Assessing the Market Potential of Second-hand Building Products

Master thesis -

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Assessing the Market Potential of Second-hand Building Products

By

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Many thanks to all the companies and institutions that have contributed to the research:

Preface

It is a pleasure to introduce *Assessing the Market Potential of Second-hand Building Products* to you. It contains the insights from a year's hard work. After graduation, I can look back on this period with a feeling of satisfaction and gratitude. It has been satisfying to contribute to a scientific field in which so many things still need to be uncovered. Since the circular economy is still in its infancy, there is value in very elementary new insights. The occasional feeling of eureka kept it interesting to stay focussed up until the end. My gratitude goes out to different people who have introduced me with the topic, got me excited about it and helped me to arrive at my results.

In the beginning of 2019, I was still not certain what my graduation topic would be. I enjoy projects like this so I had set rather high standards for finding a graduation topic. This resulted in a long period of mismatching encounters with different companies. That is, up until the moment that a friend named Harm introduced me with Bas and Gijsbert; two men who had been making great progress with several initiatives concerning Circular Economy. We quickly made arrangements, and in February I could start as graduation intern for two entrepreneurs, which meant that I could send invoices through my own proprietorship to receive my compensation. I am grateful for this unusual experience and the introduction that led to it.

Only after moving to Utrecht to start the entrepreneurial internship in Amersfoort did I finalize the composition of my graduation committee. I must say that the committee really deserves credit for this research. In the first meeting, I thought that I was way ahead of the competition by proposing a method that would tell which building products would be the most profitable to invest in; I only needed to gather some data and that would be it! Upon seeing the proposal, Marcel casually replied that the proposal was rather thin and that I should focus on developing a better method. At first this seemed trivial to me but in the end, I have to admit that he was right all along.

The committee as a whole did not get together that often but the feedback that I gathered from these moments was great; Marcel's feedback really helped to keep steering in the right direction and Sander helped me to maintain one foot in the field of engineering by reminding me that results must be quantifiable. A special thanks goes out to Daan; my mentor. Often times have I travelled up and down between Utrecht and Delft to update Daan about my progress and every single time it was completely worth it! Daan constantly introduced me with new angles to my approach and it is no exaggerated that he has inspired me to do more research. Thanks for that!

A big thanks as well to all market parties that helped me do my research. Traveling around the country for interviews made for an existing summer; thank you for the interesting talks and the coffee. Then, last but definitely not least, I want to thank Bas. When I met Bas for the first time it immediately became clear to me that his sharp thinking and business sense would be a source for learning a lot of new things. Bas really helped me to make progress with my research but most of all he made sure that it was a fun time working together. Due to the great year in Amersfoort, I have decided to stick around in the reuse business; Hopefully it won't take long before you get to know more about the initiative that Bas and I are working on to promote the reuse of building products.

For now, I want to thank you for considering this research. Hopefully, the insight that are provided here are useful to you. Feel free to contact me if you want to know more about the topic.

Hermen van de Minkelis, Utrecht, May 2020

Executive summary

Anno 2020, climate change due to CO_2 emission is a generally accepted fact and enough awareness has been raised for the severity of the problem that governments all around the world have started programs to limit emission, including the Dutch government. One program that ought to contribute to reducing CO_2 emission, among other goals, is the aim for a fully circular economy (CE) in 2050; CE cuts emissions by limiting the use of resources for which energy is consumed in the production process. As described in the transition agenda for the building industry, the circular goals apply to the building industry as well; this is the theme of the research.

Although 95% of building products are recycled in the construction industry (albeit at low grade), the sector is still responsible for 35% of Dutch CO_2 emission, mostly due to the production process of materials. By increasing the life-span of building products, the Reuse strategy has great potential to reduce this impact but it is observed that not many building products are reused because it is not economical. The government aims to overcome this issue by stimulating the development of reuse markets in the B2B market for building products but it is not yet clear for which building products it is possible for markets to arise; how to determine whether a self-sustaining B2B market for reusing specific products can arise with government support is the main question of the research.

From exploratory interviews it turns out that reusing building products is less economical than applying new products due to a couple of different types of obstacles related to the product, the involved parties, the considered projects and the market. Literature was reviewed in search for the effects of these obstacles on the costs of reusing but it turns out that literature on this topic is lacking, leaving a Research Gap to fill. Because there is already tacit knowledge available from demolition contractors who disassemble and sell second-hand products in the B2C market, whereas practical experience for applying these products in construction projects is really scarce, it is decided to focus on supply in order to make the tacit knowledge from demolition contractors explicit for the reader.

A Theoretical Framework is developed to provide the metrics for answering the main question with a supply-driven approach. It is proposed that there must be a hypothetical middleman who buys second-hand building products from demolition contractors to temporarily store them and upgrade them in order to be able to provide products that compete with new products. A model which is referred to as the Feasibility Model, demonstrates that a transaction can only occur if the demolition contractor receives the minimal price *E1*, referred to as Purchase Costs, to make reuse just as profitable as normal demolition and if the market price *B* is high enough to cover price *E1*, as well as the Middleman's Costs *E2*, while leaving a sufficient profit margin *E3*. It is reasoned that the feasibility of supply differs for different situations because the price *E1* depends on the type of contractors and the type of project. The So called Market Size Model plots the average price *E1* for different production scales to show that this price increases with the number of transactions based on the logic that harder-to-reach products are reused if demand rises. It also shows that the costs *E2* decrease with production scale because the middleman's fixed costs are spread out. The total Supply Costs (*E1+E2*) for different productions scales are compared with the market price *B* to evaluate if a market with sufficient profit for the middleman can exist. As such, it is defined if a B2B market for reusing a certain product can arise.

The challenge for the research is to develop a method, referred to as the Market Assessment Method, for determining the average Supply Costs for different products at different production scale and in order to achieve this, a tool is developed that enables the user to determine the Purchase Costs *E1* for different products that are disassembled from different types of demolition products by different types of Demolition Contractors. This Tool is referred to as the Purchase Costs Tool. The tool is synthesized by interpreting stories about disassembling and selling different products form different projects, that were gathered in semi-structured interviews with 15 demolition contractors. The tool is validated by evaluating the correspondence of the tool to the transcript and by testing the tool in practice. The Market Assessment Method is subsequently demonstrated in a case study about reusing toilets.

The result of the synthesis of the Purchase Costs Tool is a tree-shaped flow chart representing the different decisions, operations and events that demolition contractors face in different situations. Each situation (denoting a certain product, project and contractor) can be expressed by selecting a different path of the tree and by adding up the costs corresponding to all operations on the path, the total costs corresponding to a product are computed. The Purchase Costs *E1* for a situation are determined by comparing the costs on the path of disassembly with the costs on the path of normal demolition. What's more, from validation, it is concluded that the tool is reliable enough to be used in practice.

The case study about reusing toilets demonstrates the nine steps of the Market Assessment Method. Throughout these steps it is demonstrated how different categories of projects can be made that influence Purchase Costs and how many toilets belong to each category. This input is combined with different types of demolition contractors with respect to handling toilets, and their respective market shares, to arrive at the number of transactions corresponding to each situation. The Purchase Costs Tool is then applied to fill in the Purchase Costs *E1* for different situations and a hypothetical middleman is envisioned to arrive at a curve for the costs *E2* depending on production scale. The curves are combined to arrive at the end product of the research; a curve from which it can be concluded that a B2B market for reusing toilets can exist in accordance with the Theoretical Framework.

Before concluding that the developed method in fact answers the main question by demonstrating how it can be determined whether a self-sustaining B2B market for reusing specific products can arise, it is discussed to what extend the method depicts reality. It is identified that the main limitation of the method is the fact that it is based on a model that does not take into account which additional costs builders have to make in order to apply second-hand building products. In the research it is proposed how second-hand products can be supplied with equal quality but it is expected that this is unrealistic in practice. To summarize the discussion, it is demonstrated what it would look like if the Application Costs and other assumptions were to be accounted for in the Market Size Model. Based on this demonstration it is concluded that the research provides a solid basis for answering the research but that the limitations from the scope might lead to an over-optimistic result.

From the different chapters of the research it is concluded that an answer to the main question contributes to the climate goals that many governments put faith in and that it is in fact required to do obtain new knowledge in order to answer the question. Furthermore, it is concluded that the Theoretical Framework, the Purchase Costs Tool and the Market Assessment Method all contribute to science and that they help to provide a solid basis for answering the research question but it is added that there is need for additional research to cover the Research Gap completely. To wrap up the paper, suggestions for such research are done.

Table of Contents

1 Introduction

How can we determine whether a self-sustaining B2B market for reusing specific building products can arise?

This picture was taken at Schijf Restoric B.V.

This is the introduction to a research on the feasibility of reusing building products from demolition projects. More specifically, it attempts to develop a method that can be used to determine whether a self-sustaining B2B market for reusing some building product is likely to emerge. This purpose is articulated in the main research question which is presented here:

How can we determine whether a self-sustaining B2B market for reusing specific products may arise?

To answer this question, the report is divided in six chapter (excluding this one) that will each bring the reader a step closer to the understanding the outcome of the question. This introduction chapter aims to summarize what the purpose of each chapter is and how it contributes to answering the main question. Before proceeding to this summary of chapters, a reading guide is proposed below to help the reader understand the structure of the report, followed by a management summary.

1.1 Reading guide

A couple of basic rules are summed up to provide the reader with the basic knowledge required for skipping through the report more quickly

To get the most out of reading this report in a shorter period of time, some explanation about the structure of the report is provided here. This is just a set of tips, which is summed up below with bullets.

- Each chapter starts with a front page that is included with the sub question of that chapter. The goal of a chapter is to answer the sub question corresponding to it.
- The conclusion of a chapter, or the answer to the sub question in other words, is given directly after the front page of a chapter. Bolt green letters indicate the literal answer to the question.
- Each chapter is divided in subchapters with dark green coloured titles which are in their turn subdivided in second level subchapters with light green coloured titles.
- Each subchapter begins with a little introduction.
- The title of each subchapter and second level subchapter is accompanied by an action title; a single sentence that describes the conclusion of the (second level) sub chapter.
- For the quick reader, there is an opportunity to read only the action titles.
- To emphasize important sentences and terms, they are written in dark green Italic.
- Important terms that are introduced are written in dark green Italic as well
- Finally, it should be noted that some essential appendices are written in Dutch, which is a result of the fact that imported sources were in Dutch. Apologies to the non-Dutch reader.

1.2 Introduction to the research

Together, background, exploration, methodology, results, discussion and conclusion for the steps that lead the reader towards an understanding of the answer to the main question

This subchapter aims to explicate the goal of each individual chapter that helps to answer the main question of the research. Six chapters follow this chapter and each one of them plays a crucial part in answering the main question. By answering a sub question for each of the first five chapters, all necessary steps will have been taken to answer the main question in the final chapter. Below, the titles of the six remaining chapters are shown, accompanied by the questions that will be addressed by each one of them (note that the final question is the main question). The goal of each of the six remaining chapters is explicated throughout the rest of this subchapter.

2. background — Why should we determine whether a self-sustaining B2B market for reusing specific building products can arise?
3. Exploration — Which knowledge must be gained for identifying second-hand building products for which a self-sustaining B2B market can arise?
4. methodology — How do we synthesize and validate a method for determining if it is possible for a B2B reuse market for certain building to exist?
5. results — How can it be determined whether a self-sustaining B2B market for reusing toilets can arise by using the developed method?
6. Discussion — Can it be concluded that the developed method enables us to determine whether a B2B market for reusing specific products can arise?
7. Conclusion — How can we determine whether a self-sustaining B2B market for reusing specific products can arise?

1.2.1 background

the background chapter tries to answer the question why we should determine whether a self-sustaining market for reusing specific products can arise

In this chapter, the introduction, the main question for the research has been introduced out of the blue. The background chapter aims to explain WHY it is relevant to answer the main question and it introduces the reader to some prerequisite knowledge about the topic of the research.

The first part of the chapter starts out by explaining what the implications are for reusing building products and how it relates to other waste strategies such as recycling. The first part of the chapter ends with an explanation about the challenge that needs to be overcome to realize self-sustaining markets for reused building products.

The second part of the chapter attempts to explain how the challenges for reuse could be overcome. Both the role of the government as well as the role of businesses is addressed. It is then explained how these acting parties would benefit from research about the reuse market

In the Final subchapter, it is evaluated what sort of trade in second-hand building products already occurs and the difference is made up between the B2C (Business to Business) market and the B2C (Business to Consumer) market after which it is explained why the B2B market is chosen for research.

1.2.2 Exploration

The exploration chapter describes how we should define whether a market for reusing a specific product is economically feasible

Up until the Exploration chapter, it has been established that, and why, a method should be developed for assessing the possibility for specific reuse markets to arise. The Exploration chapter aims to explore which relevant knowledge is already available and which knowledge is missing, referred to as the Research Gap. Based on these insights it is determined which new knowledge must be obtained and which part of the Research Gap must be left out of the scope. Finally, a Theoretical Framework is proposed that puts the required knowledge in context with the research question.

The Research Gap is found and explored in the first subchapter. By conducting exploratory interviews, it is determined what must be sought after during literature review. Literature about the potential of supplying and applying second-hand building products is then reviewed. Based on the literature, a conclusion is then drawn about which knowledge is missing.

The second subchapter addresses the scope of the research. It is reasoned that a specific scope leads to a better answer to the research question. In five domains of reusing building products, the scope has been narrowed down in order to make it manageable for a graduation thesis. These limitations of the research are discussed in five individual subchapters. It should not be a surprise that the narrowed down scope causes a distance between the result of the research and its pertinence in practice. This influence will be covered by the Discussion chapter

Finally, a Theoretical Framework is proposed in the third subchapter. The framework consists of four separate models. Two of these models play an important role throughout the research because they provide the metrics that are used in the developed method. These models are the *Feasibility Model* and the *Market Size Model*.

1.2.3 Methodology

In the methodology chapter it is explained how the algorithm for finding an economically feasible market size is synthesized and validated

The goal of the Methodology chapter is to explain how a method for determining market potential will be developed. Apart from synthesis it is discussed how the method should be validated; validation is required for a trustworthy result. It will be explained that the research yields a method, referred to as the Market Assessment Method, and that the so Purchase Costs Tool is developed that can be used to provide the most important input data for the Market Assessment Method. The tool and the method are separately addressed in two sub chapters.

The first subchapter covers the Purchase Costs Tool. It is explained that this tool allows the user to provide insights that have been missing in literature hitherto. It is explained how this tool can be used to fill the Research Gap in other words. Furthermore, the subchapter explains what the tool is supposed to look like, how the required data for synthesis is gathered and how the tool is validated

The Market Assessment Method is addressed in the second subchapter. It is explained that the algorithm will consist of a bunch of steps that prescribe how certain data should be gathered, interpreted and processes to plot a certain graph. It is then concluded that this graph can be used to assess whether a reuse market for a product may arise or not. In other words, The Market Assessment Method, once validated, answers the research question. Then, it is proposed that a case study will be conducted to demonstrate the method.

1.2.4 Results

In the Results chapter, the question is answered whether a self-sustaining B2B market for reusing toilets may arrive according to the developed algorithm

In this chapter, the results that were envisioned in the Methodology chapter are presented. As was envisioned, these results entail a step-by-step plan that is referred to as the Market Assessment Method and a tool called the Purchase Costs Tool. Both are addressed in the Results Chapter although the Purchase Costs Tool gets most attention; the first two subchapters concern the Purchase Costs Tool and the last sub chapter covers a case study about the Market Assessment Method.

The first subchapter covers the synthesis of the Purchase Costs Tool. A detailed description is given about the structure of the tool and the way in which it is used. It is explained that tool is represented by a tree structure that consists of many different paths leading to one of five waste strategies, that it depends on the situation which path is taken and that each path results in different costs.

The second subchapter dives into the validation of the Purchase Costs Tool. The validation consists of three parts that are all discussed. It is validated that the data used for synthesizing the tool can indeed be interpreted by the independent reader. Then, an overview is provided that links all elements of the tool to different parts of the data. In the final part of the validation, it is demonstrated that the tool works in practice by doing a case interview with an expert in the field.

Finally, the Market Assessment Method is addressed in the last part of the Results chapter; the main deliverable of the research. It is described that the method consists of nine steps that are required for plotting a graph that gives insight in the potential for a market to arise. The final result is introduced in the last step of the method. All the other steps are demonstrated in a case study to demonstrate how the method is applied. These steps include a demonstration of the Purchase Costs Tool.

1.2.5 Discussion

By concluding whether the developed algorithm can in fact be used to predict market potential, the path is cleared for answering the final question how it should be done

Only after the Discussion chapter can it be concluded whether the developed method from the research can really be used to determine whether a self-sustaining B2B market for reusing certain products can arise. In the Discussion chapter it is discussed what kind of new knowledge the research contributes to science, what the limitations are to this knowledge and to what its contribution is to answering the main question of the research. These questions are asked for the four main insights of the research; the results from the exploratory interviews, the Theoretical Framework, the Purchase Costs Tool and the Market Assessment Method. These are discussed in four subchapters.

The first subchapter shortly explains how the insights of the exploratory interviews have helped to shape the Theoretical Framework of the research. About the Theoretical Framework itself it is told that it has played a vital role in answering the research question but it is also discussed that some assumptions, that have been made delimit the scope, result in some limitations to the Theoretical Framework. On the basis of the Market Size Model, it is explained what kind of effect the assumptions have on the outcome of the research.

The Purchase Costs Tool is praised for allowing the user to obtain valuable data about product costs and it is confirmed that the tool works in practice. A little side note about the rigidity of the validation is mentioned though. For the Market Assessment Method, the impact of the accuracy of the input data is discussed to evaluate the outcome of the case study.

1.2.6 Conclusion

In the Conclusion chapter it is explained how it can be determined if a self-sustaining B2B market for reusing specific building products may arise

The answer to the main question of the research is given in the Conclusion chapter. Since all preceding chapters have played a role in arriving to the answer, each of their individual findings are involved. Five subchapter are devoted to answer the sub questions corresponding to the five preceding chapters of the report. The main conclusion is given in the introduction of the chapter and the chapter is wrapped up with a couple of suggestions for follow-up research.

The first subchapter provides an answer to the question why it is relevant to develop a method for identifying the market potential of different second-hand building products. The governments interests and the emission of CO2 are included in the answer. The second subchapter answers which new knowledge is required for answering the main question. Here the process of finding the Research Gap is summarized and it is explained how the Theoretical Framework fills the Research Gap.

The third subchapter answers the question how the main method is synthesized and validated. It basically summarizes the Methodology chapter. The forth subchapter answers the question as to how the developed method is applied to determine whether it is possible for a B2B market for reusing toilets to exist. Here, the Market Assessment Method is summarized and it is explained what kind of role the Purchase Costs Tool has played in the method.

The fifth subchapter answers the question whether it can be concluded that the developed method helps answering the main question. Emphasis of this subchapter lies on the implications of the Theoretical Framework. The final subchapter proposes three follow-up research topics; one about investigating the application costs for different building products; the second topic is about the influence of material properties on the supply costs of different products; the third suggestion is a topic about the influence of different elements of a building on the project's total reuse costs.

