, a multi-case analysis was conducted that was aimed to provide insight with regards to the following question:

‘How do companies that collect, refurbish, re-use and sell used building materials, collect and use the collected material?’

The multi-case analysis did not supply the information needed for an unequivocal answer to this question. It merely served as an exploratory research that aimed to understand the underlying reasoning and motivation of companies such as Buurman. Five themes were developed, to aid the search for these insights. These themes indicated the primary information about the three companies that was sought through this research and served a guiding role in the multi-case analysis later in the study.

- What is the impact of the processing of building material from the company?
- To what extent is the collected material utilized?
- How does the vision of the company influence their way of working?
- How is the company trying to extent their influence on material re-use?

The insights of this analysis plus the insights from the previous study will be used in the development of a product, that will finalize this thesis.

The development of this ‘product’ will form the next step in this thesis; how this step will be approached can be read in chapter 11: Next steps. Additionally, the findings of this study can help to develop ideas for new potential quantitative research, aimed to give a more unequivocal answer to sub question one.

5.1.2 Summary of the methodology

The complete methodology can be found in chapter 2: Methodology. In short the methodology comprised of the following:

1. Company selection
   The selected companies:
   - Buurman
   - Jan van IJken
   - Community Wood Recycling

2. Pilot study
   In-depth interview

3. Lessons learned
   A short lessons learned report

4. Additional interview
   Remaining interview with company from pilot study

5. Official interviews
   In-depth interview (Appendix E: Interview protocol)

6. Transcription
   Transcription from audio recording (Appendix F and Appendix: H)

7. Analysis
   In short, this multi-case study comprised the following (Appendix D: Complete multi case study one):
   - Case reports of the three in-depth interviews
   - Lists of the most important findings from the three case reports
   - A list of tentative assertions derived from the most important findings
   - A list of cross-case assertions
   - Conclusions
5.1.3 Conclusions and insights

Through a multi-case analysis based on four different themes, a list of cross-case assertions was developed in order to better understand companies that collect, refurbish, re-use and sell used building materials. In the following paragraphs, the conclusions that were drawn from these assertions are explained. How these findings and assertions came to be, can be read in the report of the complete multi-case study in Appendix D: Complete multi case study one. The relation of the conclusions to the thesis, are explained in the final part of this chapter.

Development of the themes and the limitations of the present evidence

The initial rationale behind the multi-case study, was to put the concept of Buurman’s business model in a broader perspective. Through such a study, the concept of collecting, refurbishing, re-suing and selling used building materials could be studied in context of other companies. By subsequently comparing these findings to Buurman, more general insights concerning the underlying reasoning and motivation of CRRS companies could be identified. Insights in such matters, could ultimately be used as in the development of a product.

The cases that served as a comparison with Buurman, were studied by means of in-depth interviews. Although this method of studying, is proven to be a valid way of studying a case (Maxwell, 1992), using it to gain insights in the chosen subjects, might not have been the best choice. The subjects, divided in five themes, touched on: impact, utilization, vision and business model. Although the former two subjects resulted in a more general insight that could actually be used, the latter two subjects, supplied little insights that could be used in the continuation of this thesis.

Because the interviews focused on such a broad spectrum of subjects, the questions were relatively general. Logically, this resulted in general answers. This on itself would not have been a problem, were it not, that certain subjects did not apply to both companies or where just to complex to cover in an interview of 30 to 60 minutes.

This complexity resulted in findings that did not give the insights that could aid future product development. It would have been smarter to focus on a smaller selection of more specific themes. Theme one and theme two would have been the logical choice for this. The starting point of this study, sub question one, should thus have been a less general and more focused on a specific subject.

Because of the limitation of the evidence the sub question related to this research could only be answered partially.

Impact

In the current state of affairs, the amount of available building waste is so extensive that there is more than enough for the existing CRRS companies to go around (see page: Literature review). There is even so much, that CRRS companies are able to choose the materials they perceive as being the most ideal for them to use. This way of collecting material is referred to as ‘cherry picking’ and is possible for both CRRS companies that derive their material from the construction industry as for CRRS companies that derive their material from the demolition industry.

Although this method has the obvious advantages concerning material selection, it also minimizes the impact of a CRRS company on the increase in material re-use in general. By transforming a system that is based on cherry picking to one that is based on a waste management. The same materials can ultimately be harvested, but with a larger impact on material re-use. As can be seen with Community wood recycling.

With a business model that is based on a waste managementservice, the impact not only significantly increases, a CRRS company also becomes more attractive to construction companies. In the case of a cherry picking model, a CRRS company either has to pay for the material (as with material from the demolition industry), or the supplying construction company must have an ethical interest in supplying it. In the case of a waste management service, the construction company also has a practical benefit of supplying a CRRS company with material.
Another impact of the transformation to a waste management service, is the push it will bring to differentiation in applications. The more material a company collects, the higher the variety and quantity of material at the facility will be. All the material that does not get used, must be disposed. Disposal costs money and will therefore push the company to apply it in such a way, that is can be sold.

Materials that originate from the demolition industry, in general, are less suited for the production of new products. These materials are appreciated for their ‘old’ character and therefore often are used as they were intended. Whereas materials that are derived from the construction industry are often more appreciated for their ‘sustainable’ and economical character. It is therefore interesting to note, that both kind of CRRS companies attract the same kind of customers, but do is for different reasons.

Vision

Collecting used materials and using them in a business model is inextricably associated with an ethical way of working. This is similar for pursuing a vision of a sustainable future. In a business in which the core activities are inseparable from association with the term sustainability, it is obvious to assume that CRRS companies pre-eminently pursue a vision of a sustainable future. Although this might be true for some, it is certainly not true for all. Especially companies that deal with material derived from the demolition industry, are more likely to not pursue such a vision (or pursue a vision at all). Materials with an ‘old’ character are popular and therefore are valuable. Collection them, refurbishing them, re-using them and them is just good business.

Relation to the thesis

Although the multi-case analysis of the three CRRS companies might not have a very significant impact on this thesis, there are a couple of insights that might influence the development process that will follow from this research.

Because CRRS companies like Buurman could benefit significantly from combining production activities with a waste management, such a service must be considered. How this will take shape, depends on the attitude towards such a service from the construction sector (study two). Similarly, the expansion of CRRS companies like Buurman by means of a franchise system, is something that must be considered in the product development phase of this thesis. This can make CRRS companies like Buurman interesting for a wider public.

As mentioned in the conclusion of the examination of the Dutch construction industry in numbers, the amount of available material is currently excessive enough to support an increase in CRRS companies. Nevertheless, the changing landscape of resource use should not be ignored. The amount of companies that adapt to the available timber waste might increase, regulations concerning resource use might change etc. (See porters five forces, in Chapter 3.1: Internal analysis, Porters five forces). These influences should all be considered in the product development.

Although this may lay outside of the scope of this project, the use of building material that originates from the demolition industry might form an interesting combination with the use of materials that originates from the construction industry. Altogether, this might attract a wider public.
5.2 STUDY TWO: CONSTRUCTION COMPANIES

5.2.1 Introduction and Justification

The first study that was conducted in light of this thesis aimed to answer the question:

‘How do companies that collect, refurbish, re-use and sell used building materials, collect and use the collected material?’

Insights concerning this question, were derived through a multi-case study and can be found on page 54. They show certain characteristics and motives of companies that collect, refurbish, re-use and sell used building materials. This chapter is devoted to study two and will focus on the construction industry. Together the insights of study one and two, enable more sensible conclusions with regards to the thesis as a whole.

This second study, revolves around the construction industry. It aims to gives answer to the following questions:

‘What materials, that originate as waste in the process of construction, are most widely available from the construction sites of construction companies?’

‘Which initiatives, that incorporate the re-use of building material, are feasible for medium sized construction companies?’

To answer these questions, in-depth interviews were conducted with two medium sized construction companies. The results from these interviews were used in a cross-case analysis. This cross-case analysis did not supply the information needed for an unequivocal answer to this question. It merely served as an exploratory research that aimed to understand the underlying reasoning and motivation of companies in the construction industry. Five themes were developed that indicated the primary information about the three companies that was sought through this research; these themes will served a guiding role in the cross-case analysis later in the study.

Theme 1: How does the company currently manages their construction waste?

Theme 2: How can the company improve their waste management system?

Theme 3: What does the company see as limitations for the use of used building materials?

Theme 4: What does the company see as possible applications for used building materials?

The insights of this analysis plus the insights from the previous study are used to develop a product, that will might be the answer the main research question of this thesis. The development of this product forms the final step in this thesis; how this step was approached can be read in chapter 6: Ideation. Additionally, the findings of the last study can help to develop ideas for new potential quantitative research, aimed to give an unequivocal answer to the questions stated above.

5.2.2 Summary of the methodology

The complete methodology can be found in chapter 2: Methodology. In short the methodology comprised of the following:

1. Company selection
   • Era Contour
   • Vorm

2. Pilot studies
   A pilot interview with both Era Contour and Vorm.
   Goals:
   • The general working principles of the company
   • Insights in relevant subjects
   • Insight in what questions needed to be asked
   • Acquiring contact information of relevant experts within the company, for official interviews

3. Lessons learned
   Summary of pilot interviews + learned lessons (Appendix L: Summary of pilot interviews and Learned lessons)

4. In-depth Interviews
   In-depth interviews with both companies (Appendix N: Interview protocol study two)

5. Transcription
   Transcriptions from audio recordings (Appendix O: Transcription Era, Appendix P: Transcription Vorm)
6. Analysis
In short, this multi-case study (Appendix I: Complete multi case study two) comprised the following:

- Case reports of the three in-depth interviews
- Lists of the most important findings from the three case reports
- A list of tentative assertions derived from the most important findings
- A list of cross-case assertions
- Conclusions

5.2.3 Conclusions and insights

Through a multi-case analysis based on four different themes, a list of cross-case assertions was developed in order to better understand the two cases. In the following paragraphs, the conclusions that were drawn from these assertions are explained. The relation of the conclusions to the thesis, is explained in the final part of this chapter.

Development of the themes and the limitations of the present evidence

From the four themes that were developed prior to the in-depth interviews, the first three turned out to be suited for further development. These themes supplied relevant insights based on convincing evidence (read: compelling persuasion). Unfortunately the fourth (and most important) theme could not be developed to the expected level. The most important reasons for this, were the conservative mind-set and function of the interviewees. Although the evidence concerning this theme were not as compelling as the first three, a list of boundary conditions could still be identified.

Another noteworthy limitation (and at the same time advantage) of the evidence is the difference in function of the interviewees. It creates a discrepancy in the consistency of the answers, but is also helps to show that the interviewees are not bias because of their function.

Waste management in the construction industry and possible contributions of CRRS companies

Era Contour and Vorm are both considered construction companies that act from a ‘sustainable’ angle. Sustainable in this case, must be regarded with respect to the conservativeness of the construction industry. The way Era Contour and Vorm build is far from sustainable, but in comparison to other companies they perform relatively well.

Whether a construction company deals with its waste in a sustainable manner is entirely dependent on the policy of the company. Even if a company’s ‘sustainable’ policy is applied on their waste management, it remains a trade-off. The available space is a decisive factor, in such a trade-off. No matter how ‘sustainable’ the policy might be, when there is no room for waste separation, it is just not possible to implement an extensive waste separation system. There is of course a large gray area, in which there could be space for an advanced waste separation system, but it would have to be implemented at the expense of other elements. In such a case the willingness of the company is decisive.