2 Background

Why should we determine whether a self-sustaining B2B market for reusing specific building products can arise?

This picture was taken at Beijer & zn B.V.

An important first thing to consider before developing a method for solving a problem, is to wonder why this presupposed problem needs to be solved. This chapter provides an answer to that question in order to help the reader understand the relevance of this research. Three major aspects are identified in the main question that need justification in order to be able to say that the result of the research is worth-while. *1)* the suggestion that more products should be reused, *2)* the notion that it is necessary to find out if markets for these products can arise and *3)* the suggestion that focus should be applied to the B2B market. The first subchapter underlines the value of reusing in general and compared to other end-of-life strategies. The second subchapter motivates why it is valuable to find a way to determine whether self-sustaining markets for reusing products can arise. Finally, in the last subchapter it is clarified why the B2B market deserves attention instead of the B2C market. Together, these subchapters lead to the following answer to this chapter's sub question:

We should determine whether a self-sustaining market for reusing specific products can arise because reuse turns out to be a more suitable strategy when it comes to reaching our nation's climate goals than the current way of recycling building products

In order to allow the reuse strategy to be implemented successfully, the government and businesses must learn for which products markets can arise in order to focus their time and resources on the right products

Because the government focusses on reuse in the B2B market, a solution should be found for this market rather than the B2C market

2.1 Aiming for reuse

Within the scope of Circular economy, the reuse strategy would be a big improvement for environmental quality compared to current strategies if it were to be economically feasible

The introduction of this sub chapter is perhaps best expressed in a hypothetical example starring a person named Steve who buys a new house where he installs a new toilet while his old house, including his old toilet, is demolished for the site to be redeveloped. Steve represents *linear economy*.

Every year many toilets are smashed to pieces by demolition contractors and crushed to rubble to be used as foundation under a road. Like Steve's toilet, almost no toilets have a chance at being reused again after a building is demolished. This represents the lag of the *circular economy* (CE). Besides toilets, much more value is destroyed in demolition but the toilet serves as a good example.

One could argue that value is created by producing a new toilet. However, to produce it, value is lost in the form of environmental quality. Depletion of resources and warming of the planet by burning of fossil fuels in production process are common concerns. Especially the effects of burning of fossil fuels should be addressed because lots of fuel is needed in construction and producing building products. Apart from construction, it costs fuel to turn Steve's old toilet into road foundation as well. In total, the build environment accounts for 40% of Dutch energy consumption, leading to 35% of the total CO2 emission *(rijksoverheid, 2016, p. 60)*. Research *(Jarraud, M., & Steiner, A. ,2012)*, that is increasingly supported by public opinion, suggests that CO2 emission poses a serious threat to our future wealth.

Although Steve knows, and cares about the environment, he apparently cares more about the outcome of his decision to buy a new toilet. The same applies for the demolition contractor who decides that it is more beneficial for him to demolish the toilet rather than trying to sell it. Regardless of their awareness, both buyer and supply avoid reuse because it is not economical. The notion that reusing rather than destroying and making a new toilet is better for the environment, as well as the notion that this development is hindered by economical disadvantages are elaborated upon in this sub chapter.

2.1.1 The definition of CE

CE aims to accomplish sustainable development by applying certain waste processing strategies that are enabled by a change in businesses and customer behaviour

It has been established that CE itself is a concept that contributes at least to minimizing environmental impact. In order to provide a more compelling meaning, the definition of CE as described by *(Kirchherr, J., Reike, D., & Hekkert, M. ,2017)* is introduced here:

> *[circular economy is] "an economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes … with the aim to accomplish sustainable development, thus simultaneously creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations. It is enabled by novel business models and responsible consumers".*

Note that the definition describes different waste-management strategies as implementation of CE, different components of sustainable development, including environmental quality, as goal and that a change in current business models and customer behaviour are described as means for enabling circular economy. For simplicity reasons, the part about social equity is left out of the scope. The rest of the definition and its composition are used throughout this chapter to communicate the different aspects of the reusing building products.

2.1.2 Lansink's ladder

From a set of models, Lansink's ladder is selected to describe the hierarchy of different waste processing strategies in terms of creating environmental quality

After reading Steve's case, an expert in the field of carbon footprint calculations may argue that it is a dangerously oversimplified statement that the environment is better off if Steve reuses his old toilet because in some instances, buying a new product has a lower impact on the environment than reusing an old one. For example, Steve's old toilet may have to be transported 200 km to Steve's new address while new toilets are produced nearby. Also, Steve might request that his toilet is pressure washed before it is installed again. These proceedings might have a higher environmental impact than producing a new one. Concluding, reuse does not guarantee a lower environmental impact per se.

So, determining the environmental impact of reuse is not a straight-forward science. Now let's get back to Kirscher's definition. It suggests that *reduce*, *reuse*, *recycling* and *recovery* are all legitimate strategies for CE but the term 'alternatively' implies that reuse is preferred to recycling and recovery while it is not preferred to reducing. This hierarchy is very common in practice and is expressed in numerous models. This research refers to Lansink's ladder *(Lansink, A, 2017)*, shown in Figure 1. The ladder ranks from F to A in terms of creating environment quality. *Incineration* and *landfill* are NOT included in the definition of CE because these qualify as strategies belonging to the linear economy; these have a high environmental impact.

Figure 1 Lansink's Ladder

2.1.3 The Emergy model

By modelling the typical value chain of a building product, the concept of emergy can be used to validate the hierarchy in Lansink's ladder in terms of environmental impact

Environmental quality and its relation to Lansink's waste processing strategies is further explained by using the term *emergy* which is indeed spelled with an *M*. It has been established that increasing the use of energy decreases environmental quality because the majority of energy used for processes in the construction industry originates from burning fossil fuels *(CE Delft, 2014)*, which emits CO2. On top of that, resource depletion has been mentioned and besides these two, there are other factors such as land use that should be considered in assessing environmental quality. This assessment is not a straight-forward science because different factors, measured in different units must be considered.

Emergy is a collective term that accounts for different forms of energy and resources like sunlight, water, fossil fuels, minerals, etc. *(Odum, Howard T., 1996)*. It does not include all possible effects such as land-use but provides the possibility to compare most other effects. Combining the different effects in a single unit makes calculations a lot less cluttered and it is therefor used here to analyse why reuse is considered to be better than recycling for example.

The *Emergy Model* is proposed to presents the value chains of different waste-management strategies. Figure 2 demonstrates the value chain for landfill for example. It shows how different actors invest emergy to add value to a material in the first part of the value chain. E.g. the supplier invests emergy to transform raw materials into a building product. On the contrary, after the time gap, emergy needs to be invested in order to get rid of the product again. The presented collection of actors is a simplification of reality. Since only emergy is considered, land-use is given a light colour.

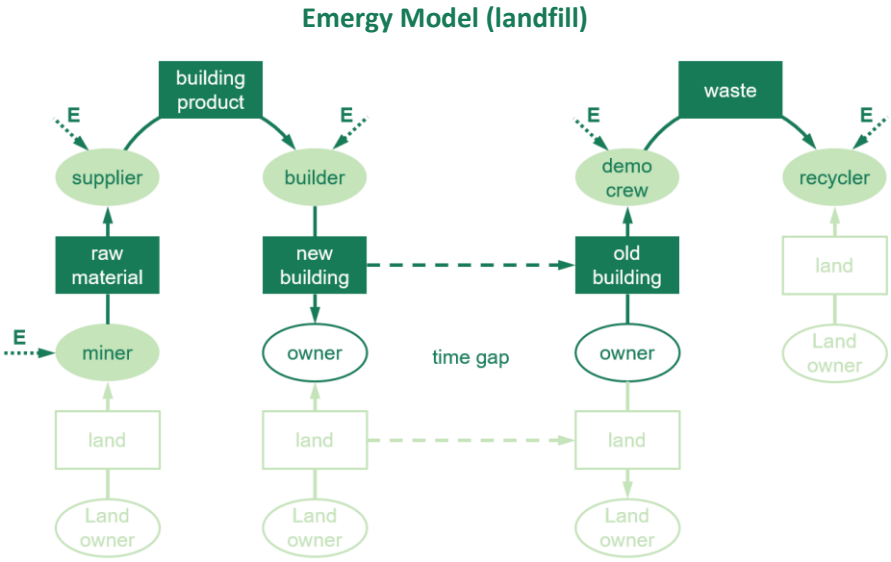


Figure 2 Emergy model (landfill)

In correspondence with the prior notice that it is not straight forward to conclude that one waste-management strategy is better for the environment than another one, the proposed model only provides a conceptual comparison between different waste processing strategies. It does however allow for quantitative analysis if the Emergy values are filled out correctly. Further on, the Emergy Model is used again and versions for different waste-management strategies will be presented.

2.1.4 Reuse tops the status quo

Reuse is chosen as theme for the research because it poses an impactful opportunity for reducing environmental compared to the status quo

It has been established that in terms of environmental impact, there is a hierarchy in the different waste processing strategies. A decision is made to focus on reuse in the research. Based on the proposed Emergy model, the value chain for reuse is demonstrated in Figure 3. It shows that a product will theoretically be continued to be used in a new building after it is removed from an old building. Clearly, according to the model, reuse yields a reduction in environmental impact compared to landfill; only two parties need to 'spend' emergy instead of five. If the Emergy Models of recycling, incarceration and energy recovery were to be shown, it would become clear they reuse would have a lower emergy input than them as well.

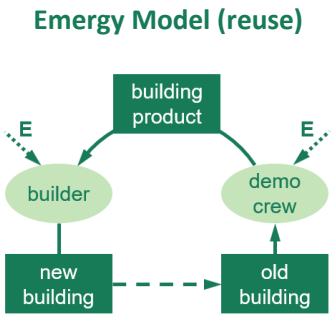


Figure 3 Emergy model (reuse)

Yet, according to Lansink's ladder it would be even better to 'reduce'. By applying the reduce strategy, no product is produced, leaving no environmental impact at all, so why bother about reuse? Besides the fact that the construction industry cannot be totally reduced, the decision to focus on reuse is fact that it is the next step on Lansink's ladder beyond recycling, which is currently the status quo in the construction industry. *(Transitieteam Bouw, 2018)* states that approximately 97% of all construction and demolition waste finds a new purpose, almost all of which is recycled rather than reused. Figure 4 indicates this current state of affairs.

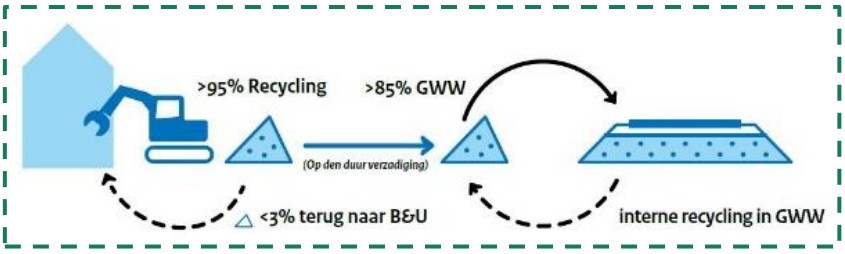


Figure 4 Recycling cyclus of building materials

The figure shows that more than 85% of construction and demolition waste is used in the civil engineering sector. This concerns all the stony materials (including toilets) that are being used as roadfoundation. A major part of the remaining 12% finds its way in other lower strategies such as recovering energy from burning wood for example *(TNO, 2018)*. Less than 3% actually finds its way back in a building, most of which accounts for recycling as well; for example, by melting plastic window frames to recycle the plastic. It is estimated that only 0.24% of all building products is being reused *(Arnodussen, 2020)*. Since this is very little, it is hypothesized that it is possible to achieve much more reuse and since reuse results in a significant reduction of environmental impact compared to recycling, reuse ought to be a notable step for CE.

2.1.5 reuse from current projects

The research focusses on reuse from current demolition projects instead of reuse in leasing models or designing for reuse because this is the only way to decrease the use of resources in the present

The research focusses on reusing building products from old buildings in order for them to be applied in construction. There are alternative ways to interpret the reuse strategy. In order to prevent confusion, it is explained which other interpretations for reuse are common and why reusing old building products is chosen as topic for the research instead of the alternatives. The other alternatives are *Design for Reuse* and *Leasing Models*.

Design for Reuse. For this strategy, new products are used in buildings but these buildings are designed in such a way that they can easily be disassembled at the end of their lifetime in order to reuse the embedded products. Instead of reusing now, this strategy focusses on reuse in the future. The goal of reuse is to decrease the use of new building products to reduce environmental impact but because the typical lifespan of buildings is many decades long, Design for Reuse can only help reduce environmental impact in the far future. In the light of the concerns about climate change and studies done on the topic *(Grey, 2007)*, mitigating measures decades into the future will be too late.

On top of the fact that Design for Reuse only has an effect in the far future, it can be questioned whether products that are easily disassembled will be reused per se. Toilets can be disassembled but it must be clear by now that they are not reused very often. Apparently, there are more factors at play when looking at reusability. Reusing products in the present can give insight in these factors. Besides, only by developing reuse markets in the present will there be a purpose for reusable products that are being extracted from future buildings that are designed for reuse.

Leasing Models. Lately, lease models are being explored in construction. not only has the leasing model proved to be viable in several cases (Search for *EZ Park* as reference), it is also legitimate to claim that a product in a leasing model is reusable because the supplier of the product actually commits to taking back the product from the client after a use cycle giving him an incentive to reuse. However, leasing models are only applicable on constructions and parts of constructions with short lifespans which only make up a small specific building types, leaving the majority of buildings.

2.1.6 The challenge for reuse

Regardless of the public awareness for environmental problems, reuse does not seem to be a feasible option for individuals and businesses because it is not very economical

Back to Steve's case. The fact that almost nobody buys second-hand toilets in a free market is empirical evidence for the fact that the consumer's considerations for buying a new toilet apparently outweigh his considerations for choosing the second-hand alternative. A more general way of putting it is through Oxfords definition of the word *economical (Lexico, 2018)*:

> *"Giving good value or return in relation to the money, time, or effort expended".*

Even though one might expect that reuse is cheaper compared to new product because no production process is need, apparently, it is still more economical to buy a new toilet. Similarly, this economical advantage of new products applies to most other building products and is observed in the B2C market and even more evidently in the B2B market. Circular projects that are being highlighted in the media seem to beg the differ but, in these cases, returns are gained in the form of publicity which makes it hard to assess how economical feasible those projects would really be without media coverage. In the linear economy, maximizing economic gain is the only aim and a logical decision between an old toilet and a new toilet should be made based on Oxford's definition. According to Kirscher's definition, Circular Economy on the other hand aims to maximize *environmental quality* and *economic prosperity* simultaneously in a decision. Moreover, the decision should regard *current and future generations*.

The fact that reuse is doing so poorly up until the time of writing could be devoted to the fact that consumers and businesses are simply not aware about CE. This notion is easily invalidated however: a survey by the EU *(Europese commissie, 2017)* shows that 93% of EU citizens think of climate change as a serious problem and that 75% claims to produce less waste because of it. Similarly, many businesses in the industry post public statements about their circular ambitions (with or without the earlier mentioned publicity projects). Since awareness does not seem to be a problem, two obvious options remain: either, businesses and individuals are irresponsible consumers who do not take environmental quality into account at all, or, the additional economical costs of reuse are simply to high compared to the additional environmental quality. The truth might be somewhere in the middle and can be expressed in the following formula:

Valuation of additional
environmental quality for
current and future generations

<

Valuation of the decrease of
economic prosperity for the
current generation

From this deduction and the empirical evidence that reuse has not caught on yet regardless of the awareness, it must be concluded that reuse is not a viable strategy for decreasing the environmental impact of the construction industry unless an external force disrupts the current building economy. The following sub chapter attempts to explained why there is still hope for reuse by introducing a disruptive force that might help increase the valuation of reuse strategies.

2.2 Finding a market

This research aims to contribute to market development for reuse, and thus contribute to the government's climate goals, by looking at the feasibility of reusing different products

Through international agreements, the Dutch government has committed to ambitious goals to minimize CO2 emission. Mainly because of this, and to reduce dependence on finite recourses, the government also introduced a nation-wide program to transform the economy in a circular economy. The program consists of five transition agendas including an agenda for buildings. The transition agenda for buildings justifies the research on reuse because it provides a reason to believe that reuse can become feasible in the future. The company Repurpose, the client of the research, demonstrates that demand for reuse is increasing indeed (since the government's attention). The company provides a motive to do research on the reuse feasibility of different products.

In this sub chapter, it is elaborated upon how the Dutch emission goals and the transition agenda for buildings came to existence, why it is justified to do research on reuse and how this leads to the theme of investigating the feasibility of different building products.

2.2.1 The government's effort

The Dutch government is implementing a program to stimulate a transition towards CE because it is involved in international agreements to reduce CO2 emission

So far, it has been established that the reuse is better for the environment than recycling according to contemporary models such as Lansink's ladder but it also turns out that reuse is barely put in practice in the current market because it is less economical than recycling. Although reuse is not economical in the current market, the government has put reuse on the agenda. Its purpose is to disrupt the current market in such a way that reuse can become more economical than alternative options in situations where reuse leads to a reduced environmental impact. The attention for reuse is part of an integral, nation-wide plan for the Netherlands to become CO2 neutral in 2050. International commitments are the motive for setting up this program. Let's have a closer look at the government's *trigger* and its *reaction*.

Trigger. A discussion is being conducted on a global scale to come up with solutions for global warming. Many organizations have raised awareness for the problems that are being faced and consecutive international treaties have pressed up nations to take action. During the Paris Agreement in 2015 Figure 5 most recently the target has been set and backed by 195 UNFCCC countries to a maximal average temperature rise of 1.5 degrees centigrade. By ratification, 185 countries *(UNFCCC, 2016)*, including the Netherlands declared to make a measurable decrease in CO2 emission.

Figure 5 Paris Agreement

Reaction. Leading examples and international agreements influence trends and policy on national level, similarly in the Netherlands. After agreeing with the conditions of the Paris Agreement and binding to earlier set European goals, the Dutch government has put CO2 reduction on the agenda. Specifically, the target has been set on a reduction of 49% in 2030 and a reduction of 95% in 2050 relative to the CO2 emission in 1990 *(Rijksoverheid, 2020)*. Also, a national change is being made from a linear to a circular economy. The outlines of this ambition of the government are set out in an official publication *(Rijksoverheid, 2016)*. Besides decreasing the depletion of natural resources and

decreasing dependency on other countries for raw material, this change ought to contribute to the national goal of reducing CO2 emissions. The government's ambitions as regards to circularity are as follows: reduce the use of primary resources with 50% in 2030 with an aim to become fully circular in 2050.Not the government itself but the market needs to make the transition towards a circular economy. The government has published actionable plans to steer the market in this transition. *Nederland Circulair in 2050* contains a government-wide program, *Rijksbreed Programma Circulaire Economie (RPCE)*. The program consists of five transition agendas that describe actions in collaboration with Dutch organizations from different sectors that were ratified to take action by an agreement from 2017 *(Grondstoffenakkoord, 2017)*. One of the five agendas is the transition agenda for the building industry *(Transitieteam Bouw, 2018)*. This document is of interest for this research.