If a company genuinely considers waste separation management to be of importance and wants to implement such a system, the extensiveness of this system will determines how a company is going to have to deal with it. Although ultimately, the foreman of a project is responsible for dealing with the construction waste, he depends on his construction site employees to manage their waste correctly. The extent to which these employees have to take this responsibility varies. A more extensive waste separation system (which can include up 14 containers), will require much more awareness and waste management from the employees, than a smaller system.

As well as the policy for internal waste management, the role of the waste disposal company, depends on how much effort and money a company is willing invest. Generally, a waste disposal company will only deliver a certain amount of containers, will collect them when they are full and will provide a report on waste quantities and separation levels. When a company wants to extent its system, the waste disposal company is likely to get more involved, because the complexity of the system increases. In such a case the system will be based on the specifications of the project and will require the knowledge of both parties.
It goes without saying, that a higher level of waste separation is preferred over a lower level of waste separation. However, no matter how extensive the separation, at best, it will end up in recycling (see chapter 4.1: Literature review). Re-use plays almost no role in the separation process. CRRS companies could be the ones that start filling this gap. The extent of their involvement is, again, dependent on the waste management system of a construction company. A less developed waste management system will benefit from contribution on a systematic level, whereas a further developed waste management system would only benefit from assistance in waste separation, concerning material re-use.

Limitations and applications of used building materials in the construction industry

How waste is currently managed in the construction industry, how it can be improved and how CRRS companies can play a role in this, is one side of the story. If a higher percentage of waste in the construction industry is going to be re-used and the stream of building material to CRRS companies increases, this material is going to need a purpose. Ideally, this purpose would be: using it the construction industry.

Because of the conservative attitude of the industry, the use of used building materials is regarded with much skepticism. Again, the policy of the company is going be decisive in this. The more a company is pursuing a sustainable policy, the bigger the chance that they are willing to make abandonments on their traditional way of working. Such abandonments are very likely to be needed.

Construction companies foresee multiple limitations in the use of used building materials. These limitations, for example, relate to quality-, safety- and strength-guarantees, certificates or to the possible conflict between newly build houses and the use of secondary resources. Whatever its reasoning, the limitations all boils down to uncertainty and unfamiliarity. It is therefore remarkable to note that ,in contrast to what one might expect, the quality of used building materials, is perceived as being sufficient for certain applications.

Through the multi-case study, it has become evident that construction industry is a very conservative one. Why this is the case, is a research on itself. Nevertheless, there are elements in construction companies that are progressive enough to be open to (albeit very carefully) the use of secondary resources. Because the risk in such an endeavor needs to be as little as possible, there are certain initial boundary conditions:

Small scale
Because the use of secondary resources is completely new to the construction industry, the risks of using these materials must be tested on a small scale.

Applications not connected to residences
All the applications that are connected to the building pose a more significant risk. When something breaks this can have mayor consequences on other elements. The applications that have the biggest chance of success are therefore the ones are not connected to buildings.

Applications with the least demanding certificates or guarantees
The less demanding a certificate or guarantee on a product is, the less risky it will be when it is implemented.

A complete product
Although this might sound obvious, ‘the use of used building materials’ does not implicate in what form. Through this study it has become evident that it has to cost as little time and money on operational level as possible. A complete and finished product, which can replace the original is therefore essential.

An option that is considered, but has less impact on the construction company itself, is offering objects outside of the construction phase, to the owners of new houses.

These five insights together with the insights concerning waste management and the possible improvements on it, guide the design process and the development of the product that will finalize this thesis. What the exact influence of these insights is can be read in the last paragraphs of this chapter.
When comparing the list of barriers for sustainable material selection with the conclusions from study two, it can be seen that barrier 1, 2, 3, 5, 6, 7, 8, 9, 10 and 11 all, to some extend, are identified by both the interviewees. Only barrier 4 and barrier 12 are not identified by them. There was no significant difference in what the interviewees defined as barriers.

1. Barriers for sustainable material selection:
2. Lack of sustainable material information
3. Uncertainty in liability of final work
4. Building code restriction
5. Lack of comprehensive tools and data to compare material alternatives
6. Perception of extra cost being incurred
7. Perception of extra time being incurred
8. Perception that sustainable materials are low in quality
9. Unwilling to change the conventional way of specifying
10. Conservative industrial culture
11. No tangible benefits
12. Hierarchy of project organization structure
13. Lack of qualified workers and expertise

A waste management as a service must be considered. This conclusions was already drawn from study one and is confirmed by study two. It should be noted that the extensiveness of such a service might need to vary from company to company. Vorm for example, is open to improvements, also with the help of a third party, but is miles ahead of Era Contour concerning waste management. The development of a service must therefore be customizable to the specific construction company.

The imminent lack of available space at construction sites, might be the key element in this. Construction companies are constantly making trade-offs, of which time and money stand at the center. Waste management has a low priority and therefore quickly slacks. The less space there is, the quicker correct and consistent waste management is abandoned. A waste management service could respond to this lack of space and help construction companies with this dilemma. An example that was mentioned by one of the interviewees was a weekly cleaning day service.

Because such a service will significantly increase the material input for a CRRS company, it ultimately needs to be combined with a product that is produced by a CRRS company. Otherwise, the collection of material will keep on growing and the output of material/products will not be able to keep up with the increase.

The difficulty of developing such products, is the inconsistency of the stream of material. This was presumed in the problem definition and is confirmed through study two. Construction companies are able to make a sensible estimate, on when certain material arises, but predicting exact amounts and exact times is not possible. The necessity of accurate material prediction, which is also identified by Solís-Guzmán, Marrero, Montes-Delgado, & Ramírez-de-Arellano (2009) and Roper (2006).

Although the multi-case analysis showed that there is willingness from construction companies to improve on both waste management as material use, the conservative culture that is characteristic for the construction industry, makes it hard to implement initiatives. The hierarchy of construction companies plays a big role in this as well. Especially the attitude towards sustainable material use from the higher management layers are very important and considered the driving force behind adaptation (Pitt, Tucker, Riley, Longden, 2009).

Construction companies, want to give certain guarantees. To give these guarantees certain certificates are needed. It is therefore necessary to consider that a product, developed by a CRRS company, might need such a certificate. Furthermore the previously mentioned initial boundary conditions must be adjourned to.
PART 2: SYNTHESIS
The following chapter will discuss how the results from the analysis were used and explains the rationale behind the design direction. Each step is discussed with sketches that explain the different ideas that were considered.
6.1 Waste management service

Two subjects were at the heart of the analysis: On-site waste management and the use of used building materials in the construction industry. The insights gained concerning these subjects served as the starting point for the ideation phase. On-site waste management was the first subject that was explored in this phase.

The illustration shows the varying ideas concerning on-site waste management services that were considered.

As was concluded in study one, it is genuinely believed that both CRRS companies as construction companies, can benefit from such a service. For CRRS companies such as Buurman, it will improve the control over their material influx, which in its turn can increase the overall quality and quantity of the materials. For construction companies such a service can result in higher waste separation. However, it will primarily increase the input and will not increase the output for Buurman. Furthermore, Buurman is already working on such a service and it is primarily an organizational challenge. For this reason the focus was shifted to the second subject:

The use of used timber in the construction industry.
6.2 Products not connected to the residence

In exploring ideas for the use of used timber in the construction industry, the second boundary condition from study two, served as the primary guideline:

Products that are not connected to the residence.

The illustration shows what kind of products were considered.
6.3 A modular system

The development of products for the construction industry, like the ones shown on the previous page, can be a good idea. Unfortunately, this would require Buurman to be able to produce a certain quantity of products with a certain consistency and quality. As can be read in Chapter 3: Internal analysis, Buurman currently is not capable in doing so, because of the limitations of the BouwAkademie and the available material:

- Enabling use of used timber, regardless of the dimensions
- Enabling use of used timber, regardless of the quality
- Enabling use of used timber, regardless of the grade
- Enabling a universal production system

To overcome these limitations the idea of a modular system was explored. Such a system could potentially overcome these limitations by:

- Limited in-house skills
- Limited production capacity
- Resources require processing
- Inconsistent material dimensions
- Inconsistent material input

The illustration shows the ideas that were considered.
6.4 Connection elements

From these ideas, the idea of connection elements was considered the most feasible to develop within the scope of this project. The three most important reasons for this are:

- It will enable the development of a wide variety of products
- It is feasible for Buurman concerning potential investments
- It poses a design challenge that fits within the IPD master

The illustration shows the connection elements that were considered:

In the next chapter, the choice of connection element will be explained alongside the system in its entirety.
As discussed in the ideation chapter, the choice was made to develop a system of connection elements, that enables the connection between wooden elements. In the concept chapter, this system is going to be discussed. Prior to an explanation on the system’s principles, an explanation will be given on the practical challenges and on the requirements the system should meet. This is followed by a detailed explanation on both the connection elements and the tool that was developed alongside it. Furthermore, this chapter will explain why the system is superior to conventional connection methods. Finally, the chapter shows how the system will function in the context of Buurman and the BouwAkademie. The chapter is concluded with conclusions and recommendations on the future developments.
7.1 REQUIREMENTS

As can be read in the ideation chapter (page 59), the choice was made to develop a system that consists of collection of connection elements. The idea behind such a system, is that it enables the user to easily form connections between wooden elements, regardless of the dimensions of the material. It aims to help Buurman to overcome the previously mentioned limitations and simplifies the manufacturing process; making it easier to produce products for business to business sales (e.g. the construction industry). More information on the reasoning behind the concept can be read in the justification section on page 90.

7.1.1 Practical challenges

While developing the connection elements, requirement two and three turned out to pose the biggest practical challenges.

Varying end-grain dimensions
Although in practice, certain sizes are collected significantly more than others, the timber Buurman collects, can potentially comprise all the industry-standard sizes. The connection elements should therefore enable the connection between all industry-standard end-grain dimensions. A, B and C in figure 26 show different combinations of end-grain dimensions.

Inconsistent dimensions (small variations)
Because Buurman’s timber originates from a variety of sources and is either used or rejected, it is inconsistent in its dimensions. Slight deviations (+-2 mm) within batches of the same size are therefore not uncommon. The connection elements should thus enable the connection between wooden elements that slightly deviate from the industry-standard size. Figure 27 shows slight variations of end-grain dimensions.

7.1.2 Program of requirements

Based on insights gathered in the ideation process of the connection elements, a list of requirements was composed; this list of requirements was updated throughout the development and can be found in Appendix Q: List of requirements. The most fundamental requirements are the following:

Function
1. The product must enable the connection between different wooden elements
2. The product must enable the design of a variety of wooden products
3. The product must enable combining all industry-standard end-grain dimensions. The product must enable the use of material that is inconsistent in its dimensions
4. The product must be usable with all the sizes Buurman standardizes
5. The product must enable the connection of wooden elements with little effort
6. The use of the product must not damage the wood
7. The product must be usable by people who are not educated in carpentry

Re-use
1. The product must be re-usable
2. The product should enable the re-use of the wooden elements

3. Production
1. The product should be produced with as little material as possible
Figure 16: Three examples of combinations of different wooden elements with different end-grain dimensions

Figure 17: Example of three elements that belong to the same batch of end-grain dimensions, but vary slightly in thickness
7.2 THE CONNECTION ELEMENTS

7.2.1 Introduction

Based on the list of requirements (page 70) a set of nine connection elements was developed, together with a gauge that can be used to simplify the use of these elements. Combined, the connection elements and the gauge form a system that can be used to design and build wooden objects.