2.2.2 The transition agenda for construction

The transition agenda for construction justifies research on reuse because it proposes measures that offer room for reuse to become feasible in the future

Figure 6 summarizes the transition agenda for the Dutch construction industry. In the document, the path to a fully circular economy is described as climbing a mountain; 2021 is a mile stone where "base camp" should be reached. The goal is set out to have created demand and have market parties invested in new, promising circular business models at base camp. Leading up to this moment, specific actions are proposed, including market development. After 2021, the transition agenda relies on its global strategy made up of three "pillars" in order to get the construction industry to be 100% in 2050.

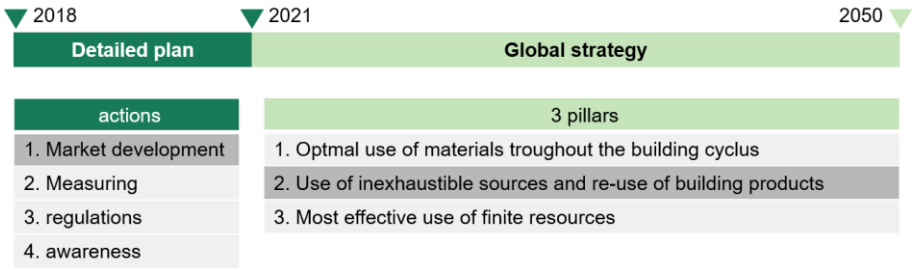


Figure 6 Transition Agenda overview

The transition agenda will be referred to for justifying certain decisions in the research design for the following reason: from the logic in this chapter it follows that reuse strategies will not hold in the current market. Therefore, the legitimacy of a research on the reuse of building products depends on a unity that seeks to change the current market to allow for re-use strategies to be applied. The transition agenda does exactly that.

2.2.3 Repurpose

As client of the research, the company Repurpose provides motivation for a research on reuse because it demonstrates that the feasibility of reuse has already been increasing

REPURPOSE

Figure 7 Logo Repurpose

So far, reuse of building products has been the topic of this report. The client of the project focusses on re-use of building products in his business model. Repurpose is a company that advises professional clients about the proper use of circular building products in their projects and arranges the supply of these products through a broad network of demolition contractors and suppliers of sustainable products. Repurpose basically forms a chain between buyers and suppliers of circular products.

Repurpose is an example of a company that responds to the governments influx to stimulate reuse strategies by the market. The fact that Repurpose is doing well can be interpreted as proof that the government's policy is catching on. Whereas the transition agenda justifies attention for reuse, Repurpose provides the motive for conducting the research on reuse. The government is trying to stimulate reuse by pushing the market and Repurpose is acting as an agent for achieving that goal.

2.2.4 Demand for insights

The feasibility of reusing different products is the topic of the research because it helps the government allocate resources and it helps Repurpose gain focus in its business

Both the government's effort and Repurpose would benefit from a better understanding of the direction in which the reuse market will be moving during the upcoming years.

The government. Among the four steps that are to be taken up until 2021, it is stated that the first priority is to create market development. In the pursuit of this goal, several specific actions are proposed for which budget has been allocated. Among these actions are the following:

- If possible, (local) governments have to reward circular ambition in tenders
- Subsidies will be handed out to companies with circular business models

About the subsidies that are to be handed out it is mentioned that research on different product categories is required but especially in the case of supply-increasing measures it is made to understand that more knowledge is needed because it is planned to enforce financial incentives in the near future according the Transition Agenda. The bottom line is, that research is required to determine which products lend themselves for large scale reuse and which ones do not. Moreover, this research recognizes that it is not a desirable outcome if the government has to keep contributing (financially) in the long run to keep the market for second-hand building products alive. It is hypothesized that a temporary influx by the government can help a market grow to a level where it remains self-sustaining after the government's financial contribution ends.

Repurpose. Anno 2019, the publication of the transition agenda for the building industry from 2018 is a recent event. It is observed by Repurpose that it has a positive impact on the number of projects. Basically, more clients in construction projects want their project to be circular and need help to achieve this. If Repurpose is hired, specific building products are searched and found. It is Repurpose's job to find out in which cases reuse is viable, or more precisely, which exact building products are viable to re-use in a specific situation.

Because the trend is rather new, market parties like Repurpose deliver mostly customized advice for unique situations. However, with the prospect of a fully circular economy in the future, one can reason that demand for reuse strategies will further increase. If reuse is going to be applied on a larger scale it gives a mediator like Repurpose a competitive advantage to know beforehand which building products will generally be more viable to reuse. This way, transactions can be handled much quicker.

Conclusion. Since Repurpose is on the frontier of reusing products, is not only benefits from growing demand for different products but it also plays a role in creating demand and supply. This way, the company really is an agent for the circular economy, making it all the more worthwhile to help them understand which products have the potential for future markets to develop. Based on the interests from both the government and Repurpose to find out which products are worth focussing on, it is concluded that there is indeed value in answering the main question.

2.3 The B2B market

The research focusses on the B2B market rather than the B2C market because it turns out that there is more reason to believe that there is more potential for growth

In the previous subchapters, it has been clarified that reuse would contribute positively to the environment, and that it is worthwhile to try to understand which markets can arrive because this helps the government and involved companies to actually make it happen. The question remains why building products from demolition projects should end up in the B2B market instead of the B2C market; or better, why should this be the topic of the research? To address this question, the alternative B2C market is evaluated first. Then, it is explicated why the B2B market deserves the focus of the research based on two arguments.

2.3.1 B2B and B2C market

The B2B market, which comprises of purchases for construction projects is more complicated than the B2C market which comprises purchases made by individual parties

In order to prevent confusion about the difference, the distinction between the B2B (business to business) market and the B2C (business to consumer) market are explained here.

B2C market. This term is used to refer to all building products bought by private parties. the main characteristic that makes up the difference between purchases by a professional and a private party, is the fact that the latter is charged with 21% in taxes whereas the prior can deduce it from taxable income. Typically, in the linear economy, B2C purchases are made in hardware stores by people who work around the house in the weekends. These are simple transactions, involving small batches and relatively high profit margins. In the case of CE, it involves private parties buying second-hand products.

B2B market. This term is used to refer to purchasing building products to be applied in construction projects. Besides the difference in taxes and the fact that purchase in the B2B market typically come in larger batch size, the whole purchase process in the B2B market is much more complex than in the B2C market. In this research the purchase process is modelled as an interplay between a supplier and a builder. In practice, the 'builder' comprises of a composition of a contractor, subcontractors, an architect and advisors. Also, instead of buying a product and applying it right away, months or even years of planning exist between the moment in which an architect decides which product to use and the moment in which it is actually applied by the contractor.

2.3.2 The B2C market is stagnant

All though there already is a B2C market for second-hand building products, it appears to be the case that is will not provide the growth needed for enabling a lot of additional reuse

In the first sub-chapter it was already addressed that only 0.24% of building products is reused. This is not much but it is something nonetheless; in other words, there is in fact a tiny market for reusing building products in existence. Some web research results in the conclusion that there are in fact demolition contractors who sell second-hand building products. There are several websites where demolition contractors offer salvaged products from demolition projects (insert.nl, oogstkaart.nl, etc.). on top of that, there are demolition contractors who offer building products on their own website.

It is only a modest portion of all demolition contractors that seem to have a business in reusing building products, but some of these businesses are quite serious. However, if one searches for cases where second-hand building products are applied in the construction of new buildings, only a couple of examples are found (e.g. Liander headquarters by RAU). Apparently, a lot more is sold from demolition

projects, than is applied in new projects. The explanation is simple; almost all reused building products end up in the B2C market. Typical buyers are farmers who need cheap materials, hobbyist looking for authentic looking merchandise and perhaps some renovation- and installation companies looking for specific products. Figure 8 shows the conceptual distribution of sales among the B2B and B2C market.

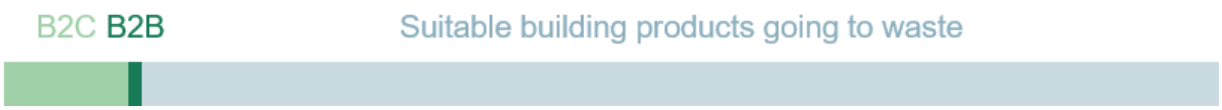


Figure 8 B2C market vs B2B market

Although the B2C market seems more promising at first glance, interview data from this research (Appendix 3) reveals that the B2C market for reusing building products is not growing. If anything, the market seems to be shrinking. Several demolition contractors talked about other contractors who had to quit their reuse business and multiple complaints have been expressed about the fact that farmers need less materials nowadays and that hobbyists prefer to go to the hardware store since the 1990s because they have become to lazy to do the additional that is required for reusing building products.

Contractor 10 - "20 jaar terug hadden ze (net als veel andere slopers) een hele werf, "toen kwam de gamma", "en de generatie met twee linker handen"

2.3.3 The B2B market has government support

Although reuse by the B2B market seems to be more complicated than reuse in the B2C market, the fact that the transition agenda especially focusses on the B2B bodes well

It has been established that reuse of building products is not increasing in the B2C market so the natural question to ask is whether this is in fact the case in the B2B market. At first sight, reusing more building products in the B2B market looks even less likely because it is a much more complicated market than the B2C market; after all, there is a reason why it is seldom done. However, it has been established that the government made reuse its mission and if one looks at the measures proposed in the transition agenda one will notice that most measures focus on the B2B market in particular. The potential of reuse in the B2C market might in fact be a blind spot in the transition agenda, but regardless of the fact that reuse in the B2B market might proof out to be very challenging, the prospect on government support makes it more worthwhile to look into.

3 Exploration

Which knowledge must be gained for identifying second-hand building products for which a self-sustaining B2B market can arise?

This picture was taken at Van der Heijden B.V.

The goal of this chapter is to answer the sub question about determining which knowledge is required for answering the main question. For determining which knowledge must be obtained, it is first determined which relevant knowledge is still missing in current literature. To do this, exploratory interviews are conducted with market parties to be able to define which knowledge is relevant for the research. Then, a literature study is done to find out which knowledge is lacking. This lack of knowledge is referred to as the *Research Gap*.

After defining the Research Gap, the scope of the research is defined in order to focus the available time and resources on obtaining the lacking knowledge that is most essential for answering the main question of the research. Doing so, the research is made more specific but on the other hand, some assumptions need to be made; these will be addressed in the discussion chapter. Finally, the remaining scope of the research is made measurable by introducing a Theoretical Framework that describes the metrics that dictate what kind of method must be developed for answering the main question.

Three subchapters cover the Research Gap, the scope of the research and the Theoretical Framework. On the basis of these subchapters, this chapter's sub question is answered as follows:

Because it is still unknown what the costs are for reusing specific products in different situations and because tacit knowledge from demolition contractors can provide solid knowledge about disassembly, the research question is approached from the supply side by proposing that a self-sustaining B2B market for reusing a product can arise if it is demonstrated that enough products can be supplied at a quality that builders are used to, for a price that builders are willing to pay, while covering the demolition contractor's additional costs and leaving enough profit to support a middleman who facilitates the market

3.1 The Research Gap

In order to focus the research, it is explored which knowledge is absent in literature and based on exploratory interviews, it is mapped what is known in practice about this gap

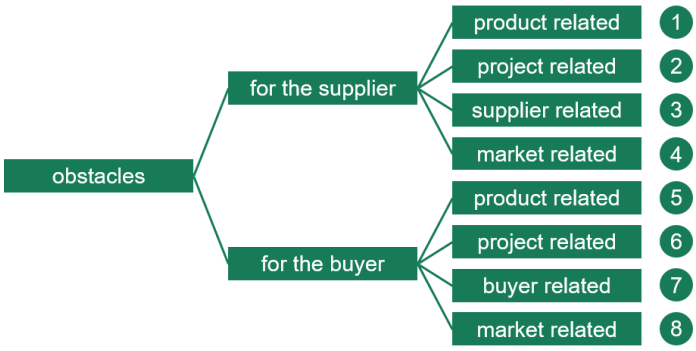
From the background chapter, it follows that it can benefit government and businesses to find a method for determining which reuse markets might arise. The question that follows is whether there is already knowledge on the topic that might help create such a method, and if there is, which knowledge is still missing. The latter is referred to as the Research Gap; the missing knowledge for fixing the problem. The most common way to search for a gap in the existing knowledge is to conduct literary research. This is done for this research as well. From literature review it turns out that there is indeed a Research Gap. So many things are actually still unknown about the Dutch reuse business, that exploratory interviews are conducted as well as a supplement. the literature review, followed by the exploratory research, are addressed here.

3.1.1 Exploratory interviews

Exploratory interviews that have been conducted as an addition to the literature review, yield an overview of the obstacles that decrease the feasibility for buying and supplying reused products

Exploratory interviews have been conducted with four market parties to get a better understanding of the reuse business, shown in Figure 9. The main focus of the interviews was to find out what makes reusing building products less economical than wasting building products from demolition projects and buying new ones to be applied in construction. It is reasoned that there are *Obstacles* that make up the difference between reusing products and applying new building products. It is reasoned that the fact that reuse proves to be less economical can be contributed to these obstacles. Therefore, with the interviews, an attempt is made to find out what the obstacles are for reusing building products.

Obstacles that cause reuse to not be feasible have been identified in the transcript of the interviews. These obstacles basically make up the disadvantages that make reuse in the B2B market uneconomical compared to the new building products and waste processing that both the builder and supplier are familiar with. The specific obstacles together with the full transcripts are included in Appendix 1. To summarize the findings, the obstacles have been categorized in eight categories shown in Figure 10.



The supplier, or demolition contractor in other words, faces obstacles that decrease his feasibility to supply. Similarly, the builder faces obstacles that decrease feasibility to apply second-hand building products. These obstacles will be the guiding factors for determining which products have market potential in the method that is to be developed. Below, the obstacles are explained in more detail:

1. Product related obstacles for the supplier include difficulties with specific products that are impossible for suppliers to overcome with current best practices. E.g. disassembly of some products can be unhealthy or dangerous (requiring for safety measures)
2. project related obstacles for the supplier are obstacles that hinder reuse of product and are unavoidable for the supplier. They are caused by specific project conditions. For example, sometimes there is not enough time for disassembly products
3. Supplier related obstacle for the supplier concern obstacles that only apply to a part of the suppliers. The fact that only some contractors face these obstacles suggests that they can be overcome. E.g. it costs a lot of time to train staff for disassembling in a proper way. Some contractors have trained staff and others don't; this is related to the contractor
4. market related obstacles for the supplier concern all the costs, additional time and risk caused by the fact that there is no suitable infrastructure for supply and demand to find each other. For the supplier this implies for example that he needs to takes a risk by storing products that might not be bought.
5. Product related obstacles for the builder include difficulties with specific products that are impossible for builders to overcome with current best practices. E.g. some second-hand products that are prone to wear down don't come with a warrantee.
6. project related obstacles for the builder are obstacles that hinder reuse of products and are unavoidable for the builder. They are caused by specific project conditions. For example, sometimes a project has advanced too far because of which, the description of required building materials worked out it too much detail in order to find a second-hand match.
7. Builder related obstacles for the builder concern obstacles that are caused by the way of doing business or mindset of the builder. E.g. builders fear that reuse is at the expense of quality, certainty and price. Not quality itself is the obstacle here but rather the prejudice. Since habits and mindset are based on past experiences it is reasoned that these conditions can change if the builder is exposed to new experiences.
8. market related obstacles for the builder concerns all the costs, additional time and risk caused by the fact that there is no suitable infrastructure for supply and demand to find each other. For the builder this implies for example that it costs a lot of time and effort to find suitable products for a project.

3.1.2 Literature review

From literature review it turns out that disassembly and design for reuse are popular topics but none of the articles give insight in the potential of different products on a macro level

Since the research tries to say something about the possibility for a reuse market to arise for specific products, the most logical thing to search for in literature is the market potential of different reusable products. The eight categories of obstacles described before are used as format to search for relevant literature on the market potential of reusing second-hand building products. For reusing a product, first, it must be disassembled and sold. Then, the product also must be bought and applied. In line with the obstacles overview in <figure>, literature about demand and supply are reviewed separately. After discussing different sources, it is assessed to what extend existing literature covers the eight different obstacles in order to define the research gap.

Supply. This concerns disassembly of different building products from different types of buildings by demolition contractors and the profitability of selling these products. The following types of research have been encountered about supply:

Guy, B. (2004). Reuse and recycling of building materials. In the abstract of the paper it is explained that it covers a case study of the deconstruction of six houses in Florida, USA, to examine the cost-effectiveness of deconstruction and salvage when compared to traditional demolition. From the description it seems that the cases cover stand-alone, wooden houses. The paper provides useful insights in the different cost drivers in demolition processes and it is mentioned that costs depend on the project although this is not further elaborated upon. The conclusion is that, for these buildings, deconstruction saves costs compared to conventional demolition but it fails to mention how different products contribute to these cost savings.

Denhard, H. (2010). Deconstructing disaster: Economic and environmental impacts of deconstruction in post-Katrina New Orleans. The abstract mentions that the paper covers findings of reclaimed material from four deconstructed houses. As well as *(Guy, 2004)*, this paper compares deconstruction costs with conventional demolition costs and concludes that deconstruction was cheaper in the investigated cases. Furthermore, this paper gives more detailed information about the available products; the local market price of the reused products is provided as well as the number of products that was salvaged. However, only the total costs of deconstruction are addressed whereas it is not clear what the costs for individual products are.

Endicott, A. (2005). Final Report | Research on Deconstruction (p. 12). This is a thesis report from a Civil Engineering student who did research on deconstructing buildings. It provides information about the different products that are suitable for reuse and about the method of deconstructing them. Also, the research explicates the environmental impact of different building products.

Besides these researches, there are sources that provide insights in the quantity of available materials and products in buildings. *(Hurley, 2003)* for example explains which results stem from different pre-demolition audits of office buildings in the UK, providing an overview all building products. *(TNO, 2018)* provides a useful overview of the occurrence of different building materials in total in the Netherlands.

From the literature it can be concluded that there is quite a lot of recorded knowledge about disassembly. Clearly, disassembly is a viable option for certain buildings in the USA. Some case studies have been found about reuse from Dutch buildings as well such as *(Te Dorsthorst, 2001)* which explores the possibility of reusing concrete elements in apartment buildings. So, there is some knowledge available about Dutch buildings as well. Also, it turns out that it is well known among specialized disassembly businesses which products are suitable for trading and which ones aren't. Based on the fact that second-hand building products are also being sold by Dutch demolition contractors, it can be concluded that this is not limited to the USA either. However, we can only draw conclusion from specific cases rather than on a macro level and it is not clear what the costs are for disassembling and trading specific products; it is only provided what it costs to disassemble entire buildings.

Application. This concerns knowledge about the possibility and costs of applying second-hand building products in construction. It turned out to be challenging to find useful sources about this topic.

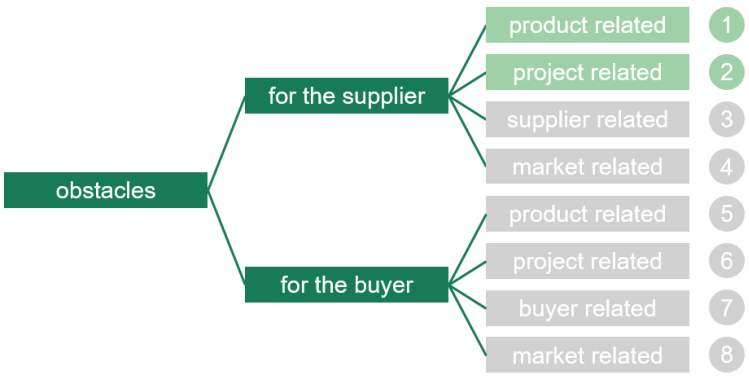
Durmisevic, E. (2006). Transformable building structures: Design for disassembly as a way to introduce sustainable engineering to building design & construction. This is an influential paper about reusable buildings. The paper raises awareness among builders that the building industry has a large environmental impact and it proposes a solution by designing for disassembly. The paper does not address the application of second-hand products in buildings though.

From literature review it turns out that papers about the application of second-hand products in buildings are pretty scarce in fact. The only product for which multiple researches were found that cover reuse in buildings, is concrete. *(Sivakumar, 2004)* for example, explores what is the effect of reusing aggregate in concrete mixtures on shear resistance. *(Batayneh, 2006)* is another paper about concrete mixtures that addresses the question whether demolition waste such as aggregate, but also glass and plastics can be used to substitute parts of concrete mixtures for new constructions. Both papers address an import topic since concrete represents a large part of demolition waste but it does not help to answer the research question since it aims to draw conclusions about the feasibility of applying many different products. In practice, building products have been reused in a couple of projects (Alliander headquarters, e.g.) but unfortunately, no documentation has been found on the implications of reusing the different products that have been applied.

Conclusion. It seems that disassembling as well as applying building products is possible in some cases but in practice it is clear that it does not happen on a large scale. Why different types of products are not reused on a large scale cannot be found in literature. About supply it can be found which products can be disassembled but it remains unknown what the costs are for supplying these products. Also, whereas it has been demonstrated in literature that some projects are suitable for reuse, this is limited to a couple of specific cases. About the product- and project related obstacles it can therefore be concluded that relevant knowledge is partly available; this is indicated with light green in <figure>.

Also, from the reviewed papers it did not became clear what the effect of different demolition contractors is on the possibility for reuse to succeed. Furthermore, no relevant literature was found regarding the market related obstacles that hinder supply of second-hand building products except for the notion that demand is lacking (Endicott, 2005). These two obstacles are therefore indicated in grey. When looking at literature about demand for second-hand building products, the main conclusion is that there is not much written about it; demand related obstacles are therefore coloured grey.

Concluding; even though there is knowledge about deconstructing building, in the light of the question which building products have economic potential to be supplied and applied on a large scale it can be stated that the research gap spans all challenges encountered in the exploratory interviews. In the chapter about the scope, it is addressed which obstacles are considered for research.



3.2 The scope of the research

The research aims to answer the question how the supply costs in the B2B market of second-hand products from conventional buildings can be determined

By defining the scope of the research, the definition of an economically feasible market is made specific. The more extensive the scope, the better will the developed method simulate reality. However, an extensive scope also means that it will be more work to come up with a solution that satisfies all variables. Since this research has limited time and resources, the scope is narrowed down to cover only a part of the reuse obstacles that were defined as Research Gap. Here, it is laid out in five steps what the restrictions of the research are. Each of the five parts of this subchapter describes one of the following restrictions with justification for making the restriction:

- Within the B2B reuse market, only the *supplier's obstacles* are investigated
- For conducting the research, *perfect market conditions* are assumed
- Only *contemporary capabilities* are considered when assessing to option for parties to reuse
- The research focusses only on reuse from *total demolition*, no renovation
- The criteria for measuring feasibility are narrowed down to just *financials*

3.2.1 Focus on the supplier's obstacles

The research focusses on the supplier's obstacles because demolition contractors possess tacit knowledge from practice while this is lacking for builders

Figure 11 shows a transaction in the B2B market for second-hand building products. In line with the background chapter, a deal between the two parties must be economical for both of them meaning that the builder must receive good value for his money and that the Demolition contractor (demo crew in figure 11) must receive enough return for his effort. In line with the exploratory interviews, the obstacles for both parties should be small enough for the transaction to take place. The challenge for reuse can be addressed from two sides to uncover for which products it might be possible for transactions to take place:

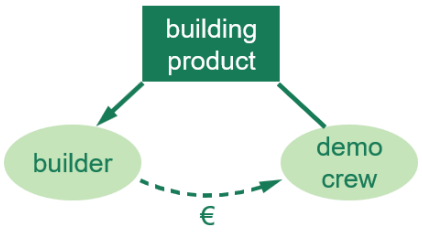


Figure 9 Reuse transaction

1. As a starting point, the demolition contractor evades his obstacles to supply second-hand products without extra effort. From an interview with Roosros (Appendix 2), this appears to be a challenge that builders face when reusing in the current market; they have to arrange everything by themselves. For research, the question would be how big the obstacles for builders are to see for which products the obstacles are low enough for a market to arise.
2. As starting point, the supplier has to overcome his obstacles and account for obstacles of the builder to supply second-hand products in such a way that the builder receives the value that he is used to when applying new building products. Then the question is for which building products the obstacles are small enough for the supplier to get enough in return for his effort.

For the research, the second approach is chosen for a practical reason, namely, that lots of tacit knowledge about the supplier's obstacles can be obtained by studying the already existing B2C market while knowledge about the builder's obstacles will be very hard to find since there is almost no practical experience with applying second-hand products in construction. In the research, *only the supplier's obstacles* will be addressed while it will be assumed what the quality of the supplied products must be in order for the builder to not experience obstacles with the application of the product.

3.2.2 Assumption of perfect market conditions

For modelling the market, market obstacles are neglected, thus it is assumed that information and the opportunity to trade is available to everyone and that buyers and suppliers act fully rational

Determining whether it is possible for a market to arise for specific products, a model of the market is needed. The expectation is that a market for reusing products will differ from any conventional market for newly produced building products. This means that a new model needs to be designed which might be a challenge. Taking into account all sorts of effects that influence real markets would overly complicate the task at hand for this research. Therefore, the most basic economic principles are used as starting point, namely:

- Buyers and suppliers will always choose the most economical option
- Buyers and suppliers are aware of, and have access to respectively all supply and demand in the market

Furthermore, from the exploratory interviews it became clear that product related obstacles, supplier related obstacles, project related obstacles and market related obstacles hinder suppliers from supplying second-hand building products in the B2B market. It has been indicated that these obstacles should be the factors to consider in developing a method for determining which markets can arise. However, it has been decided that *the market related obstacles will not be addressed*. The reason for this, is the fact that the research focusses only on supply and market obstacles for the supplier are inextricably linked with the buyer's behaviour; for a supplier it costs more to supply building products if it harder for him to find a buyer. To cancel out the market related obstacle, it is assessed whether supply is feasible in a market that has already arisen (with plenty of demand). This is a restriction to the research because the mechanisms required for the market to arise are neglected. As a compromise, a qualitative analysis is done in in chapter 3.3.4 to demonstrate that it is at least plausible for markets to arise if it is proven that they can be maintained once they are already arisen.

3.2.3 Focus on contemporary capabilities

The research focusses on the feasibility for supply based on existing capabilities of demolition contractors because it is considered surrealistic to predict innovations and the effect of investments

Kirscher's definition states that CE is enabled by *novel business models* among others. The focus of the research lies on the supplier and attention therefor goes out to novel business models that can be adapted by demolition contractors. It is reasoned that demolition contractors can engage in new business models in three different ways. *1)* they could innovate to come up with new technologies for reusing certain building products. *2)* contractors could invest in obtaining existing technologies that they did not possess before. *3)* if contractors are not reusing currently, they can change their behaviour to start reusing while using their current technology.

In order to maintain an overview on the possibilities for reuse markets to arise, the scope is limited to contractors changing their behaviour using current technology rather than investing in technology or innovating to find new solutions. In line with the exploratory interviews, *the supplier related obstacles stay unchanged*. This is a restriction to the research since these obstacles can actually change. However, the possibility for contractors to invest or innovate actually increases the possibility for reuse markets to arise. Thus, this restriction to the scope actually makes for a conservative outcome.

By the way, although innovations and investments by demolition contractors are not considered, a second party that is involved in supply, the middleman, is introduced in the next subchapter. This party is in fact expected to make certain investments in order to facilitate reuse markets.

3.2.4 Focus on total demolition

Because the market for total demolition is easier defined than for renovation, the scope will be limited to total demolition to fulfil the need to reduce the number of research variables

Building products can be released from total demolition, where a building is completely removed, or from renovation demolition, where parts of the building are removed (and replaced). Both types of demolition are interesting to consider because they both form a source for reusable products and both procedures are part of the same industry. However, addressing both procedures would add an extra variable to the research because total demolition comes with different considerations than renovation.

It is expected that it will be difficult enough to come up with an answer to the main question without variables such as the difference between two types of demolition projects and for that reason it is determined to select only total demolition. The reason for selecting total demolition projects is the fact that it is exactly clear which products are released. This makes it much easier to define the potential market size which turns out to be of importance for predicting market potential. Although total demolition accounts for a larger part of the demolition industry *(CBS)*, leaving out renovation is a restriction to the research. For what its worth, this restriction leads to a conservative outcome.

3.2.5 Focus on financials

This research focusses only on the financial implications of reuse because it is hard to measure how people validate environmental impact in their decision

In accordance with the deduction from chapter 2.1.5, the government needs to ensure that the additional environmental quality by reuse is perceived as more valuable by individuals and businesses than its decrease in economic prosperity, if the governments wants people to reuse. In order to achieve this, the government can theoretically adopt two strategies:

1. The government could somehow drive actors in the market to attach more value to the increased environment quality produced by reuse by raising more awareness
2. The government could (financially) compensate economic losses by reuse or it could increase the financial losses for the alternative, buying or selling new products

Alongside the deduction from chapter 2.1.5, it was indicated that awareness about the environment and attention for circularity are already quite high while it did not seem to motivate people to start reusing building products. It is hard to see how more awareness would change everyone's mind set all of a sudden. In defence of the first strategy, a rise in circular projects has been observed by Repurpose since the publication of the transition agenda. As mentioned before, it is hard however, to determine if these effects can be traced back to a genuine drive to preserve environmental quality or whether they are driven by the financial gains from publicity. Concluding, results from the first strategy are non-existent at worst and hard to measure at best. This leaves the financial strategy.

In line with this argumentation, the research focusses only on financial aspects of reuse: any other value in the form of environmental quality or social equity (from the original definition) are not taken into account in determining the possibility for reuse markets to arise. Leaving out the possibility that parties are willing to sacrifice financial gains because of their concerns for the environment luckily leads to a more conservative outcome of the research.

3.3 Theoretical framework

With the theoretical framework, the metrics are defined that can be used to determine whether a market can possibly exist for a product to be supplied feasibly

By developing a theoretical framework that describes the potential market for reusing products, the result of the research becomes measurable and explainable. The theoretical framework that is proposed here consists of four individual models:

1. The Cashflow Model demonstrates how cash changes hands between the actors in several value chains, corresponding to different end-of-life strategies. The value chain of products that end in landfill is presented as well as the value chain of products that are reused in the B2B market because these two value chains are used in the Feasibility Model.
2. The Feasibility Model compares the earlier mentioned value chains in order to demonstrate the choice to reuse or not to reuse (landfill) that each actor faces. It then uses the cashflows from the Cashflow Model to deduce the parameters that dictate whether reusing a building product is feasible with respect to supply.
3. The Market Size Model provides insight in how the acquired parameters from the Feasibility Model can be used to determine whether a market for reusing a certain product can exist. Once again, this model approaches the issue from the perspective of the supplier.
4. The Market Development Model attempts to support that it is justified to hypothesize that a market that is able to exist according to the Market Size Model, but cannot arise by itself, can in fact arise by the help of subsidy and remain self-sustaining after the subsidy is annulled.

3.3.1 The cashflow model

When cashflows are added to the value chain of a building product, the gross profit of any party engaging in the value chain can be determined and compared to the profit in an alternative value chain

In chapter 2.1.3, where the Emergy model was proposed, Emergy was presented as proxy for environmental impact. The use of energy and resources, or emergy in other words, comes with a financial cost as well, simply because resources cost money. To demonstrate this concept, the proposed model from chapter 2.1.3 is converted here, to represent the flow of money throughout the value chain of a building product in Figure 12. It shows the direction in which cash usually flows between the involved parties. The outgoing cashflows from all acting parties represent the costs of their operations. For example, a supplier pays a miner for raw materials, spends cash to transform the raw materials into building products and receives a payment from a builder in exchange for the building products. Similarly, it goes for the builder, the demolition contractor, the owner and recycler.

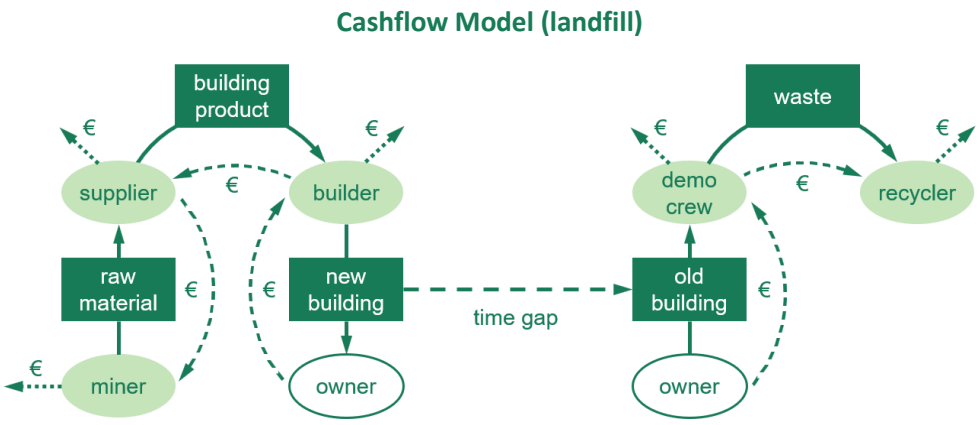


Figure 10 Cashflow Model (no reuse)

The cashflow model from Figure 12 corresponds to the value chain of a non-circular waste processing strategy; in this case landfill. Here, the value chain ends with the recycler. The cashflow model looks different for different waste strategies. Figure 13 illustrates the cashflow model of the B2C reuse market, where, for example, the builder and the owner of the new building both represent a hobbyist who builds a barn in her garden with second-hand lumber.

Here, the owner of an old building pays a demolition contractor to disassemble the building. The demolition contractor then spends cash to transform the building into building products which he sells to the builder (the hobbyist) who then spends cash to transform the second-hand building products into a new building (a barn in this case). Sometimes, in practice, the value of the second-hand building products is higher than the disassembly costs of the building. in that case, it could be the case that the demolition contractor pays the owner of the old building. However, from literature *(Guy, 2004)* this appears to be atypical since the disassembly costs seem way higher than salvage value in this research. For this reason, it is assumed that the demolition contractor gets paid by the old owner in the model.

Cash Flow Model (reuse, B2C)

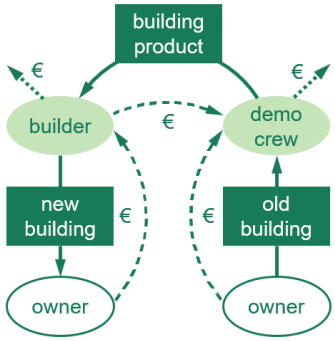


Figure 11 Cash Flow Model for reuse in the B2C market

For addressing the research question, the cashflow model for reuse in the B2B market is required. This model ought to look similar to the model that is presented in Figure 13 but as explained earlier, the B2B market is different from the B2C market in the sense that it is more complex. From the exploratory interviews, it turned out that buying directly from demolition contractors poses logistical challenges and problems with the quality of the product. In the scope of the research, it was explained that such problems have to be taken care of in order to be able to compare second-hand products with new products and answer the main question. In a discussion with Repurpose, it is reasoned that there is need for a tertiary party that temporarily stores and possibly upgrades the product in order to make reuse possible in the B2B market. To account for these aspects, an additional actor is added to the Cash Flow Model; The *Middleman*, see figure 14. Here, the middleman purchases the building product from the demolition contractor, spends some cash for tasks such as transport, storing and perhaps upgrading the product after which he sells it to a builder who pays him for the product.

Cash Flow Model (reuse, B2B)

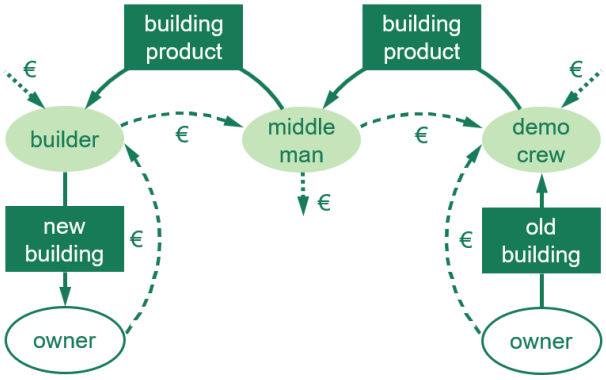


Figure 12 Cash Flow Model for reuse in the B2B market

In the different Cash Flow Models that are presented here, the profit per product can be determined for each party in the value chain by subtracting the outgoing cashflows from the incoming cashflows. in the case the owners of the old and the new building, outgoing cashflow can be subtracted from the

received value (such as a new building) to evaluate the quality of the deal. In a perfect market, no party will engage in a value chain if the outgoing cashflows are larger than the incoming cashflows or received value. Also, when given a choice between engaging in different value chains, actors will choose the one that yields the best value/profit. This is how the Cash Flow Model is used to synthesize the Feasibility Models as described in the next subchapter.

3.3.2 The Feasibility Model

The Feasibility Model compares the value chains reuse and no reuse to deduce the parameters that dictate whether it is feasible for the supplying parties to reuse

By comparing the cashflows in the value chains that correspond to different waste processing strategies, it can be analysed which value chain results in the highest profit per product for any party in the chain. Based on the differences in profit between value chains it can be assessed which value chain is more favourable for an actor to engage in. This difference is captured in the *Feasibility Model*, shown in figure 15. Basically, the Cashflow Model for Reuse and landfill are combined to visualize the choice for owners, builders and demolition contractors between engaging in either one of the value chains. The feasibility to reuse for these parties is derived from the difference in profit margin; If a party makes more or equal profit or value in the reuse-value chain than he would make in the non-circular value chain, it is said to be feasible for the party to reuse. Since this research focusses on supply, only the feasibility for the demolition contractor and the middleman are considered while the decision between reuse or no reuse for the other parties is considered to be indifferent.