7.2.2 The Principle

The connection elements are metal pieces with threaded holes that enable the connection between different wooden elements. They are used in the following order:

1. The desired wooden elements are collected and their orientation with regards to the connection element is defined. (A, B & C)
2. After the wooden elements are correctly orientated, holes are drilled in the wooden elements that align with the threaded holes in the connection elements. (D)
3. Bolts are placed through the holes and screwed in the threaded holes of connection elements (E & F).

The idea of the system will be explained by means of the most important connection element of the set (figure 18). This will merely show the principle and will not show how the connection elements are used in practice. This information can be found in the section: Context (page 92) and in the section: Justification (page 90).
Figure 20: (A) Orientation (B) Holes positioning (C) Bolt placement (D) Securing the bolts
Varying end-grain dimensions
As is explained on the previous page, the holes in the wooden elements need to align with the holes in the connection elements. In figure 21, a wooden element with a thickness of 22 mm (A) is replaced by an element with a thickness of 10 mm. As can be seen, the connection element enables the use of different thicknesses, because it is placed on the inside. However, the change in thickness of element A, does also change the alignment of the holes in the connection element with regards to the holes of element B.

In other words, the orientation of the holes in the wooden elements, depends on which end-grain dimensions are combined. The section on page 88 shows how the process of defining these holes, is simplified by means of a measuring gauge.

Inconsistent dimensions (small variations)
As can be seen in figure 22, the holes that are drilled are 4 mm larger in diameter than size of the bolts. This is done so the small deviations of the material can be corrected.

The location and the grid
As can be seen in figure 23, the distance from the threaded holes in the connection element to the side on which it is bolted, is always at least 15 mm. Because of this, the holes in the wooden elements, are always positioned at least 15 mm from the edge. The holes in the connection elements are ordered in a 15 by 15 mm grid, center to center. This grid is applied to all nine variations. How the dimensions for this grid were developed can be read in chapter 8: Production.

Figure 21: Example of how end-grain sizes define the positioning of the holes in the wooden elements
Figure 22: Margin of the drilled hole in relation to the bolt

Figure 23: The effect of the grid on the wooden elements
7.2.3 The Shape

Figure 24 shows the rudimentary shape, which was the starting point of the development. As can be seen, the rudimentary shape is a solid.

Such a solid shape would require it to be made by means of either milling or die casting, both manufacturing processes that require a large investment and (in the case of milling) produce a lot of excess material. Because of these reasons, the choice was made to manufacture such a shape by means of sheet metal forming. Figure 25 shows how the same shape can be created by means of this production process. Using sheet metal forming has a lot of implications concerning the design of the product. In Chapter 8: Production, these implications will be covered in greater depth, together with the reasoning behind the choice of production process.

Figure 24: Rudimentary shape of connection element A1

Figure 25: How the shape can be made by folding sheet metal
7.2.4 The variations

As previously explained, there are nine different connection elements that together form the system. Although ultimately people can use the connection elements according to their own intermittent, they are intended to be used as follows.

Connection element A1
The first and most important connection element, connects three or more wooden elements in three planes, always perpendicular to each other. The alignment of the length direction of the wooden elements can also be both parallel as perpendicular. Because of its strong structure, this connection element will be primarily used to create the frameworks of objects.

Figure 26: Connection element A1 from different angles

Figure 27: Step by step use of Connection element A1
Connection element A2
The second element is a smaller version of the first one, that can be used for thinner material.

Figure 28: Connection element A2 from different angles

Figure 29: Step by step use of Connection element A2
Connection element A3

This connection element has the same properties as element A1, but connects the wooden elements in a corner of 45 degrees. Because of this smaller angle, one of the sides has a smaller surface area and does not leave enough space for the complete grid to be positioned correctly.

The dimensions of the grid on this side of the connection element are unique (see Appendix V: Technical data package). This should be taken into account during the design and production of products that make use of the connection elements.
Connection element B1
Connection elements B1 is less strong and rigid than the previous elements and can only connect two wooden elements perpendicular to each other. Because of this, the alignment of the wooden elements can also only be perpendicular to each other. It will most likely be used to connected elements on which lesser force is exerted.
Connection element C1

Connection element C1 is the first of three rectangular connection elements. These elements also are less strong and rigid and can only be used to connect wooden elements on which little force is exerted.

This can for example be needed when a framework needs to be sealed of. C1 is able to connect wooden elements in both the same plane as perpendicular to each other. The alignment of the length direction of the wooden elements can also be both perpendicular as parallel.

Figure 33: Connection element C1 from different angles

Figure 34: Step by step use of Connection element C1
Connection element C2
Element C2 has the same properties as C1, but is smaller and can only connect wooden elements perpendicular to each other. The alignment of the length direction of the wooden elements can in effect also only be perpendicular.

Figure 35: Connection element C2 from different angles

Figure 35: Step by step use of Connection element C2
Connection element C3

C3 is the smallest of the C-serie, because of its size it can only connect wooden element perpendicular to each other, with the length direction aligned parallel to each other.

It will most likely serve to connect wooden elements as shown in figure 38.

Figure 37: Connection element C3 from different angles

Figure 38: Step by step use of Connection element C3
Connection element D1
This connection element serves to connect two wooden elements parallel to each other. The alignment of the length direction of the wooden elements can be both perpendicular as parallel.

Figure 39: Connection element D1 from different angles

Figure 40: Step by step use of Connection element D1
Connection element D2
Connection element D2 is practically the same as element D1, only two times its size. It can therefore form either a stronger connection between two wooden elements or can be used to connect four wooden elements.

The alignment of the length direction of the wooden elements can be both parallel as perpendicular.

Figure 41: Connection element D2 from different angles

Figure 42: Step by step use of Connection element D2
In addition to the connection elements and the gauge, a list of rules was developed that aims to simplify the process of designing products with the connection elements.

Three requirement were important in the development of this guide. These are stated as follows:

1. The product must enable combining all industry-standard end-grain dimensions
2. The product must enable the design of a variety of wooden products
3. The product must be usable with all the sizes Buurman standardizes

Separate from each other, these requirements are easily, but when you combine them, they become challenging. Ideally, the designed objects would exclusively incorporate: wooden elements, with lengths standardized by Buurman in all industry standard sizes of end-grain. Unfortunately, this gives rise to the following problems:

**Challenge one**
When the end-grains of two wooden elements with equal length are not aligned, one of the two elements extends the other by the material thickness of the element perpendicular to it (figure 43 A).

**Solution one**
This can be solved by aligning the end-grain of these wooden elements (figure 43 B).

**Challenge two**
Unfortunately this will create another problem. When a framework needs to be sealed of, this can be done as shown in figure C. However, when this is repeated, the element does not match the length of the element perpendicular to it, because the length is not a multitude of the width (figure 44, D). The width of a wooden element not being a multitude of the length of the element perpendicular to it, is a recurring problem. After all, the system is designed to fit all industry-sizes of end-grain. These sizes simply cannot all be multitudes of the lengths standardized by Buurman.

**Solution two**
This problem can be solved by choosing elements from which the lengths are multitudes of the width. Although the two problems can easily be solved, the solutions limits the possibilities for design.

With this in mind, the following rules were devised to guide the design process.

- For length direction use standard sizes
- For width directions, use custom sizes
- Use wide elements
- Use as little connection elements as possible
- Use as little bolts as possible
Figure 43: (A) Problem one (B) Solution one

Figure 43: (C) Problem two (D) Solution two
7.3 THE GAUGE

7.3.1 The Principle

As mentioned in the introduction of the connection elements, the system also includes a gauge that can be used to simplify the use of the connection elements. The function of the gauge is primarily to define the location of the holes that need to be drilled in the wooden elements.

As already mentioned in the explanation of the connection elements, the location of the holes is determined by the orientation of the wooden elements with regards to each other and the thicknesses of these elements (figure ). If the user would have to define the location of the holes manually, this would require too much effort and one of the most fundamental requirements would not be met (requirement function : 5).

The gauge works as follow

1. The orientation of the wooden elements with regard to each other and to the connection element is defined (E, F)
2. The ruler on the gauge shows all the standard industry sizes and is set at the correct distance for both directions. (I, J, )
3. The handles on the gauge include pointers that allow for precise adjustment. (C, D)
4. The gauge is placed against the corner of the wooden elements (A, B, G, H, I)
5. The grid is used to mark the with holes that need to be drilled
6. The holes are drilled in the wooden element
7. This is repeated for all wooden elements
8. When holes need to be located that are not on a corner, the extra stop on the gauge can be used (K, L)
9. The ruler can be used to define the correct distance in one direction along the edge of the timber (K)
### 7.3.2 Justification

A question that can be asked concerning the proposed system is: Why not use conventional connection methods? These will save the material of the connection elements and are probably cheaper. Although that might be true, there are a couple of reasons why this system is superior to conventional methods. In order of importance:

#### Applicable for all dimensions of timber

The proposed system can be used in combination with timber of all dimensions. This makes it easier to collect the timber needed for a certain circulation of production (the implications of using timber with varying dimensions for a production circulation can be read in Chapter 9: Marketing). It also simplifies the design process, because it gives the designer one uniform way of connecting elements together.

#### Downside of conventional connection methods

When using conventional connection methods, it is more difficult to combine materials with different end-grain dimensions (intentional or because of deviations), because there is no uniform way of connecting different elements. This makes it much more complex. Thinner material, for example, cannot be connected end-grain to face-grain by means of screws.

#### Production line

In the proposed system, all the manufacturing steps in the process can be executed separately for each wooden element. Simple notations in the construction manual can show how and where each element should be adjusted. Since the system can correct small deviations from the standard size, adjacent elements do not need to be present, when the exact locations of the holes are defined.

This enables Buurman to incorporate an efficient and systematic approach in which the timber can be processed per circulation of products. Such an approach also enables them to store their material, ready to be assembled.

#### Downside of conventional connection methods

In principle, a production line, as stated in the previous paragraph, can also be established with conventional connection elements, like screws. It is just more complex, because of how the elements are connected. Instead of connecting them to a shared connection element, they need to be connected to each other. This means, that for each operation the other wooden elements is needed, because the holes need to align perfectly.

#### Assembly and disassembly

The products that are produced by means of the connection elements and the gauge, are easy to assemble and disassemble. This is not only beneficial for the production line, but also for the people who buy the products. It enables them to easily transport the products, assemble them at home and disassemble them when they need to move them again.

#### Suitable for layman

The proposed system is intended to be appropriate for everyone who does not have a background in carpentry or is not handy in general. The only skill involved, is being able to drill and to read the assembly instructions. Because it is intended to be so easy in use, the threshold of building with used timber, possibly will go down. In effect used timber might become more interesting for a wider audience. The simplicity of the system also makes it suitable for an initiative such as the BouwAkademie.

#### Downside of conventional connection methods

When using conventional methods, screws for example, holes need to be pre-drilled in preparation of screwing them together. The small holes that are pre-drilled need to align perfectly. This makes it much more difficult for a layman to build an object.

#### Aesthetic characteristics

The proposed system differs in aesthetics from conventional connection elements and although aesthetics are always subjective, a comparison is appropriate. The connection element themselves are not of high aesthetic quality, but since these are mostly on the inside of an object, this has little effect on the overall aesthetics. The outside however, will always show the bolts in the same pattern, a characteristic of the system that (in the eyes of its creator) is of much higher aesthetic quality than a pattern of screws.
7.4 CONTEXT

7.4.1 Current situation

Buurman’s business model entails different elements (see business model canvas in Chapter 3: Internal analysis). Each element offers a different route, through which the building material reaches the customer. Figure 50 shows this process, from collection to use, its current situation.

Phase 1: Material source and collection
Phase 1 shows how the materials get from the source to the material market. They get transported, sorted and processed by both Buurman and BouwAkademie employees. Once at the material market, they are sold as building material or are used by Buurman.

Phase 2: Use by Buurman
In phase 2, the materials are assigned to a certain branch of Buurman. This can mean that the material:

- Will be used in a course or workshop
- Will be used in the manufacturing of Furniture or other products (BuurmanBouwt)

In this phase the production plans are made and workshops plans are developed.

Phase 3: Production and sales
In the third phase, the material is applied in the manufacturing of products (with or without the help of third parties and the BouwAkademie) or by participants in carpentry workshops and courses. The BouwAkademie helps in the manufacturing of the products.

Phase 4: Use by customers
In the final phase the destination of the material or product can be seen. Here, either the public sector:

- Builds products (with or without renting a workbench)
- Directly uses the products bought at Buurman (with or without renting a workbench)

Or the trade sector:

- Manufactures products
- Directly uses the products bought at Buurman
Figure 50: Current business structure of Buurman based on the material stream
7.4.2 Context of future use

Production and workshops
Figure 51 show how the process will change in phase one two and three, when the proposed system is implemented. On the next page the change that apply to phase four can be found.

The most important change in, are those of product development, production and sales. Section 1 does not change with respect to the current process.

Phase 1: Material source and collection
This phase shows what happens to the material before it reaches the material market.

Phase 2: Use by Buurman
This phase shows which branch of Buurman is going to use the material, if it is not directly sold as building material. At this level, the products are designed. This includes a production plan that shows the step by step instructions for the proposed system, aimed at employees of the BouwAkademie.

The courses and workshops are also ‘designed’ at this level. This includes the design of the manuals for the use of the proposed system in the courses and workshops.

Phase 3: Production and sales
In this phase, the manufacturing process at the BouwAkademie begins, based on the production plan. This can be done by means of conventional production methods (this process will not be discussed here), or by means of the proposed system.

The latter starts by collecting all the material for one circulation of production. After the material is collected, the elements that need to deviate from the lengths standardized by Buurman, get sawed into the correct lengths. Next, stacks of material are made that comprise the material needed for one product (A).

Next, a BouwAkademie employee uses the gauge to mark where on each wooden element, the holes should be drilled (B). Because it is likely that the timber for each production circulation, will comprise a limited amount of different end-grain sizes, simple non adjustable gauges will be used. Figure 52 shows an example of such an non adjustable gauge. Subsequently, the holes are drilled on the market positions (C). All of this will be done according to the production plan that was developed in phase two.

In the next step there are two options. Either the timber for one product, will be collected and packaged with the required connection elements, bolts and assembly manual (E). Or a BouwAkademie employee will assemble the product according to the production plan (D). Finally, the products/Do-It-Yourself packages are sold and either collected or delivered.

Workshops and courses
Workshops and courses will essentially be the same as they are now. The only difference will be the possible addition of the proposed system during the course. This will require the instructors to explain the use of the system. The participants of the course/workshop will use the system as explained previously.

![Figure 52: Simplified gauge](image)
Figure 51: Potential structure of Buurman based on the material stream and the proposed system.
Use by public and trade sector
The proposed system also gives rise to a new way of building for the customers themselves. The change in process (phase four) can be seen in figure 53.

Phase 4: Use by customers
The material, products and Do-it-yourself packages are sold to either the public sector or the trade sector. Both can either: Use the already finished products or manufacture products themselves. In the last case three options are possible.

- The products are assembled from a Do-it-yourself package, using the connection elements from the proposed system
- The products are manufactured with the bought material and the connection elements from the proposed system.
- The products are manufactured with the bought material using conventional production methods.

In the case of the public sector there is also the option for them to rent a working bench for the manufacturing.
Figure 53: Potential structure of Buurman based on the material stream and the proposed system
7.5 CONCLUSIONS AND RECOMMENDATIONS

The requirements
When looking concept, it can be concluded that the following requirements are met:

Function
1. The product must enable the connection between different wooden elements
2. The product must enable the design of a variety of wooden products
3. The product must enable combining all industry-standard end-grain dimensions
4. The product must enable the use of material that is inconsistent in it dimensions
5. The product must be usable with all the sizes Buurman standardizes

Re-use
1. The product must enable re-use of the product

Determining the applications
Although, the system is able to combine all industry standard sizes of end-grain, in some situations conventional connection methods are more logical to be used. For what kind of applications the system is most suited, is something that needs to be find out in process of product development.

Use in practice vs. on paper
On paper, the system is able to combine all industry standard sizes of end-grain. In practice however, certain combinations will be made much more than others, because certain sizes of end-grain are simply much more available for Buurman than others. In production, the gauge will therefore be replaced by tools that are much simpler and cannot be adjusted. Figure 54 shows four of those tools. Each tool can be used for a certain combination of end-grain sizes.

Recommendations
There are a couple of things that have to be considered.

Amount of variations
The system currently comprises of nine variations. During the development of products that make use of the system, it should be assessed if additional connection elements are needed, or if certain elements are redundant.

Development of simplified gauge system.
Because each combination of end-grain sizes needs four different simplified gauges (Fig. 52). It is necessary to develop a system that can be used in both product development and production.

Simplifying production
Currently the idea is, that the position of the holes are marked by means of the simplified gauges and then are drilled. If the system is further developed, it is recommended that the step of marking the position of the holes, is taken out of process and the holes are drilled directly. For this to be possible, a method has to be developed in which the proposed system is combined with a pillar drill.

Gauge with friction
Currently, the complex gauge can be adjusted by unscrewing the handles. This makes adjusting it time consuming. If the system is further developed, it is advised to develop a gauge which is fixed by means of friction. This gauge can than be used for unusual combinations of end-grain.
Figure 54: collection of four simplified gauges for the combination of 22 mm thickness with 22 mm thickness
PART 3 EMBODIMENT
In the following chapter, the production process of the connection elements will be discussed. The production of the gauge is not included in this chapter because it initially will not be produced with a commercial purpose. Because the production is of significant influence on the design of the connection elements, the chapter discusses how each production element has influenced the design of the product. This includes: the bolts, production choice, production steps and material choice. The chapter is concluded with an overview of the production costs.
8.1 PRODUCTION

8.1.1 Bolts

The choice to manufacture the connection elements by means of sheet metal forming has significant implications for the design. This chapter will elaborate on the production choice and will show how it influenced the design of the connection elements. Because the gauge will not be produced for a commercial purpose, this will not be discussed.

The thickness of the bolt was the starting point for the design iteration based on the production process. Table 11 shows the tensile loads and proof loads for the different bolt diameters. Based on this information, the following was calculated:

A D=4 mm bolt (property class 5,6) has a minimum tensile load of 4390 N and a proof load of 2460 N with a nominal stress area of $0,88 \times 10^{-5}$ m. The tensile strength of the M4 bolt from table 10 therefore is $500 \times 10^6$ N/m$^2$.

![Figure 55: Index for the dimensions of a thread ("ISO 68:1973", 2017)](image)

![Figure 55: Index for the dimensions of a thread ("ISO 68:1973", 2017)](image)

![Table 10: Dimensions for a M3,5 M4 an and M5 bolt ("ISO 68:1973", 2017)](table)

![Table 11: Tensile loads and Proof loads for M3,5 M4 and M5 Bolts ("Metric Multistandard Components Corp.", 2017)](table)

The stress area (halve of a cylinder) is calculated for a length of 22 mm with:

$$A = \frac{2\pi \cdot r \cdot h + 2\pi \cdot r \cdot h^2}{2}$$

The stress area (halve of a cylinder) is calculated for a length of 22 mm with: With a stress area of 38 mm$^2$, the proof load becomes 6164 N. This amounts to 1086 kg of force. Since the Shear capabilities of bolts that smaller than 5mm are bigger than the tensile capabilities (“Grade 5 vs Grade 8 Fasteners - TineLok”, 2017), a bolt of 4 mm is strong enough to endure forces up to 6164 N in both direction. This is about 10 times the force an average person can push (Shigley, 2006).

Because the connection elements make use of a grid and multiple bolts are used in one wooden element, it is assumed that the bolts together are strong enough to withstand proper and improper use. Moreover, it is likely that the wooden elements will give in before the bolts do.

Figure 55 and table 10 show the dimensions of a M3,5, M4 and M4,5 Bolt

![Table 10: Dimensions for a M3,5 M4 an and M5 bolt ("ISO 68:1973", 2017)](table)

![Table 11: Tensile loads and Proof loads for M3,5 M4 and M5 Bolts ("Metric Multistandard Components Corp.", 2017)](table)
8.1.2 Grid

The grid that was used in each connection element (see figure 56) places the holes 15 mm from center to center. These dimensions were based on the rules that should be taken into account when defining a grid for a wooden element (United States Department of Agriculture, 2010):

Minimum spacing, parallel to grain: 3.5 \times\text{diameter of the bolt}

Minimum spacing, perpendicular to grain: 3 \times\text{diameter of the bolt}

Because a symmetrical grid was required, the spacing was chosen to be 3.5 \times\text{diameter of the bolt}. This resulted in a spacing of 14 mm, which was rounded to 15 mm.

The placement of the grid in each connection element, defined the placement of the grid on the wooden elements (figure 57). For this reason, the minimum edge distance for the holes in timber needed to be defined. This was based on the following rules:

Minimum edge distance parallel to grain: 1.5 \times\text{the diameter of the bolt}.

Minimum edge distance perpendicular to grain: 3.5 \times\text{the diameter of the bolt}.

Again this resulted in a distance of 14 mm, which was rounded to 15 mm.
8.1.3 Production method

As mentioned in the concept chapter, the chosen shapes would require them to be made by means of milling, die casting or sheet metal forming.

Table 12, 13 and 14 show the typical and feasible capabilities of these production processes. From the first (shape) and third row (materials) was deducted that all three production processes are suitable for the shapes that needs to be manufactured. Concerning surface finish, tolerance and max wall thickness the three production processes are also equally suitable because all three are capable of much more than is required.

The advantages of sheet metal forming became evident when the quantity, advantages and disadvantages were compared. Quantities for die casting start at 10000 pieces and ask for a large investment because of the high tooling and equipment costs. Furthermore, the advantages of die casting are almost all irrelevant for this application. Die casting is therefore the least suited.

The possible quantities concerning milling are suited for this application, but again high equipment cost make it unsuitable for the production of the connection elements. Moreover, milling also produces a lot of scrap.

Ultimately sheet metal forming is the most suitable because of its possibilities concerning quantity and relatively low investment costs. A few side notes have to be given here:

- At first, the flat patterns of the connection elements need to be lasered. This will decrease the quantity of 1000 - 100000 to 1 - 1000 and enable test phase production.
- When the system turns out successful, the flat patterns can be cut out by means of punching. This will require a higher investment.
- Because of the shapes and the nesting capabilities of the connection elements, the scrap is limited with sheet metal forming.