The Feasibility Model

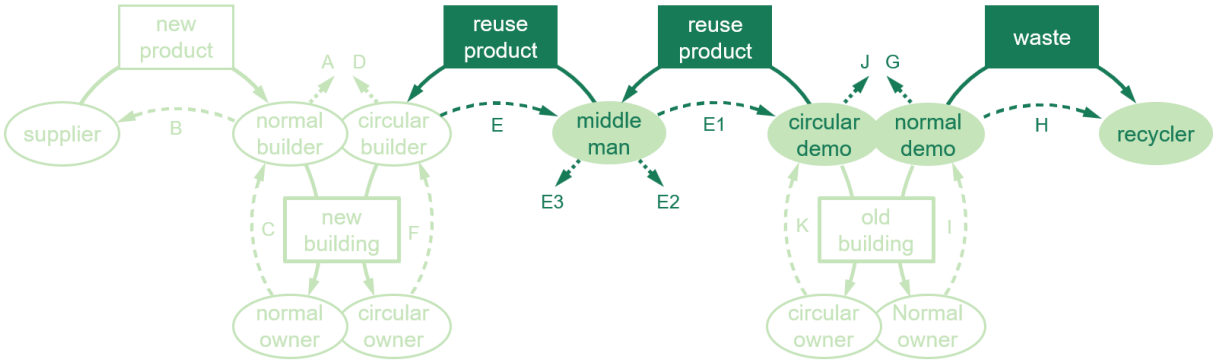


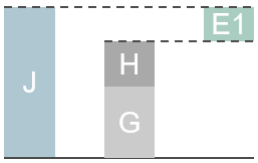
Figure 13 Feasibility Model

A. Normal Apply Costs
B. Normal Product Price
C. Normal Project Price
D. Reuse Apply Costs
E. Reuse Product Price
E1. Reuse Purchase Costs
E2. Middleman's Costs
E3. Middleman's Profit
F. Reuse Project Price
G. Normal Demo Costs
H. Normal Waste Costs
I. Normal Project Price
J. Reuse Supply Costs
K. Reuse Project Price

In order to be able to refer to individual cashflows in the model, each one of them is labelled. The labels are explicated above. Since only the demolition contractor and the middleman are addressed, other cashflows are indicated in a lighter colour. In line with the assumption that only financials are considered, it is assumed that cashflows K and I are equal; owners of demolished buildings will not pay more for reuse. These cashflows therefor don't contribute to the demolition contractor's decision because of which they are indicated with a lighter colour as well. Up next, the relevant metrics are introduced for determining feasibility for the demolition contractor and the middleman.

Demolition contractor. Based on the Feasibility Model, the metrics for supply feasibility for demolition contractors can be defined. A demolition contractor has a choice between reuse, in which case he engages in circular demolition (*circular demo*), or normal demolition (*normal demo*). On the basis of cashflows *E1*, *J*, *G* and *H*, the gross profit for circular demolition can be compared with the gross profit for normal demolition. Reuse is feasible for the demolition contractor if circular demolition is equally or more profitable than normal demolition; this is demonstrated here in mathematical form:

Reuse Demo Profit (R) = E1-J (+K)
Normal Demo profit (S) = -G-H (+I)
Supply Feasibility (U) = R-S or E1-J+G+H (+K-I)
Reuse is considered feasible for the demolition contractor if U > 0



According to (*Schraven, 2019*), parties involved in a transition towards CE make parties responsible that have the greatest impact on their business. In general, the most impactful party for any business can be considered to be the party that brings in revenue for the business. This implies that demolition contractors will only engage in the supply chain for reuse if another party pays to cover the additional expenses compared to normal demolition. Since it is assumed that owners won't pay extra for circular demolition, the additional expenses (*J-G*) need to be covered by the Reuse Purchase Costs *E1*. Based on this logic, the relevant metrics for the demolition contractor can be expressed as follows:

Reuse is considered feasible for the demolition contractor if E1 is large enough:

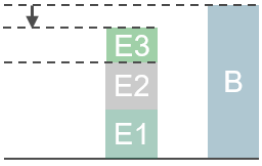
E1 > J-G-H (+I-K)

Middleman. The feasibility for the middleman is defined differently than that of the demolition contractor or the other parties. Whereas the demolition contractor's core business is to remove old buildings and reuse or no reuse merely represent two alternative ways to achieve this goal as cheaply as possible, the middleman on the other hand, is only in the business for reusing. The middleman only has one option; for him the question is if the reuse business is profitable enough. If the business turns out to be not profitable enough, he won't engage in the value chain and reuse in the B2B market won't be possible as a result. The middleman's profit per unit can be expressed by the following formula:

Middleman's profit E3 = E-E1-E2 or E3 < E-E2-J+G+H (-I+K)

The total profit made by the middleman depends on the profit per product *E3* and the number of units sold (*n*) which is addressed further on; here, let's just look at the profit per unit. Applying Schraven's findings implies that Builders must pay a price *E* that is high enough to result in a unit profit *E3* that leads to an acceptable profit. Since there will be no reuse without the middleman, the question is whether the builder is willing to pay the price *E*. The Builder's choice is left out of the scope so it must be assumed that *D* is equal to *A* and that *C* is equal to *F*. As a result, it can be concluded that reuse price *E* must be equal or lower than the equivalent price *B* of new products in order to make reuse feasible for the Builder; leading to the following formula:

Middleman's profit E3 < B-E1-E2



Conclusion. Figure 16 demonstrates the different parameters that were introduced by the Feasibility Model and the mathematical correlation they have with one another. According to the model, a value chain can only exist if reuse is feasible for both the middleman and the demolition contractor so their feasibility is used to derive the formula for reuse feasibility.

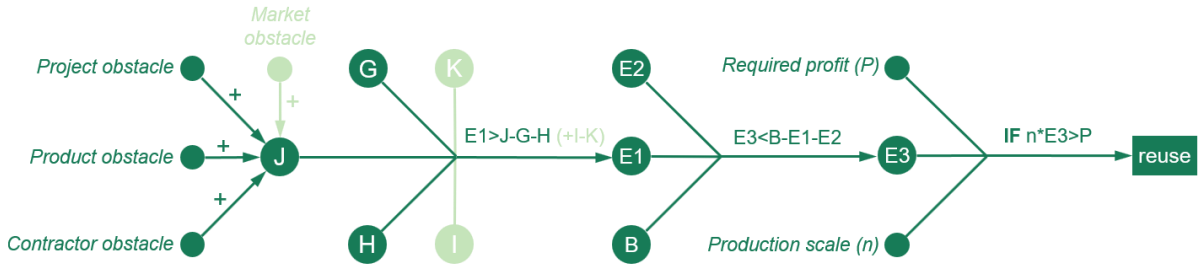


Figure 14 Parameters from the Feasibility Model

E1. Reuse Purchase Costs
E2. Middleman's costs
E3. Middleman's profit
B. Normal Product Price/Quality
G. Normal Demo Costs
H. Normal Waste Costs
I. Normal Project Price
J. Reuse Supply Costs
K. Reuse Project Price

Whether it is feasible for the middleman depends on middleman's production scale *n* and the profit *E3* per unit sold. the profit per unit depends on price *B* that the builder is willing to pay, the middleman's costs *E2* and the price *E1* that the middleman has to pay the demolition contractor to make it feasible for him. The latter depends on several factors including the Reuse Supply Costs *J*. As an addition to the parameters from the Feasibility Model, figure 17 illustrates the obstacles that were extracted from the exploratory interviews; each one of the obstacles leads to an increase in the costs *J*, decreasing feasibility. In line with the scope of the research, the market obstacle is neglected here.

3.3.3 The Market Size Model

The Market Size Model plots the total unit costs for a middleman for different production scales and compares them with product price to assess how large the resulting profit is

Together, the parameters from the Feasibility Model can be used to answer the question whether a reuse value chain for a certain product can exist. From figure 16 it could be derived that not only needs the value chain to be feasible for the concerned parties but also that a minimal required number of transactions is required in order for the middleman to engage in the value chain. This observation is used in this subchapter to define whether a reuse market can exist or not:

If there is a market size at which the average middleman's profit per unit (E1) multiplied by the number of units (n) leads to sufficient profit for the middleman, it is considered possible for a market for reusing a product to exist

For simplicity reasons, a single *Hypothetical Middleman* is considered who has access to the entire Dutch demolition market; In line with the assumption of a perfect market, he is aware of all purchase options and he always pays a just price to the demolition contractor and receives a fair price from the builders. Since it is assumed that he is the only middleman, a market is considered to be possible if he alone can capture a sufficient profit from the Dutch reuse market.

To calculate the Hypothetical Middleman's profit, *n* and *E3* are required and to calculate the latter, the values of *E1*, *E2* and *B* must be determined. The *Market Size Model*, shown in figure 17 relates these parameters to one another. The model shows three curves of which the third one represents the middleman's costs at different production scales which are compared to his income to see whether it is possible to make a profit. The first two curves plot the middleman's purchase costs *E1* and production costs *E2* respectively at different production scales. The super position of these curves results in the third curve. The shapes of the curves are hypothesized and explained hereafter.

Market Size Model

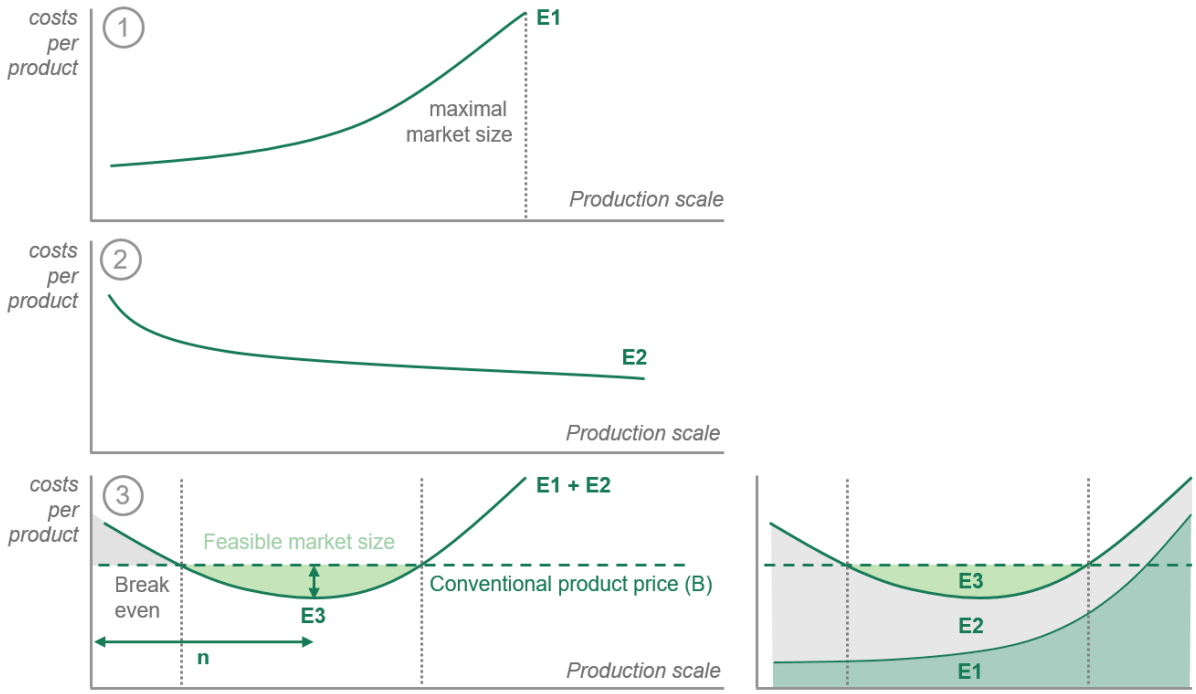


Figure 15 Market Size Model

1. Purchase Costs (E1) are the Hypothetical Middleman's costs that involve purchasing toilets from demolition contractors. The key takeaway is, that for a given product, the Purchase Costs will vary for different situations due the difference in contractor- and project related obstacles. The top diagram in the Market Size Model shows that the average Purchase Costs per product will rise as the production scale increases. This logic is in line with the assumption of a perfect market; for any production scale, the middleman will only purchase the cheapest products and only if he wants to sell more and increases his production scale, will he purchase the more expensive ones. At some point, there are no more products to purchase because there is a limited number of demolition projects in a year; this is the Maximal Market Size.
2. Middleman Costs (E2) are the Hypothetical Middleman's costs apart from the Purchase Costs. This costs curve has more resemblance with that of a conventional business. Economy of scale results in lower average costs per product if the production scale increases. This effect can be attributed mostly to the fact that fixed costs will be spread out over more products.
3. Supply Costs (E1+E2) represent the total unit costs for supplying second-hand products to the B2B business. If the Supply Costs are exactly the same as the price that buyers will pay (assumed to be *B*), the Hypothetical Middleman will break even. If the Supply Costs drop below the price (*B*), the middleman makes a profit on each product sold, leaving a total profit of *E3* multiplied by the number of sold products *n*. It is considered possible for a market to arise if the product of these two parameters can be considered reasonable compared to the investment. The curve will look different for different products; if the curve lies to high relative to the Conventional Product Price, it is considered to not be possible for a market to exist.

By recreating the three curves from the Market Size Model, it can be determined whether a market for reusing a product can exist; these are the final metrics required for answering the question whether a reuse market can exist. Whether a market can arise by government influx and remain self-sustaining afterwards, is addressed in the final model.

3.3.4 Market development model

The Market Development Model attempts to support the hypothesis that feasible markets according to the Market Size Model can arise with subsidy and remain self-sustaining afterwards

The Market Size Model demonstrates whether a B2B market can exist as regards to the feasibility of supplying second-hand building products and it is presupposed in the research that there are products out there for which this is the case. However, this presupposition is not in line with the observation that almost no B2B markets for second-hand products exist anno 2019; why have no entrepreneur already succeeded if reuse is supposedly feasible? From this miss-match it can be concluded that second-hand products that are supposedly feasible to supply are not being traded because there is a problem with demand for the products.

Some of the demand related problems are already covered in the research by including costs that are required for upgrading second-hand products to meet B2B standards concerning quality and logistics. This cancels out product- and project related obstacles. In line with the observed obstacles in the exploratory interviews it must therefore be the market- and buyer related obstacles creating the miss-match. Simply put, if, based on the developed method, it is concluded that a product can be supplied for a competitive price, at a required quality standard and in such quantities that is profitable for all involved parties, reuse might still not be possible in the current market because builders cannot find the product or because owners don't trust reused products (Appendix 1).

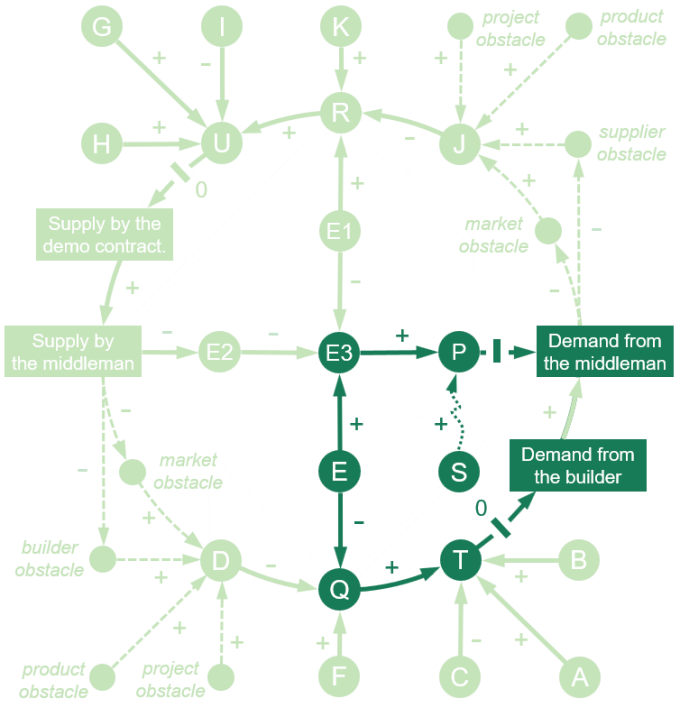
In line with the background chapter, a temporary government influx is presupposed to help overcome the mentioned issues. For example, the outcome of this research might suggest that a production scale of 5000 second-hand toilets per year can make for a profitable business while an entrepreneur is still not willing to invest his funds in this business because he fears that no one will buy the products because they are not used to it or because they just don't like the idea of a reused toilet (regardless of the quality). Then comes the government: subsidy allows the entrepreneur to supply 5000 second-hand toilets a year which he can actually sell because he offers them for half the price and because he has budget for extensive marketing. The entrepreneur builds a reputation and people start to see that there is nothing wrong with second-hand toilets. As a result, after two years in the business, the middleman can ask the full price for his toilets and he does not need the subsidy anymore.

The transformation of the hypothetical business described here, represents the decrease of buyer- and market related obstacles as a result of market development. The hypothesis that a temporary government influx can help a market to arise and remain self-sustaining depends on this phenomenon. Quantifying the mechanism is not part of the scope but by means of the *Market Development Model*, the concept is illustrated in an attempt to support the hypothesis that the research is depending on.

The Model is shown in the figures on the last page. It captures the effect of the earlier introduced parameters on one another. Two versions are shown to be able to transfer the idea in full. The first illustration of the model captures the mechanism by which subsidy can allow for a stagnant market to arise. The Second figure illustrates how the reduction of market- and builder related obstacles can help a market develop in order for it to stay self-sustaining after the subsidy stops. the demonstrated feedback mechanisms work as follows; if a parameter increases and the parameter next in line increase as well as a result, the influence is positive, indicated with a +. Opposite, the influence is negative (-) if the parameter next in line decreases as a result of an increase of the first parameter. In both versions of the model, the relevant interactions are indicated in a darker green. Up next, these interactions are explicated. Finally, unlike the Feasibility Model and the Market Size Model, this model does not result in metrics that are used throughout the research but is considered to be essential for understanding why results from this research help answering the research question.

If a middleman wants to sell second-hand toilets, there is a maximum price *E* that he can ask from the builder because the builder will just buy new toilets if price *E* is to high; there will be no demand for reuse if the Application Feasibility *T* is less than zero, which will be the case if the builder's profit *Q* is to low which is the case when *E* gets too high. No demand means no reuse. Thus, reuse is only possible if *E* is low enough but if *E* gets too low, reuse is not possible either because the Middleman's Profit *P* would then be too small. By increasing profit with subsidy *S*, the middleman can sell cheaper in order to reach a production scale that is sufficient. By the way, by looking at the entire model, it can be observed other influxes like rewarding circular demo projects (raising *K*) have similar effects on the middleman's profit.