<table>
<thead>
<tr>
<th>Shapes</th>
<th>Typical</th>
<th>Feasible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid: Complex</td>
<td>Thin-walled: Cylindrical</td>
<td>Flat</td>
</tr>
<tr>
<td>Solid: Cubic</td>
<td>Thin-walled: Cubic</td>
<td>Thin-walled: Cubic</td>
</tr>
<tr>
<td>Solid: Complex</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Materials</th>
<th>Metal</th>
<th>Copper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metals</td>
<td>Aluminum</td>
<td></td>
</tr>
<tr>
<td>Lead</td>
<td>Magnesium</td>
<td></td>
</tr>
<tr>
<td>Zinc</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Part size:</th>
<th>Weight: 0.5 oz - 500 lb</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface finish - Ra:</td>
<td>32 - 63 μin</td>
<td>16 - 125 μin</td>
</tr>
<tr>
<td>Tolerance:</td>
<td>± 0.015 in.</td>
<td>± 0.0005 in.</td>
</tr>
<tr>
<td>Max wall thickness:</td>
<td>0.05 - 0.5 in.</td>
<td>0.015 - 1.5 in.</td>
</tr>
<tr>
<td>Quantity:</td>
<td>10000 - 1000000</td>
<td>1000 - 1000000</td>
</tr>
<tr>
<td>Lead time:</td>
<td>Months</td>
<td>Weeks</td>
</tr>
</tbody>
</table>

| Advantages:     | Can produce large parts |                           |
|                 | Can form complex shapes | High strength parts      |
|                 | Very good surface finish and accuracy | High production rate |
|                 | Low labor cost          | Scrap can be recycled    |
| Disadvantages:  | Trimming is required     |                           |
|                 | High tooling and equipment cost | Limited die life       |
|                 | Long lead time           |                           |
| Applications:   | Engine components, pump components, appliance housing | |

Table 12: Characteristics Die casting ("Die Casting Process, Defects, Design", 2017)
### Table 13: Characteristics Milling ("Milling Process, Defects, Equipment", 2017)

<table>
<thead>
<tr>
<th>Typical</th>
<th>Feasible</th>
</tr>
</thead>
</table>
| Shapes  | Solid: Cubic  
          | Solid: Complex |
|         | Flat  
          | Thin-walled: Cylindrical |
|         | Thin-walled: Cubic  
          | Thin-walled: Complex  
          | Solid: Cylindrical |
| Part size: | Length: 0.04 - 72 in  
             | Width: 0.04 - 72 in |
| Materials: | Metals  
              | Alloy Steel  
              | Carbon Steel  
              | Cast Iron  
              | Stainless Steel  
              | Aluminum  
              | Copper  
              | Magnesium  
              | Zinc |
|         | Ceramics  
              | Composites  
              | Lead  
              | Nickel  
              | Tin  
              | Titanium  
              | Elastomer  
              | Thermoplastics  
              | Thermosets |
| Surface finish - Ra: | 32 - 125 μin |
| Tolerance: | ± 0.001 in. |
| Max wall thickness: | 0.04 - 40 in.  
                    | 0.04 - 72 in. |
| Quantity: | 1 - 1000  
            | 1 - 1000000 |
| Lead time: | Days  
             | Hours |
| Advantages: | All materials compatible  
               | Very good tolerances  
               | Short lead times |
| Disadvantages: | Limited shape complexity  
                    | Part may require several operations and machines  
                    | High equipment cost  
                    | Significant tool wear  
                    | Large amount of scrap |
| Applications: | Machine components, engine components |

### Table 14: Characteristics sheet metal forming ("Sheet Metal Fabrication", 2017)

<table>
<thead>
<tr>
<th>Typical</th>
<th>Feasible</th>
</tr>
</thead>
</table>
| Shapes  | Flat  
          | Thin-walled: Cylindrical  
          | Thin-walled: Cubic  
          | Thin-walled: Complex |
| Part size: | Area: Up to 80 ft²  
              | Weight: 0.5 oz - 100 lb |
| Materials: | Metals  
              | Alloy Steel  
              | Carbon Steel  
              | Stainless Steel  
              | Aluminum  
              | Copper  
              | Lead  
              | Magnesium  
              | Nickel  
              | Tin  
              | Titanium  
              | Zinc |
| Surface finish - Ra: | 32 - 125 μin |
| Tolerance: | ± 0.01 in. |
| Max wall thickness: | 0.08 - 0.5 in. |
| Quantity: | 1000 - 100000  
             | 1 - 1000000 |
| Lead time: | Weeks  
             | Hours |
| Advantages: | Can form complex shapes  
               | Many material options  
               | High production rate  
               | Low labor cost  
               | Short lead time possible |
| Disadvantages: | Limited to constant part thickness  
                    | Part may require several operations and machines  
                    | High equipment cost  
                    | Significant tool wear  
                    | Large amount of scrap |
| Applications: | Brackets, panels, cans, utensils |

8.1.4 Flat pattern

Because all the connection elements will be made from sheet metal, the flat patterns of these elements need to be ‘cut’ out of sheet metal plates. As mentioned, this initially will be done by means of laser cutting. In figure 56 till figure 64, the flat patterns of the different variations can be seen. Figure 65 shows an example of how they can be nested.
Figure 63: Flat pattern connection element D1

Figure 64: Flat pattern connection element D2

Figure 65: Example of how Connection element A1 can be nested
8.1.5 Dimpling and threading

**Dimpling**

The holes in the connection elements need to be threaded, but because the material must be as thin as possible (1 mm, see test one in Chapter 8 validation), a problem arises. This problem is solved by a production process called dimpling. This process works as shown in figure 66. (EWI Forming center, 2014)

A piercing punch, punches a hole through the metal and is caught and pulled down by a pressure bushing. This bends the sheet metal and creates a shape as can be seen in figure 64.

The holes that results from this process should be as big as the drill diameter of the required bolt. 3,3 mm in the case of an M4 bolt (see table 10). It creates a cylinder with an inner length of between 2 and 2,5 mm.

**Threading**

The dimpling process creates a shape as shown in figure 67. These dimensions allow for the thread height of 0,4 mm that is needed for a M4 Bolt. The length of the shape allows for a maximum of 3 pitches. (Quality Tool, 2008)

8.1.6 Material

The material that was chosen, is stainless steel AISI 304 (“G-Style S.A., Products”, 2017). This is the most standard metal available at sheet metal forming manufactures.

- It is relatively inexpensive
- Has properties that make it suitable for outside use
- Is very suited for forming, laser cutting and punching

More detailed information can be found in Appendix R: Technical material specifications

8.1.7 Bend Radius

Concerning the bend radius, the following rule was applied:

\[ R \geq \text{Material thickness} \]

When a bend radius is smaller than thickness of the material, this can cause the metal to fracture. The bend radius that was applied in the connection elements, is therefore 1 mm or 1,5 mm (depending on the connection elements) (Quality Tool, 2008).

![Image of dimpling process](image1)

![Image of shape of sheet metal after dimpling](image2)

![Image of side view connection element A1 with bend radius 1 mm](image3)

![Image of side view connection element C1 with bend radius 1,5 mm](image4)
8.1.8 Bend Relief

When a bend is too close to the edge of the sheet metal (A, Figure 70) this can cause the metal to tear. In such a case, a bend relief should be cut into the material (C). Such a bend relief will not be necessary in the case of the connection because of the appropriate distance to the edge (B). (Quality Tool, 2008)

![Figure 70](image)

8.1.9 Forming Near Holes

Placing a hole too close to a bend, can cause the hole to deform into a teardrop shape. To prevent such deformation the holes should be placed at a proper distance from the bends. The following formula was used to calculate the minimum distance required:

\[
\text{Minimum distance} = 2 \cdot \text{Material thickness} + \text{Bend radius}
\]

For the connection elements with a material thickness of 1 mm the minimum distance is 3 mm.

For the connection elements with a material thickness of 1.5 mm the minimum distance is 4 mm.

In the connection elements the holes are at a distance of 12.4 mm (1 mm thickness) or 11.9 mm (1.5 mm thickness) from the bend, well over the minimum distance. (Quality Tool, 2008)

![Figure 71](image)
8.1.10 Form height to thickness ratio

When bending sheet metal, a minimum bending height is necessary to prevent the need for extra production steps. To determine the minimum form height for sheet metal (figure 71 and figure 74), the following formula was used:

\[ \text{Minimum distance} = 2.5 \cdot \text{Material thickness} + \text{Bend radius} \]

For the connection elements with a material thickness of 1 mm the minimum distance is 3.5 mm (figure 74).

For the connection elements with a material thickness of 1.5 mm the minimum distance is 5.25 mm.

Figure 71: Minimum distance for form height

For the 45 degrees connection element (figure 75) it is not possible, at one of the two overlapping bends, to achieve this minimum distance (C). The top one of these bends, preferably needs a notch to prevent an unwanted deformation. Unfortunately there is no space to integrate such a notch (figure 72), and because the shape of this bend is not of influence on the performance of the connection element, such a notch is not applied.

Figure 72: Example of a notch

8.1.11 Edge Distortion

When bending sheet metal, edge deformation can occur that results in an overhang (as shown in figure 73 A). Relief cuts, as shown in figure 73 B, can prevent such a deformation. In the case of the connection elements, this overhang is very limited, such relief cuts are therefore not necessary.

Figure 73: (A) Exaggerated example of deformation because of bending (B) Prevention measure by means of relief cuts

Figure 74: Form height in connection element A1

Figure 75 Form height in connection element A3
8.1.12 Folding steps

In the final production step the connection elements are folded. These folding steps are shown for connection element A1 in figure 77. The folding steps for the other connection elements speak for themselves.

Although the Folding process could be done by the company that also manufactures the flat patterns, there is no reason why this could not be done by the BouwAkademie. The foldings steps are easy and it only requires Buurman to purchase a small sheet metal forming tool (see figure 76).

Figure 76: Manual sheet metal bending tool

Figure 77: Folding steps connection element A1
8.1.12 Production costs

Initially the flat patterns of the connection elements will be manufactured by means of laser cutting. The costs for this process are estimated on a quotation by the company 247 Tailorsteel. The costs per connection element vary between 0,39 euro and 1,03 euro. 100 pieces per connection element. An additional 20 cent per part is assumed for the dimpling process (ETM manufacturing, 2013).

Table 14 shows what the production costs are going to be for connection element A1, when the flat pattern is manufactured by means of punching (Dallan, 2005) (“Stainless Steel metal prices, news, charts and historical prices.”, 2017). The production costs for the other elements are calculated the same way (see Appendix S: Costs and prices) and amount to the following:

It also requires an initial investment of 500 euro per connection element. (Dallan, 2005)

<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity</th>
<th>Reference Price (5/30/2017)</th>
<th>Selected price (5/30/2017)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Joint 1 - One tangerine (element in t.)</td>
<td>100</td>
<td>€ 0.03</td>
<td>€ 0.05</td>
</tr>
<tr>
<td>2. Joint 2 - One tangerine (element in t. 4.4)</td>
<td>100</td>
<td>€ 1.03</td>
<td>€ 1.03</td>
</tr>
<tr>
<td>3. Joint 3 - One tangerine (element in t. 4.5)</td>
<td>100</td>
<td>€ 0.56</td>
<td>€ 0.56</td>
</tr>
<tr>
<td>4. Joint 4 - One tangerine (element in t. 4.6)</td>
<td>100</td>
<td>€ 0.86</td>
<td>€ 0.86</td>
</tr>
<tr>
<td>5. Joint 5 - One tangerine (element in t. 4.7)</td>
<td>100</td>
<td>€ 0.63</td>
<td>€ 0.63</td>
</tr>
<tr>
<td>6. Joint 6 - One tangerine (element in t. 4.8)</td>
<td>100</td>
<td>€ 0.57</td>
<td>€ 0.57</td>
</tr>
<tr>
<td>7. Joint 7 - One tangerine (element in t. 4.9)</td>
<td>100</td>
<td>€ 0.93</td>
<td>€ 0.93</td>
</tr>
<tr>
<td>8. Joint 8 - One tangerine (element in t. 4.10)</td>
<td>100</td>
<td>€ 0.37</td>
<td>€ 0.37</td>
</tr>
<tr>
<td>9. Joint 9 - One tangerine (element in t. 4.11)</td>
<td>100</td>
<td>€ 0.07</td>
<td>€ 0.07</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Description</th>
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<th>Reference Price (5/30/2017)</th>
<th>Selected price (5/30/2017)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine 1: Punching</td>
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<td>€ 60.00</td>
</tr>
<tr>
<td>Machine 2: Dimpling</td>
<td>1000</td>
<td>€ 0.50</td>
<td>€ 60.00</td>
</tr>
<tr>
<td>Total Material costs</td>
<td></td>
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<td>€ 0.12</td>
</tr>
<tr>
<td>Machinic costs</td>
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<tr>
<td>Cost of labour</td>
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<tr>
<td>Total labour costs</td>
<td></td>
<td>€ 156.00</td>
<td>€ 5.13</td>
</tr>
<tr>
<td>Total processing costs</td>
<td></td>
<td>€ 126.00</td>
<td></td>
</tr>
</tbody>
</table>
CHAPTER 9 MARKETING

The connection elements and the gauge serve as tools that help in the development, production and use of wooden products; it is not their primary purpose to be directly sold to the public. Concerning marketing, this thesis will therefore mainly focus on the products in which the connection elements are applied. In the following chapter the marketing plan for these products is discussed. This is done this by means of the marketing mix (Kotler, & Armstrong, 2005), this includes the marketing aspect of the Product, Promotion, Price and Place of the system. The chapter is concluded with conclusion and recommendation concerning these subjects.
9.1 MARKETING MIX (PPPP)

9.1.1 B to B and B to C

At the start of this thesis the following question was asked:

‘How can companies that collect, refurbish, re-use and sell used building materials, grow?’

If the products, developed with the connection elements, are the answer to this question (see Chapter 11: Conclusion), and Buurman can indeed increase their sales to this industry, this will require Buurman to increase their business to business marketing. However, the success of the products still completely depends on the attitude towards used timber from the construction industry. As discussed in Chapter 4: Literature review and Chapter 5.2: Study two, the conservative attitude of the construction industry is a deeply rooted phenomenon. Strong product design, consistent quality and the ability to deliver the required quantities might not be convincing enough to win from the stigma that is associated with used timber. Exclusively focusing the marketing on business to business sales would therefore not be smart. For this reason, this chapter, will focus on Business to consumer marketing.

The marketing of the products that are developed with the system will be described by means of the marketing mix (Kotler, & Armstrong, 2005). This is a tool that combines four elements (Product, Promotion, Price and Place) to determine the marketing strategy.

9.1.2 Product

An important question to ask is:

What is the buyer really buying?

This question is answered through the following sub categories:

Quality

The customers know that they are buying products that are made of used timber. For this reason, they will not have the same expectations of the products as they would, when they would buy new products. Nevertheless, there should be a consistent minimum level of quality throughout all the products. That being said, there should also be an acceptable margin for deviations in both quality and dimensions, because of the inconsistency of the material. This margin should be clearly defined by Buurman and communicated to the customers.

Design

As previously mentioned, the system does not claim to be the best solutions, for all applications. Products that are developed should not exclusively be made by means of the connection elements and the gauge, if other methods are better suited. Buurman should find out which applications work best for the system. This will force Buurman to create products that vary in shape, size and production method. As suggested in the previous paragraph, the aesthetics of these products are limited to the quality of the timber. This ‘rough’ look and feel should be iconic for the products and a feature that is exploited.

Two other features that should be exploited, are the fact that the products are easy to assemble and disassemble. This enables Buurman to create DIY building kits. When buying DIY kits, customers do not need to:

• Own a cordless drill
• Pre-drill the holes
• Be handy with tools
9.1.3 Promotion

When defining a plan for the promotion of a product, it is important to identify the target audience. In the case of the products that will be made by means of the connection elements, the target audience broadens with regards to Buurman’s current target groups (see Appendix B: Personas). The use of the connection elements eliminate the need for DIY skills, which makes the products attractive for a bigger audience.

Fig. 78 shows an overview of how information travels from the company to the consumer to the public and back. In Buurman’s case the step of intermediaries is skipped, because Buurman initially will be the only enterprise that sells their products. Promotion will be done through the same channels as through which Buurman currently promotes their products and services.

Advertising and Promotions
Advertising will be done through:

- Local advertising
- Social media
- A stand-alone Buurman product website

Promotions will be done through local initiatives like the Rotterdampas

Personal selling
Personal selling is an important way for Buurman to sell their products because it involves personal attention to the customer. This is especially important to Buurman, because this helps to get across the story behind their company, a feature of Buurman which makes it very attractive to a lot of people. It is important that this story also is included in the branding of the products. Information that indicates from where the material originates, could be an option for this.

Brand name
Buurman is currently in the process of developing the brand for their product line. A choice has yet to be made concerning the brand name. The product line can either be developed under the Buurman brand or as an independent one. Both have their advantages, but because of Buurman’s already established name and the strength of its name in general, the choice was made to brand the products under the original brand name: Buurman.

Packaging
Being able to easily assembly and disassemble the products, is an important feature because it creates the possibility of DIY building packages. These packages can be stored and transported easily, but also require some form of packages. Because sizes of DIY kits will vary, a universal way of packaging is needed. This can be done by means of a simple piece of textile on which the instructions for the specific product printed.

Service
A final addition to the product brand, is the option for customers to buy replacement parts when a wooden element breaks. Because of the DIY packages system, these spare parts can be made and stored easily.

Figure 78: Distribution of information through promotion
9.1.4 Price

The prices for the individual products will depend on four factors:

- The amount of timber that is used
- The kind of timber that is used
- The production time (complexity of the product)
- The amount of connection elements that are used

The first three factors vary per product. For the last factor, the connection elements, two costs and price calculations were made.

As previously mentioned, the connection elements will initially be used by the Buurman to produce products with. In that scenario, the flat patterns will be manufactured by means of laser-cutting.

Table 16 shows the costs and prices for connection element A1. The prices for other connection elements are calculated likewise and are shown in table 17 till table 24.

As can be seen in table 16, the margin for intermediate trade and the margin for the retail store are not taken into account, because it is assumed that the elements that are produced by means of laser-cutting, will never be sold to retailers.

The following numbers are of importance:

Production cost price
This is an estimate of the production cost per element, based on the laser costs of the prototypes.

Sales price
This is the advised price that should be added to the price of the product in which the element is used.

Advised selling price
This is the price that should be used when a connection element is sold in the material market.

<table>
<thead>
<tr>
<th>Table 16: Production cost price, sales price, advised selling price for connection element A1. When produced by means of laser cutting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production cost price assembled product for internal calculation</td>
</tr>
<tr>
<td>Overhead factor for general company costs</td>
</tr>
<tr>
<td>Overhead factor for sales costs</td>
</tr>
<tr>
<td>Profit factor</td>
</tr>
<tr>
<td>Total factor = product of (each of these factors+1) min 1</td>
</tr>
<tr>
<td>Sales price</td>
</tr>
<tr>
<td>Margin intermediate trade</td>
</tr>
<tr>
<td>Wholesale selling price</td>
</tr>
<tr>
<td>Margin retail store</td>
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<tr>
<td>Netto Selling price (excluding sales tax)</td>
</tr>
<tr>
<td>Sales tax</td>
</tr>
<tr>
<td>Advice selling price</td>
</tr>
<tr>
<td>Connection element A1</td>
</tr>
<tr>
<td>15%</td>
</tr>
<tr>
<td>5%</td>
</tr>
<tr>
<td>40%</td>
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<table>
<thead>
<tr>
<th>Table 17: Production cost price, sales price, advised selling price for connection element A2. When produced by means of laser cutting</th>
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</thead>
<tbody>
<tr>
<td>Production cost price assembled product for internal calculation</td>
</tr>
<tr>
<td>Sales price</td>
</tr>
<tr>
<td>Advice selling price</td>
</tr>
<tr>
<td>Connection element A2</td>
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<td>€ 1,88</td>
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<tr>
<td>€ 2,23</td>
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</thead>
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<td>Production cost price assembled product for internal calculation</td>
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<tr>
<td>€ 1,88</td>
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<thead>
<tr>
<th>Table 19: Production cost price, sales price, advised selling price for connection element B1. When produced by means of laser cutting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production cost price assembled product for internal calculation</td>
</tr>
<tr>
<td>Sales price</td>
</tr>
<tr>
<td>Advice selling price</td>
</tr>
<tr>
<td>Connection element B1</td>
</tr>
<tr>
<td>€ 1,80</td>
</tr>
<tr>
<td>€ 3,95</td>
</tr>
</tbody>
</table>
If the system turns out to be successful, the choice can be made to manufacture bigger quantities. As explained in the Part 3: Embodiment, the connection elements in that case, will be manufactured by means of sheet metal punching. Table 25 show the costs and prices for connection element A1. Because of the production process, the prices of the other elements are similar and only vary a couple of cents. These can be found in Appendix S: Costs and prices.

As can be seen, the margin for intermediate trade and the margin for the retail store are taken into account here. When the connection elements are manufactured by means of sheet metal punching, the price per product goes down and sales on a bigger scale become feasible.

The following numbers are of importance:

**Production cost price**
This is the cost price of the production process as calculated in Chapter 8: Production

**Sales price**
This is the advised price that should be added to the price of the product in which the element is used. It is also the price that should be used when a connection element is sold in the material market.