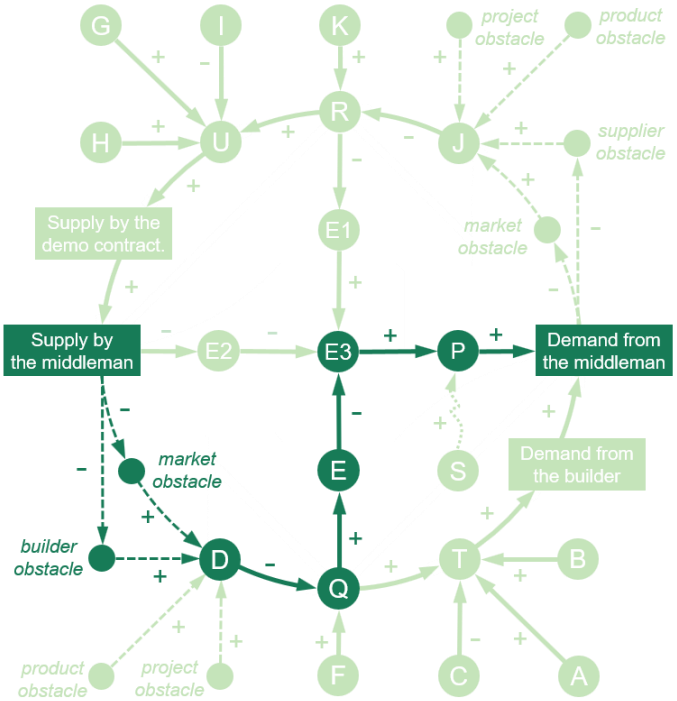
Market Development Model (1)



A. Normal Apply Costs
B. Normal Product Price
C. Normal Project Price
D. Reuse Apply Costs
E. Reuse Product Price
E1. Reuse Purchase Costs
E2. Middleman's Costs
F. Reuse Project Price
G. Normal Demo Costs
H. Normal Waste Costs
I. Normal Project Price
J. Reuse Supply Costs
K. Reuse Project Price
P. Middleman's Profit
Q. Reuse Builder Profit
R. Reuse Demo Profit
S. Subsidy
T. Application Feasibility
U. Supply Feasibility
E3. Middleman's Unit Profit

Once the market has arisen by subsidy (or other influxes), there will be more supply. The increase in supply logically leads to a decrease in two obstacles. 1) the market obstacle, which entails that finding second-hand products costs much time due to scarcity, decreases because supply becomes more plentiful. 2) the builder obstacle, which entails that reusing costs extra effort because builders' procedures are not attuned to it, decreases because reuse becomes more normal. By decreasing these obstacles, it costs less to reuse (*D*), meaning that the builder can pay more (*E*) while maintaining the same profit *Q*. By the increase in *E*, the middleman's profit *P* increases, meaning that Subsidy *S* is no longer needed. this change in circumstances makes it plausible that a market maintains self-sustaining after the subsidy ends.

Market Development Model (2)



4 Methodology

How do we synthesize and validate a method for determining if it is possible for a B2B reuse market for certain building to exist?

This picture was taken at Weba Bouwmaterialen B.V.

As mentioned in the introduction of the report, the research attempts to develop a method for answering the question whether a self-sustaining B2B market for reusing specific products can arise. This chapter explains how this method is synthesized and validated. In the Exploration chapter, the Feasibility Model and the Market Size Model were introduced to provide the metrics for the method that is to be developed. It was explained that the Market Size Model illustrates whether a B2B market can exist for a certain product and that this provides an answer to the main question within the scope of the research. In line with this logic, a method is proposed for reconstructing the two cost curves from the Market Size Model for different products to arrive at the Supply Costs Curve. This method will be referred to as the *Market Assessment Method*.

Furthermore, from the literature review it became clear that knowledge is lacking about the demolition contractor's costs for supplying particular second-hand building products in different situations. These were later referred to as the Purchase Costs *E1*. Determining *E1* is essential for reconstructing the Market Size Model and it therefore plays an important part in the Market Assessment Method. Specially for the purpose of determining *E1* for different products, a tool is therefore developed, referred to as the *Purchase Costs Tool*.

The methodology for the Purchase Costs Tool in particular and the Market Assessment Method in general are each addressed in a separate subchapter. These subchapters have been structured to consist of three parts. First, it is described what the intended result ought to look like. Then, the methodology is proposed for synthesizing the tool and the method respectively, accompanied by a strategy for gathering data. Finally, it is explained how the tool and the method will be validated. These subchapters can be summarized to answer this chapter's question as follows:

The Market Assessment Method provides a step-by-step instruction manual for plotting the average Supply Costs (E1 + E2) for a product at different production scales to evaluate if a market for reusing the product can arise and as part of the step-by-step manual, the Purchase Costs Tool will be used to compute Purchase Costs E1 for different products in different situations.

The Purchase Costs Tool should be synthesized by interviewing experienced demolition contractors and validated by proving that the tool corresponds to their stories, and the Market Assessment Method should be demonstrated with a case study addressing a specific product.

4.1 The Purchase Costs Tool

The Purchase Costs Tool is envisioned as a tree structure composed of the operations, decisions and circumstance described in interviews with demolition contractors

The Purchase Costs Tool actually aims to be able to calculate the Purchase Costs E1 for many products in different situations. By offering a way to generate this knowledge, the Purchase Costs Tool fills the Research Gap found in the literature review. In this chapter the plan is laid out to make this happen.

First, a rough design for the Purchase Costs Tool is proposed to provide the reader with an understanding of how a tool should be able to calculate costs for many different situations. After a clear understanding of the envisioned tool is established, it is explicated what kind of method is used to synthesize the tool. Since the tool aims to fill the Research Gap, the focus of the method lies on the way in which new data is collected. Finally, the strategy for validating the Purchase Costs Tool is explained; after all, there must be a way to determine whether the result is legit.

4.1.1 Envisioning the Purchase Costs Tool

The tool is envisioned to resemble a tree structure consisting of operations, decisions and circumstantial splits that depend on the product, project and the contractor

As explained, the Purchase Costs Tool will compute the price (E1) for different products in different situations. Let's look at those situations. In the Exploration chapter, it has already been proposed to consider three main obstacles: project obstacles, product obstacles and suppliers' obstacles. This suggests that obstacles can differ for different products, projects and different demolition contractors. The Purchase Costs Tool aims to calculate the costs of purchasing all sorts of products, from various sorts of projects executed by different types of demolition contractors. The combinations between different projects and different contractors are referred to as *situations*.

The processes that a demolition contractor will have to go through for reusing a product, will be referred to as *Paths*. It is hypothesized that these Paths will differ in different situations and because the Purchase Costs Tool aims to compute costs for many situations, the tool should represent many Paths. If many different Paths are laid over each other, a structure will emerge with different branches. Conform this logic, the Purchase Costs Tool is envisioned to resemble a tree structure. this concept is shown in Figure 18 and further elaborated upon hereafter.

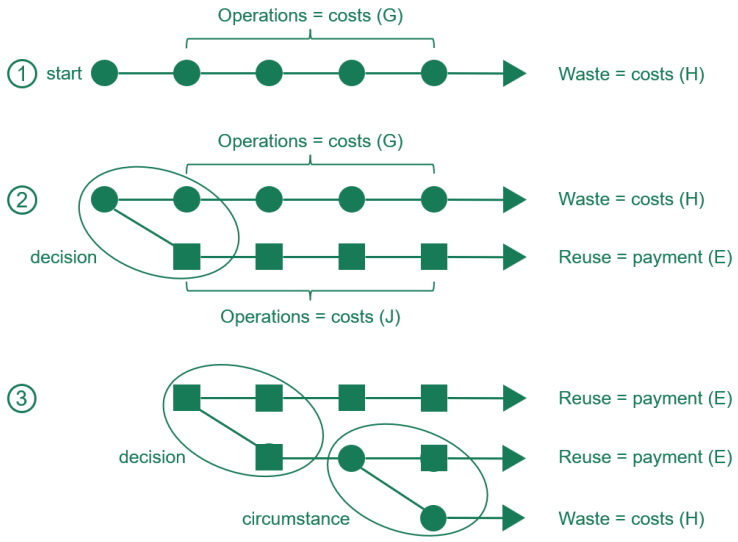


Figure 16 Envisioned paths

1. The first process demonstrates the outlines of a conventional demolition process of a product, in a project, performed by a certain demolition contractor. the different dots represent *operations* that bring about the Normal Demo Costs *G* in the form of manhours, energy and equipment. These costs vary depending on the product, project or contractor. At the end of the process the product is wasted, which (mostly) comes with costs as well.

2. The second process demonstrates disassembling and selling the product parallel to the first process of demolishing and wasting a product. The squares represent the operations for reuse that lead to Reuse Supply Costs *J* and at the end of the process the product is sold which yields a payment *E1*. The split at the beginning of the second process represents a *decision* by the contractor which might depend on the product, project or contractor. this decision can be attributed with a percentage for each of the outcomes to be chosen.
3. The third process suggests that contractors with the same goal of selling the product might decide to take alternating routes based on the product, project or contractor. On top of that, a *circumstance* is illustrated that forces a contractor to take a certain route because of external conditions. Not surprisingly, these circumstantial deviations also can be attributed a percentage as to the number of times a circumstance emerges.

Whereas the Purchase Costs Tool should facilitate the process of all combinations of products, projects and contractors, the tool will be used to plot a specific combination of these three factors at a time. The result will be a path through decisions and operations that results in sum of operational costs and payment (E-J) that can be compared by the sum of the costs if the conventional path would have been taken (-G-H). See Figure 19.

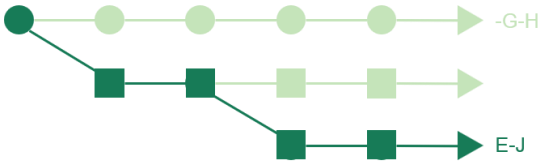


Figure 17 One path per situation

4.1.2 Gathering data for the Purchase Costs Tool

During two series of interviews, pictures of building products are presented and discussed in order to discover how operations, circumstances and decisions differ per product, project and contractor

As mentioned before, the main reason for focussing on the supply side of the market is the fact that there is a lot of tacit knowledge about reuse available among demolition contractors. For this reason, it is chosen to use interviews with demolition contractors as source for information. Based on online research, an overview of circular demolition contractors is made. A selection of contractors from the overview has been approached for an interview. Variation is applied to the selection in order to get a comprehensive view; demolition contractors (mostly) and traders; large and small contractors; urban and rural contractors; contractors with or without a boutique. The effort resulted in extensive conversations with the 15 different parties. Appendix 3 includes all transcripts.

Figure 18 All interviewed demolition contractors

Here, it is addressed which topics were discussed during the interviews, what kind of format was used to lead the interviews and what kind of interview method and strategy were applied.

Topics. During the interviews, three main topics are addressed, namely, the product, the project and the contractor. a short description of the three topics is discussed hereafter. Appendix 4 contains an overview of the actual questions that were asked although this list has evolved over time.

1. Contractor's profile. In order to identify differences in the way different contractors handle certain situations, general questions about the company are asked such as: size of the contractor, type of equipment they use, type of projects they do, etc.
2. Project types. In order to get a broad understanding on the influence of different type of projects on the reusability of products, questions are asked about the different types of projects in general and the attitude of the contractors towards these projects. Examples of questions concern the type of projects that contractors come across, whether the yields from reuse are significant enough to take into account in the project price, etc.
3. Product types. Questions about the reusability of different products forms the main part of the interviews. By interviewing a certain person, the product is automatically put in context with different types of contractors. Also, the products are put in context with different projects. By showing different places where the product can be found. Examples of questions are; whether it is in good shape; whether it is disassembled and why not in case of NO; which operations are needed for disassembly; who buys it, etc.

Interview format. In order to provide a means of communication about the extensive number of products and projects, the decision is made to present images of the products and projects as shown in figure 21. A page shows a picture of a typical building surrounded by products that can be found in it. The products are labelled in order to keep track during transcribing. Furthermore, some basic information about the project is provided in order to recreate a realistic scenario for the interviewee to imagine. The type of projects and products that were shown originate from a part of the research that is further elaborated upon in context of the Market Assessment Method.

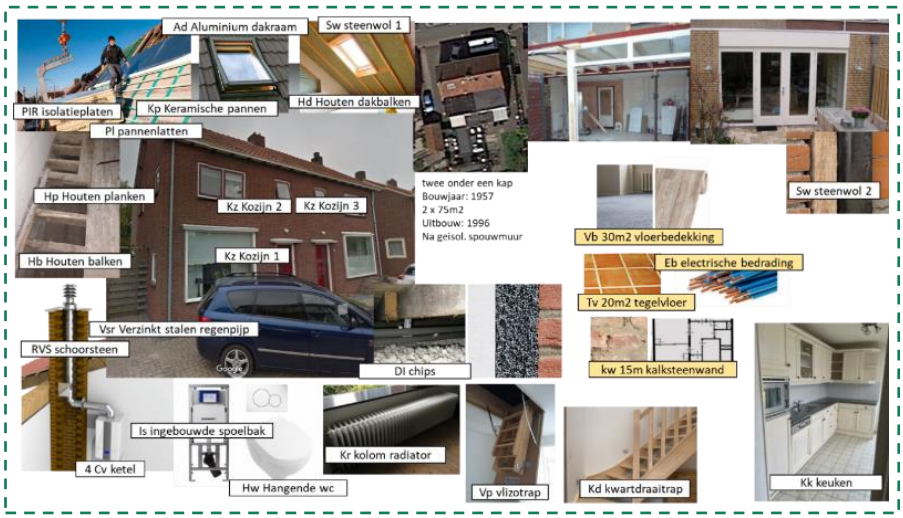


Figure 19 Example interview case

Interview method. The interview style is semi-structured. During the interview there is a list of questions to fall back on but if the interviewee takes a side road to talk about other experiences or angles, it is welcomed. In that case, the opportunity is grabbed to elaborate on the new topic. There are two reasons to choose for this style:

- Personal insights from demolition contractors lead to a better understanding of the industry. It is unrealistic to think that it is possible to predefine all relevant questions. Personal stories from experts will most likely lead to relevant additional information about products and projects and might also lead to additional projects and products that have not been considered
- From the exploratory interviews it turned out that a fully structured interview will probably not work with experts in the field. Time is valuable for the contractor and there must be something in return for the interview; namely, the opportunity to share experiences. If the interviewee cannot tell his story uninterrupted, the conversations is bound to end quickly.

Research strategy. When deep diving into a new field, it is unrealistic to think of all the right questions beforehand. As a result, the semi structured interview method, as described in the interview method, will result in an evolving understanding of the demolition business with an evolving list of questions as a result. A strategy has been thought up to lead this process in the right direction. Two phases are defined with a milestone in between:

1. Diverging Phase. Through the first series of interviews an attempt is made to cover all relevant products in combination with accessory projects. The goal of this phase is to map the differences between products / projects (and contractors, since many were interviewed) and to figure out which products are interesting. During this phase, a list with standard questions is constantly updated to filter out irrelevant questions and add new question. Also, a list is maintained with products specific questions. This list is supplemented after each interview.

   Milestone. Once (almost) all products and accessory projects are addressed during the Diverging Phase, a milestone is reached. At this point, a selection is made from the most interesting and diverse products. If contractors are able to tell extensive stories about reusing or explicitly NOT reusing a product it is considered interesting, especially if the stories are contradictory. At this point, many product specific questions probably have been written down. The reason for making a diverse selection is the fact that the Purchase Costs Tool ought to cover a broad range of different products from different projects.

2. Converging Phase. Through this phase, the list of product specific questions about the selected products is processed. As a result, more questions are probably added to the list after each interview which will be processed during the following interviews. The goal of this phase is to learn as much as possible about the operations for disassembly, the decisions by different contractors and the circumstance that contractors face in different type of projects. If saturation of knowledge about a product occurs, it can be taken of the list.

4.1.3 Validating the Purchase Costs Tool

On the basis of the transcript and an additional interview with an expert, the separate elements and their sequence, respectively, are validated

The Purchase Costs Tool is the backbone of the research. It generates most of the input for the Market Assessment Method which basically combines all this input to deliver the end product. Therefore, if the Purchase Costs Tool gives false results, it cannot be concluded if there is a suitable market size, and hence, the main question from the research cannot be answered. To answer the research question, it is therefore needed to validate the Purchase Costs Tool. Three aspects from the tool need to be validated in order to be confident to use it. These aspects and their validation method are shown here:

1. Interpreting the transcript. The data that is used to synthesize the Purchase Costs Tool will consist of many pages or written transcript. The tool itself will be a technical composition of different elements. There must be a way to convince the reader that the elements of the tool truly originate from the transcript. To make this step traceable, a linguistic key is used to interpret different elements in the written text. The validity of this key is then verified by inviting a volunteer to use the same key on a piece of text to see whether the results match.
2. Collecting all elements. After verifying that written text can actually be interpreted as one of the different types of elements (Operations, Decisions and Circumstances), it must be demonstrated that all elements that are applied in the Purchase Costs Tool are actually grounded in the transcript. To do this, an overview is made in which each element is accompanied by one or more quotes from the transcript that verify its legitimacy
3. Creating the right sequence. Once all elements have been identified from the transcript, they have to be put in the right sequence. It is anticipated that the process of doing this will resemble a design process rather than following an algorithm because it is not expected that the right sequence will result from the transcript. Intuition will have to be used to determine the sequence. In order to validate the design, a demolition contractor will be asked to describe the process of reusing several products on the basis of the tool. The tool is approved if his process corresponds to the tool.

4.2 The Market Assessment Method

By combining input from the Purchase Costs Tool with other market data, the Market Assessment Method will demonstrate what the average costs for a product are for any production scale

Since the Market Assessment Method is just a set of steps for plotting graphs, less can be said about it than about the Purchase Costs Tool. Here it is envisioned which important parts make it possible to plot the concerned curves. Then, it is briefly discussed what sort of data will be used as input for the algorithm. Finally, it is concluded that a case study is most suitable way to demonstrate the validity of the developed method.

4.2.1 Envisioning the Market Assessment Method

The Supply Costs Curve will be reconstructed by combining the increasingly more expensive costs E1 from demolition contractors and the declining costs E2 of one hypothetical middleman

The Market Assessment Method is the end product of the research. It is envisioned to be a step-by-step guide for plotting a graph for Supply Costs (E1+E2) that resembles the graph that was introduced as the Market Size Model. this graph can be used to evaluate whether a reuse market for a product may arise. Therefore, by delivering this method and proving that it works, the research question should be answered. From the Market Size Model, it already stood out that two separate curves are needed to compose the Supply Costs curve; namely, the Purchase Costs curve and the Middleman Costs curve. Plotting these curves should be the goal of the Market Assessment Method. What these curves are envisioned to look like, is discussed here.

Purchase Costs Curve. This is the curve that will be computed by combining output from the Purchase Costs Tool applied to all different situations that are distinguished in the total market; Purchase Costs, E1. As follows from the Theoretical Framework, the Purchase Costs differ depending on the product, the project, and the type of contractor, and since the Market Assessment Method plots the curve for a single product, the tool needs to account for the Purchase Costs of a product for combination of the different contractors and the different projects that can be distinguished in the market. Figure 22 demonstrates that it would yield nine situations if there would be three types of contractors and three types of projects.

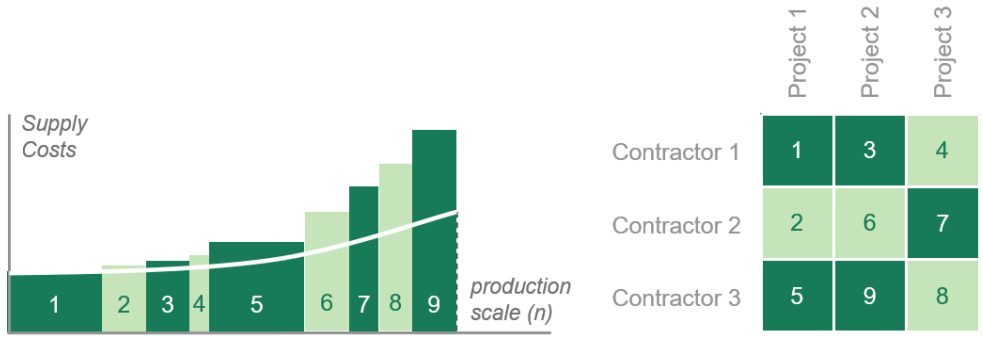


Figure 20 Purchase Costs curve

Each of these situations will have a market size and a value E1 (computed with the Purchase Costs Tool), resulting in the type of diagram depicted on the left. Assuming perfect market conditions, it should be possible to plot the average Purchase Costs per toilet that the hypothetical middleman has to make for a given production scale. (depicted in white). Part of the steps that make up for the Market Assessment Method will be contributed to gathering the required data such as market sizes of contractors and projects, and most of all, the cost per situation.

Middleman Costs Curve. This curve demonstrates the decrease of the Middleman's costs per product as his production scale increases. Quite intuitively this happens because of economy of scale but a description for the way in which the curve will actually be computed is provided here. The first step would be to determine the costs for a Dutch business dealing in a certain product. It is envisioned that the costs of a business can be divided in fixed costs and variable costs. The fixed costs per product will decrease if more products are dealt with while the variable costs per product will remain constant. The decreasing costs per product will theoretically approach the variable costs if infinite units are sold. This is all there is to it. It is envisioned that one of the steps in the Market Assessment Method will be dedicated to gathering data for reconstructing this curve.

4.2.2 Gathering data for the Market Assessment Method

The supply costs model will be quantified by combining the increasingly more expensive operation costs of different contractors and the declining costs curve of one hypothetical middleman

Whereas the Purchase Costs Tool is envisioned to be synthesized on the basis of newly gathered knowledge, the Market Assessment Method as envisioned here, is just a simple set of steps. No particular data needs to be gathered for synthesis. However, a lot of data needs to be gathered as input for the Market Assessment Method. The type of data that is acquired is explained here. Required data for the Middleman Costs Curve and the Purchase Costs Curve are discussed here separately.

Middleman Costs Curve. Logistics and storage are conventional things. Easily available key figures can be used for reconstructing them. In addition, it needs to be estimated what it costs to upgrade building products to match B2B standards. This will depend on the product.

Purchase Costs Curve. The Purchase Costs *E1* corresponding to different contractors, executing different projects are already provided by the Feasibility Model. What is needed, is the market share belonging to each type of project and type of contractor. two steps are required to complete these final parts of the model, namely:

1. Market share per project type or in other words, the different types of projects in which the product occurs and the corresponding share of the total number of products corresponding to each type of project. In order to achieve this, project types are defined based on web research, the number of times each type of project occurs on a yearly basis is determined based on the national administration of buildings (BAG) and the number of units of the concerned product in each type of building is estimated.
2. Market share per demolition contractor. The different types of contractors and their respective market share must be determined. In order to do that, architypes of demolition contractors must be defined based on the conducted interviews and the market share corresponding to each type must be based on market data.

4.2.3 Validating the Market Assessment Method

Considering the hypothetical nature of the Market Size Model, the results are validated by a case study whereas the input data is considered to be sufficient accurate without validation

Since the Market Assessment Method is merely a set of steps for gathering and processing certain data, Validation of the method itself seems trivial. However, there is a need to demonstrate that useful results yield from it. A case study about toilets seems to be a suitable to provide this demonstration. In the demonstration, all the required data about a specific product will be gathered and processed to recreate the Supply Costs curve. Assuming that the theoretical framewor which forms the basis for the method, is correct, it is presupposed that the outcome is correct as long as the input data is reliable.

5 Results

How can it be determined whether a self-sustaining B2B market for reusing toilets can arise by using the developed method?

This picture was taken at Schijf Restoric B.V.

This chapter displays the results of the work that was set out in the previous chapter; namely the development of a method for determining whether a self-sustaining B2B market for reusing specific products can arise. As was explained, the result is referred to as the Market Assessment Method, which makes use of the Purchase Costs Tool. The main achievement of the research is the Purchase Costs Tool. The synthesis of the tool rests on a lot of newly collected knowledge while the Market Assessment Method just combines the results from the Purchase Costs Tool with available data from the demolition market to arrive at a final answer. This chapter therefore emphasizes the Purchase Costs Tool.

The first subchapter covers the Synthesis of the Purchase Costs Tool. Here, all aspects of the tool are explicated to create an understanding of what the tool does, what it looks like and how it can be used. The second subchapter dives into the validation of the Purchase Costs Tool. The last subchapter demonstrates the Market Assessment Method in a case study which constitutes the end result of the research. Since the input from the Purchase Costs Tool is used in the Market Assessment Method, the tool is also demonstrated here. As was already revealed by the sub question of this chapter, toilets are the product of choice for demonstrating the developed method. A two-part conclusion can be drawn from validating the Purchase Costs Tool and demonstrating the Market Assessment Tool respectively:

From the validation process it follows that the Purchase Costs Tool can be trusted to provide input data for the case study

According to the developed method, which is based on the Market Size Model from the Exploration chapter, it is in fact possible for a self-sustaining market for reused toilets to arise

5.1 Synthesis of the Purchase Costs Tool

Different paths, built up of operations, decisions and circumstances throughout a demolition project provide a comparison between conventional costs and reuse costs to derive the required product price

The Purchase Costs Tool is synthesized to determine Product Costs *E1* of reusing a product depending on the type of project and the type of demolition contractor. The tool does this by comparing the conventional processes performed by demolition contractors with the most cost-effective processes for disassembling and selling the products to a hypothetical middleman. From this comparison, the required price is derived for which it is feasible to supply, based on the metrics defined in the Feasibility Model. because the tool must be applicable on many situations, it provides multiple *paths*. These paths consist of a chain of *operations* associated with costs in addition to *decisions* and *circumstances* that define the path. These *elements* are grouped in several *processes* that form nodes in the network of different paths. These processes themselves are organized by grouping them into four different *phases* in demolition projects. This sub-chapter demonstrates the different aspects of the Purchase Costs Tool.

5.1.1 Different paths and phases

The conceptual form of the feasibility model is an upside down tree with different paths branching out from the start to different waste strategies, covering four defined process phases

In order to make the model applicable to as many situations as possible, it is necessary to map multiple paths, forming the shape of some kind of reversed tree. Figure 24 provides a conceptual visualisation. The top of the reversed tree represents the start of the project which applies to all situations. On the bottom of the tree there are five possible outcomes, namely, the waste strategies from Lansink's ladder. Besides the fact that there must be at least five different branches in the tree (one for each strategy), there are also different possible routes to arrive at the same waste strategy. Which route is taken depends on the contractor, the project and the product. The tree can be divided in four phases that apply to all different paths. From synthesizing the tool, it turns out that the tool is quite naturally divided in these categories. In Figure 24, the phases are indicated with numbers that have the following meaning:

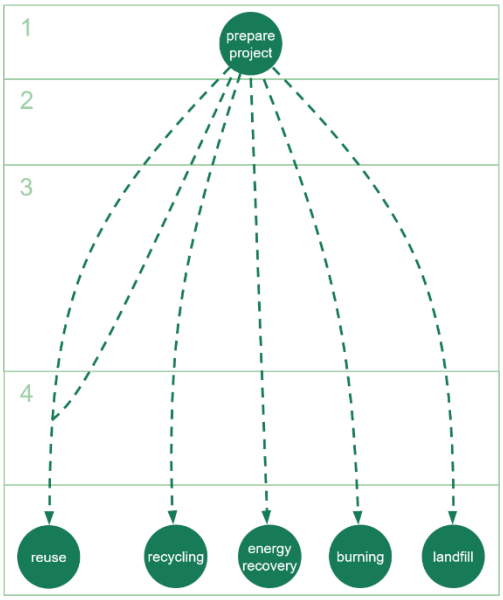


Figure 21 Conceptual design Purchase Costs Tool

1. Preparation of the work
2. The work (meaning breaking down the building)
3. Between the work and finding a destination to the product
4. Finding a destination to the product

5.1.2 Different processes

The different paths that a demolition contractor can take consist of a chain of processes that he has to go through to complete his job

The operations, decisions and circumstances that make up the tool are combined in groups that are referred to as *processes* here. The processes belong to a certain phase and each phase can contain multiple processes. The processes and the interconnecting paths that lead down to the destination of the product, summarize the Purchase Costs Tool. This summary is visualized in Figure 24. The numbers indicate different phases once again and the processes are indicated with numbers and letters (e.g. 2b). Note that there are many routes that a certain contractor might take when dealing with a certain product from a specific project. The path to the right (*b*) represents the conventional way of demolition. The different processes are further elaborated upon in the next sub-chapter. The different paths connecting the processes are explained in Appendix 5.

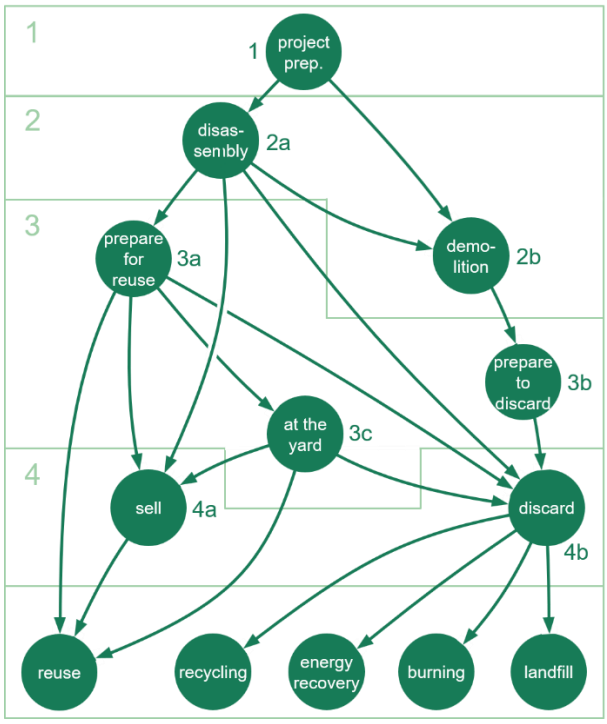


Figure 22 Different processes of the Purchase Costs Tool

The visualisation from Figure 24 can be considered as the user interface of the Purchase Costs Tool. When in use, the tool will show percentages and costs, attributed to the connecting paths and processes. this is demonstrated in Figure 25. What these data implicate is explained here.

Figure 23 Input & output Purchase Costs Tool

- Percentages. Each connecting arrow has a value attributed to it, representing the total percentage of units taking that path in a certain situation. Each process has a percentage of products going through it, equal to the sum of the percentages attributed to the arrows that point towards it. The sum of the values attributed to the arrows leaving a process must be equal to the sum of the values attributed to the arrows pointing towards it. The top process starts with 100% and all processes in a phase add up to 100% as well.
- Costs. Each circle representing a process has a value attributed to it that represents the cost of the process for a single product that is handled. The value depends on the percentage of products going through the process and the operations belonging to the process. Simply put, if the operations within a process add up to a cost of €10 for a product if 100% of the products go through the operation, the circle will show a value of €5 if 50% of products goes through the process. Adding up the costs of all processes results in the costs per product (*J-E1*).

5.1.3 Different elements

Each process is built up of several elements representing operations, decisions and circumstances

As explained, each Process from figure 24 represents a chain of operations, decisions and circumstances. This may have sounded abstract so far. Here, an attempt is made to clear up any confusion about the meaning of this notion. Figure 26 visualizes that each Process itself consists of a tree structure built up of elements (shown in the circle) leading from top to bottom. For a detailed overview of all elements, reference it made to Appendix 14. The input of the top most element is a percentage equal to the sum of all paths leading to it (in the example, one arrow originating from the process of disassembly). The blue elements are decisions, the green elements are operations and the red elements are circumstances. These individual elements are explained further on. Important to note here are the following:

- All elements have an input percentage that is passed on to the next element. Bifurcating elements spit this input percentage in two parts and distribute these in different directions.
- Only elements representing operations have a cost attributed to them. Thus, the cost of a process constitutes of the sum of the costs of operations multiplied by their percentages.
- Each element that is not followed by another element represents the end of a process. This is where the percentage attributed to the element is passed on to another process through one of the arrows from figure 24. The bolt words marking these elements indicate the next process.

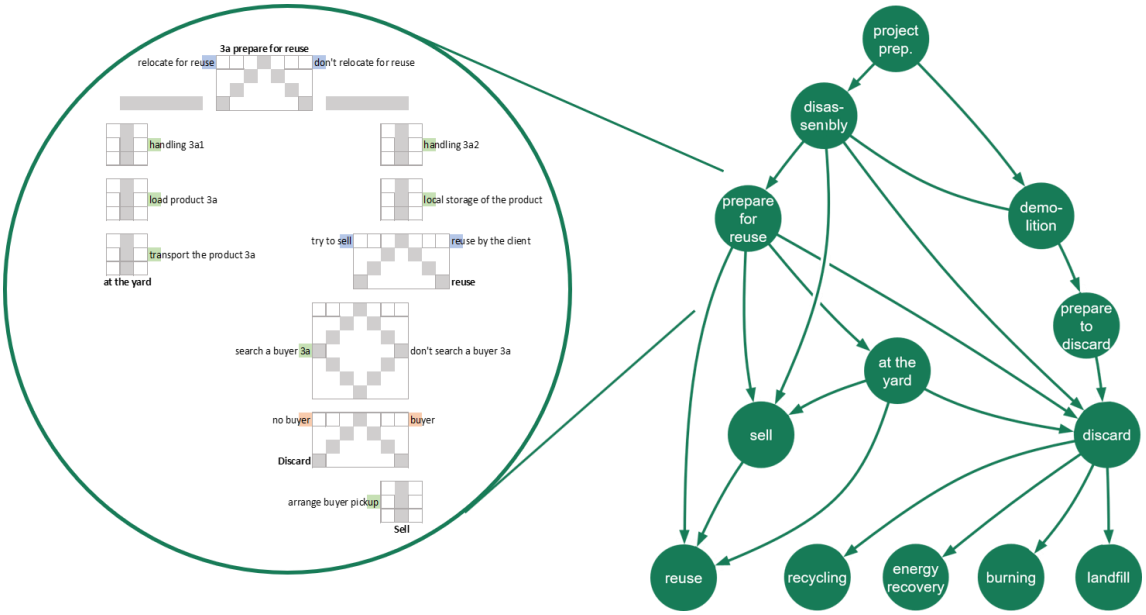


Figure 24 One of the processes highlighted

5.1.4 Operations

Elements that represent an operation compute a cost based on an input cost per product multiplied by the percentage of products that undergo the operation

Operations were described as elements that have costs attributed to them. Literally, this implies that everything a demolition contractor needs to do for dealing with a product that costs time, effort or resources, is labelled as an operation. In the Purchase Costs Tool, operations are represented by two types of elements, namely a single operation and a double operation. The difference is explained hereafter.

Single operations. The structure of an operation element is shown in Figure 27. it receives a percentage as input and it outputs the same percentage. The second input value of an operation is a value of cost. This value represents the cost for the operation for a single product. the cost output is the actual cost attributed to the operation, namely, the cost input multiplied by the percentage input. This output is added up with the cost output of the other operations belonging to a process to arrive at the costs of the concerned process.

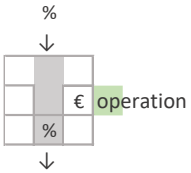


Figure 25 Single operation element

Double operations. The difference between a single operation and a double operation originates form combining different paths, demonstrated in Figure 28. It might be the case that the process followed in situation 1 or situation 2 are equal to one another except for one operation (B or C). the double operation element offers a way for capturing two options in one element. Besides covering two operations in one element it could also be the case that an operation is skipped in one of the situations. In that case, the double operation provides the choice between an operation or no operation. Finally, if both operation 1 and 2 occur simultaneously, part of the input percentage is attributed to B by factor (b) and the rest is attributed to C by factor (c). those percentages are then combined again and transferred to the next element.

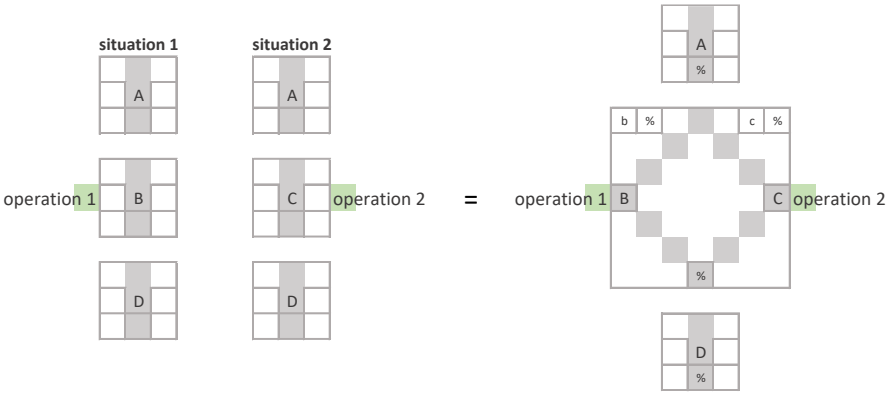


Figure 26 Double operation element

5.1.5 Circumstances

An element representing a circumstance takes the form of a bifurcation for which the two different outcomes represent different circumstances for a given situation

The word situation was reserved for describing a certain product from a certain type of building being handled by a certain type of contractor. Circumstances describe different cases that can occur in the same situation. For example, a certain demolition contractor working on a certain type of building can encounter a wholesome toilet or a vandalized toilet. Vandalism is the circumstance in this example. A circumstance has influence on the things that a demolition contractor will do next. An element in the Purchase Costs Tool representing a circumstance therefore takes the shape of a bifurcation with two outcomes shown in Figure 30.

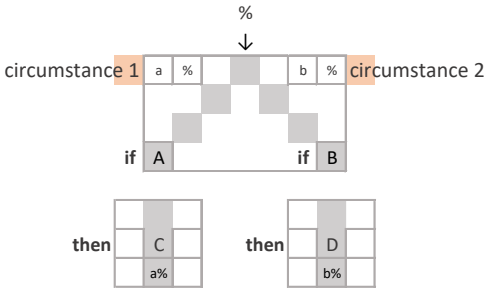


Figure 27 Circumstance element

Like all other elements, circumstance elements have an input value representing the percentage of products to which the element applies. Because the element takes the shape of a bifurcation, this percentage is split in two new values that are passed on to the subsequent elements. If the input is 60% for example, and 1/3 of the times circumstance A occurs, output A is 20% (1/3 * 60%). As a result, output B will be 40% (2/3 * 60%).