**Wholesale selling price**
This is the price for which the wholesaler will sell the product

**Advised selling price**
This is the price for which the retailer will sell the product

### Table 21: Production cost price, sales price, advised selling price for connection element C2. When produced by means of laser cutting

<table>
<thead>
<tr>
<th>Production cost price assembled product for internal calculation</th>
<th>Connection element C1</th>
<th>€ 1,00</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sales price</strong></td>
<td></td>
<td>€ 1,69</td>
</tr>
<tr>
<td><strong>Advice selling price</strong></td>
<td></td>
<td>€ 2,01</td>
</tr>
</tbody>
</table>

### Table 22: Production cost price, sales price, advised selling price for connection element C3. When produced by means of laser cutting

<table>
<thead>
<tr>
<th>Production cost price assembled product for internal calculation</th>
<th>Connection element C3</th>
<th>€ 0,59</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sales price</strong></td>
<td></td>
<td>€ 1,00</td>
</tr>
<tr>
<td><strong>Advice selling price</strong></td>
<td></td>
<td>€ 1,19</td>
</tr>
</tbody>
</table>

### Table 23: Production cost price, sales price, advised selling price for connection element D1. When produced by means of laser cutting

<table>
<thead>
<tr>
<th>Production cost price assembled product for internal calculation</th>
<th>Connection element D1</th>
<th>€ 0,77</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sales price</strong></td>
<td></td>
<td>€ 1,30</td>
</tr>
<tr>
<td><strong>Advice selling price</strong></td>
<td></td>
<td>€ 1,55</td>
</tr>
</tbody>
</table>

### Table 24: Production cost price, sales price, advised selling price for connection element D2. When produced by means of laser cutting

<table>
<thead>
<tr>
<th>Production cost price assembled product for internal calculation</th>
<th>Connection element D2</th>
<th>€ 1,13</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sales price</strong></td>
<td></td>
<td>€ 1,91</td>
</tr>
<tr>
<td><strong>Advice selling price</strong></td>
<td></td>
<td>€ 2,27</td>
</tr>
</tbody>
</table>

### Table 25: Production cost price, sales price, wholesale selling price advised selling price for connection element A1. When produced by means of punching

<table>
<thead>
<tr>
<th>Production cost price assembled product for internal calculation</th>
<th><strong>Connection element A</strong></th>
<th>€ 0,36</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Overheadfactor for general company costs</strong></td>
<td>19%</td>
<td></td>
</tr>
<tr>
<td><strong>Overhead factor for sales costs</strong></td>
<td>5%</td>
<td></td>
</tr>
<tr>
<td><strong>Profit factor</strong></td>
<td>40%</td>
<td></td>
</tr>
<tr>
<td><strong>Totalfactor = product of (each of these factors+1) min 1</strong></td>
<td>69.4%</td>
<td>€ 0.25</td>
</tr>
<tr>
<td><strong>Sales price</strong></td>
<td></td>
<td>€ 0.61</td>
</tr>
<tr>
<td><strong>Margin intermediate trade</strong></td>
<td>30.0%</td>
<td>€ 0.18</td>
</tr>
<tr>
<td><strong>Wholesale selling price</strong></td>
<td></td>
<td>€ 0.79</td>
</tr>
<tr>
<td><strong>Margin retail store</strong></td>
<td>70.0%</td>
<td>€ 0.55</td>
</tr>
<tr>
<td><strong>Netto Selling price (excluding sales tax)</strong></td>
<td></td>
<td>€ 1.24</td>
</tr>
<tr>
<td><strong>Sales tax</strong></td>
<td>19.0%</td>
<td>€ 0.26</td>
</tr>
<tr>
<td><strong>Advice selling price</strong></td>
<td></td>
<td>€ 1.60</td>
</tr>
</tbody>
</table>
9.1.5 Places

Assortments
The product line of Buurman is currently in a premature state. This means that the assortment of products is currently very small. As the products are developed, so will the assortment of products, Buurman offers for sale.

Locations
Currently, Buurman only has one venue through which products can be sold. However, in the foreseeable future, Buurman is possibly going to open new venues in other cities. This will create new channels through which the products can be sold, which will significantly increase Buurman’s reach.

Inventory
Buurman currently has no inventory of their materials and products. If the production of products is going to be increased, such an inventory is going to be necessary. Primarily, because it will enable the people who design the products, to design products based on the available material. An inventory on what kind of products are in stock is also essential, because it will enable Buurman to assess which products to promote.

Such an inventory becomes especially important if more Buurman venues are opened. In such scenario, the people who design the products are able to use the inventories of the different venues. This will stimulate the design of more diverse products and also enables the production of larger quantities.

Transport
Because initially all the products will be sold and produced at Buurman, transport to retailers does not have to be taken into account. Buurman does offer a transport service for their building materials. This transport service can also be used for products, but because of its scale (currently only one car and one driver), is relatively expensive and will therefore only be suited for bigger orders.

9.1.6 The Business Model Canvas

When looking at Buurman’s complete business model (Chapter 3: Internal analysis), no drastic changes are needed to implement the use of the connection elements and the gauge. Only the value proposition and customer segment changes.

Fair products
In Buurman’s current business model, products are primarily sold as finished products. When products are produced by means of the connection elements, this value proposition does not change, but is merely broadened with the addition of simple building kits.

Customer segment
One group of customers will become increasingly important if the production of products increases: the conscious consumer. Although the business model canvas in Chapter 3: Internal analysis does not show this target group yet, it was already identified by Buurman. Currently Buurman does sell finished products that are suitable for this target group, but because the sales of products has not had priority for Buurman, the company has not been very attractive for this target group.
9.1.7 Conclusions

When looking at the proposed marketing implementation plan in combination with the connection elements and the gauge, it can be concluded that it fits within Buurman’s business model. It requires very little changes and can be easily implemented on a small scale.

Because the system is suited for both business to business sales as for business to consumer sales, Buurman is able to test the possibilities for the construction industry, but is not bound to this sector. This is important, because the success in this industry is dependent on something that lays out of Buurman’s control: the industry’s attitude towards used timber. Developing this system initially for the business to consumer marketing is therefore a safe way for Buurman to experiment with it. This will enable them to test its capabilities and to test the options for possible applications.

Buurman is a relatively young company and is still growing. This, among other things, means that a lot things can change concerning how they run their business and how they market their products. These changes will also influence how Buurman is going to develop their product line. This should be taken into account when this implementation plan is considered.

Figure 79: Business model canvas that shows the adjusted value proposition (left) and the adjusted customer segment (right)
CHAPTER 10 VALIDATION

In the validation chapter, the system that is developed will be tested. Because this system consists of multiple elements that are used by multiple target groups, at multiple occasions, not all aspects of it are validated. Two tests will be described. One that focuses on the strength on the connection element itself and one that focuses on the assembly of a product by means of the connection elements. The chapter will describe how the tests were conducted, the results and what can be concluded from those results. The chapter will be concluded with recommendations concerning future use and future validations.
10.1 Test one: material thickness

Introduction and justification
One of the fundamental requirements previously defined is:

The product should be produced with as little material as possible

The thickness of the material is of significant influence on the amount of material that is used in the connection elements. For this reason, they should be as thin as possible.

Main question test one:

What is the minimal thickness that can be used for each connection elements?

Process

1. Holes were drilled in the required wooden elements.
2. The connection elements of thickness 0.6 mm were bolted to the wooden elements
3. The wooden elements were fixed to a working bench
4. By means of muscle strength, a force was exerted on the wooden element as shown in figure 81.
5. Results were observed and recorded
6. The connection elements of thickness 1.0 mm were bolted to the wooden elements
7. The wooden elements were fixed to a working bench
8. By means of muscle strength, a force was exerted on the wooden element as shown in figure 83.
9. Results were observed and recorded
10. The connection elements of thickness 1.5 mm were bolted to the wooden elements
11. The wooden elements were fixed to a working bench
12. By means of muscle strength, a force was exerted on the wooden element as shown in figure 85.
13. Results were observed and recorded

Limitations
As can be read in the process section, a force was exerted on the wooden elements by means of muscle strength. This is of course no accurate way of testing the strength of each element. Unfortunately, it was not possible at that time to produce a product (table, chair etc.) to perform an accurate test with. The test is therefore merely able to give a first indication concerning thickness.

Assumptions
The assumption was made that a force exerted as shown in figure 81, figure 83 and figure 85, exceeds the force a connection element would experience when used in a product.

Instruments
The following prototypes were used:

- Connection element A1 0.6 mm prototype
- Connection element A1 1.0 mm prototype (figure 80)
- Connection element A1 1.5 mm prototype
- Connection element B1 0.6 mm prototype
- Connection element B1 1.0 mm prototype
- Connection element B1 1.5 mm prototype (Figure 82)
- Connection element D1 0.6 mm prototype
- Connection element D1 1.0 mm prototype
- Connection element D1 1.5 mm prototype (Figure 84)
- Wooden element A
- Wooden element B
- Wooden element C
- Wooden element D
- Wooden element E
Figure 80: Prototype of connection element A1 (1mm thickness)

Figure 81: Set up of test with connection element A1

Figure 82: Prototype of connection element B1 (1.5mm thickness)

Figure 83: Set up of test with connection element B1

Figure 84: Prototype of connection element D1 (1.5mm thickness)

Figure 85: Set up of test with connection element D1
Results

Conclusions

With the limitations of the test in mind, a conclusion concerning the thickness of each element can be given:

Connection element A1
Based on the results, a thickness of 1 mm is defined as suitable for connection element A1. Because of its strong and rigid shape this element can be used to carry loads in 3 different directions.

Connection element B1
Based on the results, a thickness of 1.5 mm is defined as suitable for connection element B1. Because of its weaker structure this element can only be used to carry loads in two directions.

Connection element D1
Based on the results, a thickness of 1.5 mm is defined as suitable for connection element D1. Because of its weaker structure this element can only be used to carry loads in two directions.

Requirements

One of the most fundamental requirements from the list of requirements was defined as:

The product should be produced with as little material as possible

Unfortunately, due to the lack of a precise test, only a first estimate, on the minimal amount of material that can be used, could be given.

Recommendations

Because of the limitations in precision, the most suitable thickness for each element can only be estimated. More precise tests, that make use of the second iteration of prototypes (see test 2), should provide a more definitive answer. In such tests, the second iteration of prototypes should be used to build and test products with (chairs, tables etc).

<table>
<thead>
<tr>
<th>Type</th>
<th>Thickness</th>
<th>Bend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corner prototype</td>
<td>0.6 mm</td>
<td>Slightly</td>
</tr>
<tr>
<td>Corner prototype</td>
<td>1.0 mm</td>
<td>Not</td>
</tr>
<tr>
<td>Corner prototype</td>
<td>1.5 mm</td>
<td>Not</td>
</tr>
<tr>
<td>Corner flat prototype</td>
<td>0.6 mm</td>
<td>Significantly</td>
</tr>
<tr>
<td>Corner flat prototype</td>
<td>1.0 mm</td>
<td>Slightly</td>
</tr>
<tr>
<td>Flat prototype</td>
<td>0.6 mm</td>
<td>Significantly</td>
</tr>
<tr>
<td>Flat prototype</td>
<td>1.0 mm</td>
<td>Significantly</td>
</tr>
<tr>
<td>Flat prototype</td>
<td>1.5 mm</td>
<td>Slightly</td>
</tr>
</tbody>
</table>

Table 26: Results test one

Figure 86: Examples of figures that were used in the instruction manual of test two
10.2 Test two: Assembling a product

Introduction and justification
The system in its entirety, has four phases in which it can get used. Furthermore, the system can potentially be used by different target groups in each of these phases.

Design
In the design phase, the principle of the system is implemented in the design of products. This also includes the development of production plans and instruction manuals.

Target groups: Buurman employees, customers

Material preparation
In the material preparation, the wooden elements are sawed in the right lengths and the gauge is used to define the location of the holes. This is done on according to the production plan.

Target groups: BouwAkademie employees, customers

Assembly
In the assembly phase, the connection elements are used to assemble the product according to the instructions.

Target groups: BouwAkademie employees, customers

Use of assembled product
After the products are assembled and sold, they are used by the customer

Target groups: customers (public sector), customers (trade sector)

Although all of these phases and target groups are important, the choice was made to limit the user tests to the second and the third phase and focus it on the BouwAkademie. In these two phases the limitations of the material should be overcome and the system is used in its tangible form. This makes them the most important to test.

Two user tests were developed: one to test a simple version of the gauge and one to test the assembly of the products by means of the connection elements. Unfortunately, the first user test had to be canceled because of time constraints. This user test is ready to be carried out; this can be done by Buurman succeeding this project. Both of the user test manuals can be found in Appendix: T: Instruction manual one and Appendix: U: Instruction manual two

Goal of test two
Two of the most fundamental requirements are:

- The product must enable the connection of wooden elements with little effort
- The product must be usable by people who are not educated in carpentry

The goal of this test is to find out if these two requirements can be met. The main question that needs to be answered therefore is:

To what extent are employees of the BouwAkademie able to independently assemble a product by means of the connection elements, with only the help of an instruction manual?

Process
1. Preparations of instruments
   As explained in the introduction, user test two focused on assembling a product. For this reason the holes were drilled beforehand and the wooden elements were sawed in the correct lengths.

2. Introduction
   A short introduction was given on the graduation assignment and the reason behind the user test. Because of the limited Dutch language skills a short introduction was given on the principle of the system.

3. Handing out the instructions.
   The instruction manual was handed out and the participants were asked to follow the instructions. Figure 86 shows a selection of the figures that was used in the manual

4. Use
   The participants followed the instructions and built the product from the instruction manual
5. Filling out questionnaire
Together with the student, the questionnaire was filled out.

6. Making notes
During the user test, the participants were observed and notes were made.

6. Analyzing the questionnaires and notes
Proceeding the user test, the questionnaire and the notes were analyzed. Conclusions were drawn and written down.

Assumptions
The following assumptions were made prior to the user test:

• The product that was built in the user test by the participant, sufficiently resembles a product that would be build in an order for Buurman
• The situation during the user test sufficiently resemble regular production.
• The prototypes sufficiently resemble the connection elements

Limitations
The following limitations were defined prior to the user test:

• Just before the user test, it appeared that the Dutch and English language skills of the participants was much lower than expected. This obstructed the use of the questionnaire and limited the test to observation.

• The clarity of the system is partially dependent on the manual. A conclusion concerning the clarity of the system is therefore limited to one that takes the format of the manual into account.

Instruments
The following prototypes were used:
Connection element A2
Connection element C2
Connection element C3

The following Bolts were used:
16 x Bolt M4x30
16 x Bolt M4x40
16 x Bolt M4x50

The following wooden elements were used:
6 x Wooden element 22x150x800 mm
2 x Wooden element 22x100x55,5 mm
8 x Wooden element 22x100x400 mm

The following tools were used:
Flat head screw driver
Figure 87: Second iteration prototypes connection elements A1 from different angles

Figure 88: Second iteration prototypes connection elements C2 from different angles

Figure 89: Second iteration prototypes connection elements C3 from different angles

Figure 90: Participant one, conducting test two
Samples
Because of time constraints from both student and BouwAkademie only three BouwAkademie employees could participate in the user test. Information was gathered through observation.

Results
The following things were observed:

- Without being able to read the text in the manual the participants were still able to assemble the product according to the manual
- The participants merely looked at the pictures
- The pictures were too small
- After the principle of the system was clear, the assembling went fast
- The used bolts prevented the process from going faster
- Bolting costs by far the most time
- The average assembly time was 35 minutes
- The participants screw in the bolts really tight, this destroys the timber
- Participants used the margin of the drilled holes (see Chapter 7: Concept), to compensate for the deviations in the timber

Conclusions
The following conclusions were drawn from the user test:

Through the observations it could be concluded that it was clear to the participants how the system should be used. With only a short introduction, the participants were able to assemble the complete product by merely using the pictures in the instruction manual. This shows the importance of clear and big pictures in such a manual.

Because the bolts that were used in the test, could only be used by means of a flat head screwdriver, the process of assembling took much longer than was possible. When a cordless drill and another kind of bolt are used, this can significantly speed up the assembly process.

The holes that were drilled in the wooden elements prior to the user test are 6 mm wider in diameter than the bolts. The participants used this to compensate for the deviations in the timber. It can be concluded that (concerning assembling) this system works.

Recommendations
Based on the results from test two, the following recommendations are made:

Developing a coherent format for manuals. Because the pictures in the instruction manual turned out to be the most important, it is important that a coherent and tested format for these manuals is developed.

M4 hex-bolts and cordless drill
In future products, M4 hex bolts should be used. These, in combination with a cordless drill, should significantly speed up the assembly process.

Flat washers
The system requires the bolts to be screwed tight, this in combination with soft pine wood, caused the participants to screw in the bolts too tight and destroy the timber. The use of flat washers (either integrated in the bolt or separate) can prevent such damage.
CHAPTER 11 CONCLUSIONS

In this chapter, the final conclusions of this thesis will be drawn. These conclusions will be divided into the analysis and the product development of the project (synthesis and embodiment). Most of the specific conclusions have already been drawn throughout the thesis, so the conclusions in this chapter will be on a general level. Throughout the conclusions chapter, the sub questions and the main research questions will be used as guidance.
11.1 ANALYSIS

11.1.1 Conclusions

The analysis of this thesis aimed to answer the question:

‘How can companies that collect, refurbish, re-use and sell used building materials, grow?’

The main research question entailed the following sub questions:

Sub question one: ‘How do companies that collect, refurbish, re-use and sell used building materials, select, collect and use their material?’

Sub question two: ‘What materials, that originate as waste in the process of construction are most widely available from the construction sites of construction companies?’

Sub questions three: ‘Which initiatives, that incorporate the re-use of building material, are feasible for medium sized construction companies to implement?’

This question was answered by means of a multi case analysis between three CRRS companies and a multi case analysis between two construction companies. Based on the sub questions, the final conclusions will be discussed.

11.1.2 Sub question one

This sub question is answered in chapter 5.1: Study one. The amount of available used building material is currently so extensive, that CRRS companies are able to choose the materials they find the most suitable (cherry picking). Because the available material allows for such selective collection, these companies are able to also apply these material selectively. The application vary between companies and it is difficult to give an unequivocal answer on how the materials are used.

Although this is currently an ideal situation for these companies, the resources that are now extensively available, may very well become scarce in the future. Shifting from cherry picking to waste collection services might be the answer to this. This not only creates a bigger influx of material, but also increases the (positive) environmental impact of the company on and makes it more attractive for the construction industry from a practical perspective.

11.1.3 Sub question two

This sub question is answered in Chapter 5.2: study two. What kind of materials will arise as waste, in the course of a construction project, is information that is available. Construction companies are also able to make a sensible estimate, on when certain material arises, but predicting exact amounts and exact times is not possible.

11.1.4 Sub questions three

This sub question is answered in Chapter 5.2: study two. Based on their attitude towards the use of secondary resources, it has become evident that the construction industry is a very conservative one. This conservative culture is of big influence on the sustainability of the policy of the companies in this sector.

This can also be seen in waste management policies. Even if a company’s has a ‘sustainable’ policy concerning their waste management, it remains a trade-off, in which space is the decisive factor. Besides taking up more space, a more extensive waste separation system will require much more awareness and waste management from the on-site employees, than a simpler system. It is therefore no surprise that construction companies are interested in improving waste management with the help of third parties. CRRS companies could play a role in this.

Because of the conservative attitude of the industry, the use of used building materials is regarded with much skepticism. Again, the policy of the company is going be decisive in this. Construction companies foresee multiple limitations in the use of used building materials. These limitations relate to quality-, safety- and strength-guarantees, certificates or to the possible conflict between newly build houses and the use of secondary resources. Whatever its reasoning, the limitations all boils down to uncertainty and unfamiliarity.
11.1.6 Recommendation for future work

Through the analysis it has become evident that growth for CRRS companies through the construction industry, is very difficult. The attitude from the construction industry towards secondary resources lays at the heart of this problem. Future studies that revolve around the use of used timber (or secondary resources in general) in the construction industry are recommended to take this conservative culture into consideration beforehand and assess the influence of the culture that characterizes the industry for that specific situation.

Another phenomenon that also lays at the heart of the problem, is the high price of labor versus low the price of material. This phenomenon is of big influence on the little use secondary resources in general. In future studies the influence of this phenomenon should be taken into account when assessing the feasibility of the implementation of these resources.

11.1.5 Main research question

Through the answers to sub question one, two and three it has become evident that growth through the construction industry is difficult for CRRS companies. The only direction in which the studied construction companies showed any convincing interest, was that of waste management; and although it is genuinely believed that both CRRS companies as construction companies can benefit from such a service, this will only increase the input of materials for CRRS companies. Whereas what is actually needed is a medium to increase the output.

The deeply rooted conservative culture makes the implementation of initiatives that incorporate the use of secondary resources ( and with that increase the output,) very difficult. Strong product design, consistent quality and the ability to deliver the required quantities might not be convincing enough to win from the stigma that is associated with used timber. This also makes investing in such an industry, risky for CRRS companies. A change of attitude is needed and CRRS companies have little influence on this.

For this reason, CRRS companies should focus on finding new methods/products/services that help them to overcome the limitations of used building material. This will enable them to increase the possible applications for the material and with that increase their reach, which will eventually make such companies attractive for a bigger audience. Attracting a bigger audience will eventually enable the CRRS companies to grow.
11.2 SYNTHESES AND EMBODIMENT

11.2.1 Conclusions

Throughout the thesis it is shown that the proposed system is able to meet all of these fundamental requirements (The complete list can be found in Appendix Q: Program of requirements). There are four other subjects on which conclusion can be drawn:

Applications
Because the system enables the use of used timber in general and is not focused on the production of specific products, it can be used in practically all of Buurman’s business elements.

Feasibility
From beginning to end, the system has been developed with feasibility for Buurman in mind. When looking at the different elements of the system, it can be concluded that further development, should not pose any serious difficulties.

Future
The system is developed to serve as a tool in the production of varying products and Do-it-yourself kits. The system initially was intended to be used by the BouwAkademie in production, but can function in the other business elements of Buurman as well. For which target groups and which business element of Buurman, the system will function properly and for which it will not, is something that will have to be experienced in practice.

Answer to the main research question
The main research question from the analysis was:

‘How can companies that collect, refurbish, re-use and sell used building materials, grow?’

If the proposed system is the answer to these questions and indeed makes Buurman as a company grow, is something that has to be proven over time. However, it can be said with certainty that the idea of a system that simplifies the connection between used timber, can only help to increase the output for a company such as Buurman. If the proposed system can live up to this, is something that has be extensively tested.
11.2.2 Recommendations

Throughout the thesis recommendation per subject have been given for further development. The following recommendations can be given with regards to the system as a whole.

Development of design process
It has to be extensively tested what works and what does not work in the use of the connection elements, in both the design phase as during the product. This includes answering questions like:

- How little bolts can you use?
- How little connection elements can?
- How many wooden elements can be connected to one connection element?
- etc.

Testing different applications
The connection elements also will need to be tested in different objects. Varying in size, material and application.

Testing with different target groups
Just as the different applications, the system needs to be tested with different target groups. Each group has different needs, which might demand small changes to the connection elements and the gauge.

Products for the construction industry
Although the system is currently not aimed at the construction sector, the products that are made with it, can eventually become interesting for this industry. Which products this will be, is something that has to be discovered over time.
REFERENCES


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  Ir. te Kiefte A.W.E. (Partner)