5.1.6 Decisions

Decision elements are added to the Purchase Costs Tool at places where paths corresponding to different situations deviate from one another

Whereas the circumstance element is defined as a bifurcation between two outcomes depending on different circumstances within the same situation, a decision element represents a bifurcation between two outcomes depending on the situation (contractor, product, building). if a different path is followed in two different situations, a decision element is needed in the Purchase Costs Tool to mark this location. See Figure 30. Just like the circumstance element, the input percentage is split in two parts and passed on to two different subsequent elements.

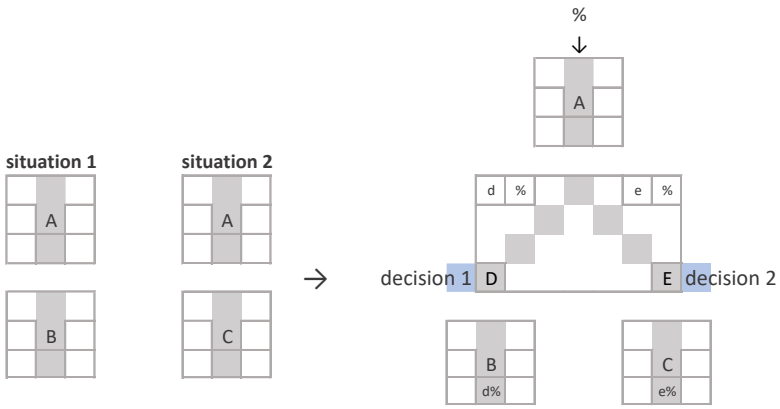


Figure 28 Decision element

Finally, note that a decision element does not necessarily imply that a demolition contractor needs to make a decision. On the contrary, the fact that decision elements mark the difference between two situations (defined by the type of product, project and contractor) implies that within a given situation, no decisions occur. Actually, from the transcript it seems that contractors commit to the same approach when dealing with a certain product from a certain building (unless circumstances within this combination differ). However, interestingly enough, different demolition contractors turn out to do different things with the same product from the same building, so in that respect, it appears to be a decision from the perspective of an independent observer.

5.1.7 Using the Purchase Costs Tool

To determine the price for which supply is feasible, the costs of the conventional path are compared to the most cost-effective path that enables reuse

The goal of the tool is to determine for which price it would be feasible for a demolition contractor to disassemble and sell a product. As was proposed in the Theoretical framework, reuse is feasible if the profit per product for reuse is higher than the profit per product of the conventional alternative. It was deduced that reuse is feasible when *E1 > J-G-H*. All four variables are integrated in the Purchase Costs Tool. A spreadsheet is created with a tabular interface for filling in all paths and operation costs as well as a canvas with a visualisation of the paths of the processes resembling the visualisation of Figure 26 which highlights the filled-out path. To use the tool, the following steps must be taken:

1. Determine the conventional path for a certain contractor dealing with a certain product from a certain building by drawing the path through all operations, decisions and circumstances.
2. Determine the most cost-effective path for which the product can be sold to the hypothetical middleman introduced in the methodology chapter.
3. Fill in the operation costs for both paths. The product price is left blank at this point. The tool outputs the reuse costs for both paths
4. Find the minimal price for which the reuse path results in a higher profit per product than the conventional path. The result is the price for which reuse is feasible for this situation

5.1.8 Application limits

Although the Purchase Costs Tool is widely applicable, it does not cover the full range of possibilities since it is based on a limited number of observations

It was envisioned that the Purchase Costs Tool would be capable of reproducing the chain of operations, decisions and circumstance of any building product, from every type of building taken care off by any kind of demolition contractor. Because of this, it ought to be able to calculate the costs of any such product. However, due to limitations of the method (interviewing a limited number of contractors), it cannot be guaranteed that the resulting tool will be applicable to all situations since the tool is based only on the products, projects and demolition contractors covered by the interviews.

Furthermore, the model represents a limited level of detail, meaning that disassembling and selling certain products could be described in more detail. This, on the other hand, is done on purpose. By compressing operations in the reuse process, it becomes generally applicable on different situations and it provides a better overview. Finally, only operations, decisions and circumstances that apply to specific products are addressed by the tool while costs that apply to the entire project (such as preparing a tender) are not included since these costs will be made regardless of the path.

5.2 Validating the Purchase Costs Tool

A volunteer has proven the validity of interpreting the transcript with predefined rules, the different elements are validated by the transcript and the sequence of elements is approved by an expert

The transcript of the conducted interviews is the one and only source used for synthesizing the Purchase Costs Tool. The transcript is extensive and contains lots of information about reuse and demolition but using it as source requires validation. Even though it was an iterative process to deduce the Purchase Costs Tool from 140 pages of transcript, the process of doing so can be described by three logical steps:

1. Developing a key to distinguish elements from continuous blocks of text. Validating this step is done by inviting another person to use the key on a part of the transcript in order to find out whether the same results will be found.
2. Collecting all elements from the transcript. Validating this step is done by gathering different supporting quotes from the transcript for each identified element.
3. Creating the right sequence of the found elements to form a representable tree structure. this part of the synthesis is made possible by the acquired intuition for conversations with demolition contractors. It is reasoned that the best way to validate this step is to obtain feedback from an actual demolition contractor

Before these three steps were performed, the transcript was organized. This process is not validated but it is worth mentioning that, for synthesizing the Purchase Costs Tool, only the parts of the interviews were used that cover demolition or reuse of specific building products from specific building. Figure 31 demonstrates how these data is organized.

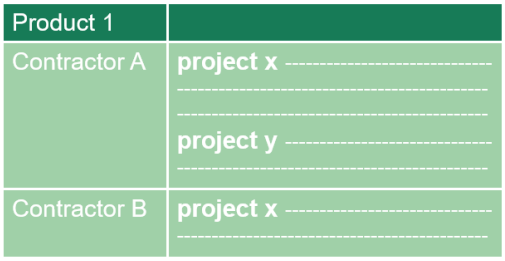


Figure 29 Transcript structure

5.2.1 Interpreting the transcript

The key for identifying elements is a logical rule that describes what readers must look for in sentences from the transcript to identify elements

Since the Purchase Costs Tool consists of various types of elements, keys for identifying different elements are developed. *Single operations* and *Circumstances* can be identified from a single sentence, for which reason linguistic keys are developed for those. As was explained earlier, *Double Operations* and Decisions are applied when the paths of different situations are combined. These elements cannot be identified from individual sentences. Instead, multiple stories from demolition contractors need to be compared which makes it a more intuitive task and hard to capture in a set of rules. The intuitive task of identifying elements is demonstrated in Appendix 6 by using quotes from the transcript.

It is important to note that the linguistic keys presented here are not detailed algorithms for dissecting the grammar of sentences. Appendix 7 shows such a key but Unfortunately, it turned out to be too cumbersome for practical use and are therefore simpler keys are used in combination with some intuitive interpretation. In order to test the performance of these keys, a volunteer has been asked to apply them to a part of transcript to compare the sentences that she selected with the sentences that were selected for synthesizing the Purchase Costs Tool. the results are shown in Appendix 8. From the test it is concluded that the provided keys are possible to be applied by other persons. The actual keys are introduced and demonstrated below.

Single operations. As explained earlier, effort, time and resources spent on (or gained from) dealing with a product are labelled as operations. Therefore, in order to identify operations in the transcript, a description of an 'something' must be sought that happens with the product as a result of something that the demolition contractor does. Below, it is described what such a sentence should look like in the transcript, this is referred to as the Key:

A sentence or sub clause describing something[1] that happens with the product[2] at the hands of the demolition contractor[3]

1. Something describes the operation. It comes in the form of a nominal / verbal predicate
2. Product may appear in the text as an appointment of / reference to a (part of a) product
3. Demolition contractor may be appointed in the text as subject or might not be mentioned (in which case the product is the subject of the sentence

Circumstances. These are elements that describe the possibility of two resulting operations that a demolition contractor might involve in depending on a *condition* of the product. The key is shown here:

A sentence or sub clause describing a possible[1] condition[2] outside of the contractor's influence that results in a (or no) operation[3]

1. Possible refers to a gradient of occurrence (e.g. 'sometimes', 'often') or an indicator of conditional tense (e.g. 'if')
2. Condition indicates the circumstance. It describes (part of) the product or the situation
3. Operation as was described earlier in the key for identifying operations. In some cases, the operation needs to be interpreted from the context.

Demonstration. Table 1 shows a part of the transcript that has been translated to English for the sake of demonstration. Within this piece of text, operations are marked green and circumstances are market blue. Hopefully, this provides insight in the identification of elements. The same example is used later on to further explicate the collection of elements

Table 1 Example interpretation of the transcript

toilet	
Contractor 10 Operation Circumstance	**gallery flat** toilets are easy to disassemble: just unscrew 1 or 2 bolts. It is possible to gain value from them if you find a new purpose for 100 toilets but in that case, you need to look for someone who agrees with buying old and dirty toilets. {disassembly} how long it takes is the same for not reusing the toilet. If you demolish it, you have to clean it up which costs more time…It is confirmed that toilets break if they are thrown in a container…10 toilets [and other stuff from the bathroom] costs a day per person including transporting it down. maybe 8 is possible if they have to stay intact because then you need to put them away carefully.

5.2.2 Collecting all elements

By providing quotes from the transcript for each different element in the Purchase Costs Tool, the validity of each element is strengthened and meaning of each element is amplified

Many elements make up the Purchase Costs Tool. They account for the different operations, decisions and circumstances discussed during interviews with 14 different demolition contractors. Appendix 6 provides an overview of all different elements accompanied by sections from the transcript that support their validity. An attempt is made to include each element with more than one quote.

It will appear that some quotes describing quite different things, are interpreted as the same element. For example, smashing a toilet with a hammer or crushing a steel beam with a crane both qualify as the operation 'demolish the product'. The reason for this, is keeping the tool user friendly. To yield a practical tool, operations have been bundled, minor variation in decisions and circumstances have been left out and paths have been combined where possible. As a result, the tool still covers all paths that were discussed albeit that the elements are less detailed. Bundling different descriptions in a single operation or circumstance results in the generalisation of the labels used for these elements. The operations and circumstances from Table 2 are provide with the general labels used in the Purchase Costs Tool to demonstrate this concept.

Table 2 Interpreted labels generalized

Original label	Element type	General label
Unscrew 1 or 2 bolts	Operation	Disassemble the product
To gain value from them	Operation	Receive payment
Find a new purpose for 100 toilets	Circumstance	Find a buyer
Look for someone	Operation	Search a buyer beforehand
Demolish	Operation	Demolish the product
Clean it up	Operation	Demolish the product
Thrown in a container	Operation	Load the debris
Transporting it down	Operation	Transport the product outside
Put them away carefully	Operation	Local storage of the product

5.2.3 Creating the right sequence

The tree structure that results from an iterative design process is validated by testing whether a demolition contractor is able to use it to describe his routines

As mentioned, designing the Purchase Costs Tool was an iterative process. This process involved putting the elements in the right sequence. Although some parts of the transcript may have provided information about the logical order of operations, more often than not, the semi-structured interview strategy has resulted in an entanglement of information. This makes it impractical to analyse the sequence of elements based on a set of rules. The intuitive way of interpreting text proves to be effective on the other hand. The example from Table 1 serves as an example once again. This time to demonstrate what the tree would look like if this was the only available piece of transcript, Figure 33:

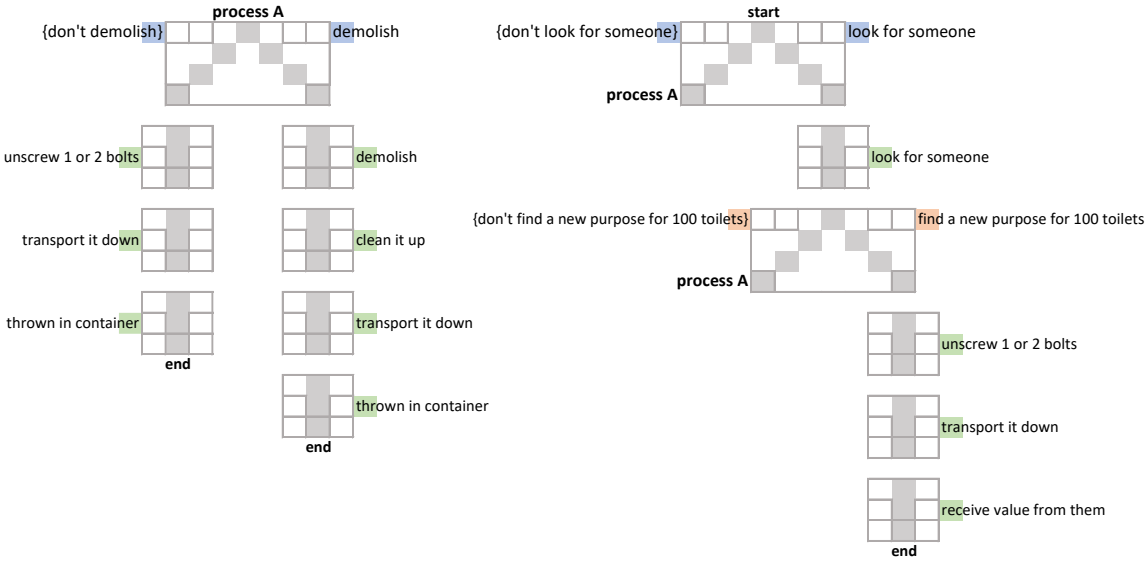


Figure 30 Conceptual tree structure for the transcript example

- The decisions have been added to account for the fact that the contractor explicitly says that there are two options. Not all decisions can be located so easily.
- descriptions between parentheses don't originate from the transcript but have been added due to the fact that their counter parts are said to be one of two options
- for practical reasons, the tree is split in two parts. This is why the Purchase Costs Tool is segmented in different processes as well.

By interpreting more parts of the transcript, overlap is found between paths from different situations. Also, interpreting other parts of the transcript allows to add elements before, after or in between the elements found from Table 1 to make a more complete tree. Finally, labels are generalized, elements are combined and the tree is divided in processes. The way in which elements are formed and put together is dictated by a set of rules but the other steps described here have more resemblance with a design process than exact science. Since the resulting design ought to depict the processes that demolition contractors encounter daily, it is considered a suitable validation to test whether demolition contractors are able to explain their routines on the basis of the Purchase Costs Tool.

Figure 31 Vermeulen & Zonen logo

One of the contractors that was interviewed earlier was interviewed again. This time, he was shown the Purchase Costs Tool. The relevant part of the concerning interview is included in Appendix 9. two paths of the tool have been discussed. These paths are shown in Figure 34. Each path was run through with a different product. for each path, first the question was asked per element what he would do. In all cases, an answer was given that fit the available options in the tool. After that, the path was summarized and the question was asked if the path was correct. To this question, the demolition contractor replied that the sequence corresponded to his normal line of work with the following quote (translated to English):

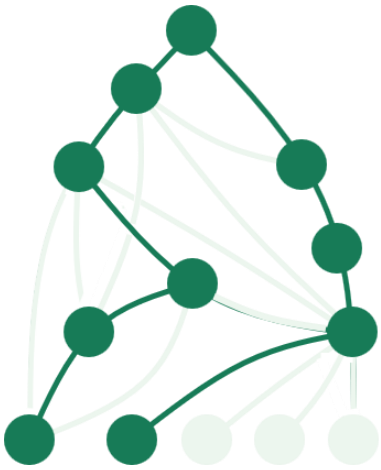


Figure 32 Discussed paths

"YES, that is it, that is it"

5.3 Demonstration of the Market Assessment Method

Through six steps, the production costs for reusing toilets are determined for any given production scale by using the input from the Purchase Costs Tool and information about a hypothetical middleman

Here, a demonstration is given for using the Market Assessment Method to determine whether there is a market size for which it is possible for a hypothetical middleman to maintain a business in second-hand toilets that is competitive with new toilets in the B2B market without considering government influx, application costs or value perception of the buyer; answering the main question of the research in other words. This is the end product of the research. Since the method uses input data from the Purchase Costs Tool, the latter is also demonstrated in this sub-chapter.

The Market Assessment Method consists of nine steps to go through. Each step will be demonstrated individually throughout this subchapter but first they are summarized here:

Step 1 Define different types of projects and determine their market sizes*.

Step 2 Define different types of demolition contractors and determine their market shares*.

Step 3 Combine different types of projects and contractors to find different *Situations* and their respective market sizes*.

Step 4 Use the Purchase Costs Tool to compute the *Purchase Costs E1* for all different situations.

Step 5 Supplement E1 with the average** *Pickup Costs**** to obtain the improved costs E1 (and plot these prices to the corresponding market size, from low to high).

Step 6 Compute and plot the average** Purchase Costs for any *production scale*.

Step 7 Compute and plot the average** *Middleman Costs* for any production scale (by combining variable and fixed costs).

Step 8 Plot the superposition of the average** Purchase Costs and Middleman Costs to arrive at the average** *Supply Costs* for any given Production Scale.

Step 9 Evaluate whether there is a Production Scale possible for which the Supply Costs are low enough for a profitable business model.

*market size refers to the number products (regardless of the chosen unit)
**average refers to the average cost per product (regardless of the chosen unit)
***pickup costs are the costs that the middleman needs to make for picking up the product at different projects. These costs depend on the average distance to projects and the number of products that he can transport at each trip. These costs are added to E1 because unlike other middleman's costs, these depend on the project and the demo contractor

As was already mentioned, toilets are chosen for the demonstration. For simplicity reasons, only standing toilet bowls are considered. This may sound arbitrary but from conversations about toilets in Appendix 10, it turns out that demolition contractors make a clear distinction between cheap, old fashion standing toilets and modern, more valuable, hanging toilets. For the demonstration, these are considered as different products because they are treated differently in practice. Finally, throughout the last couple of steps, reference is made to the Hypothetical Middleman. For computing results, information about this middleman is used that originates from a case study that is explained in more detail in Appendix 11, part 1.

5.3.1 step 1 – market size of different projects

Define different types of projects and determine their market sizes

It has been addressed earlier that the Purchase Costs Tool computes the required asking price by required by the demolition contractor (E1) depend on the contractor, the project and the product. Since the Market Assessment Method is applied to a single product at the time, the different situations that are combined by the model are defined by the difference in contractor and the difference in project. The differences in project are elaborated upon here.

Different project types. Different types of projects are distinguished for which it is possible to determine the number of times such a project is done in a certain period of time. Three categories by which projects are categorized are the following:

- user functions from the BAG database
- building typologies based on literature and sampling
- year of construction from the BAG database

There are many other factors by which a product can be distinguished since each project is unique in some way. However, the three distinctions described above were possible to make on the basis of available data and provide enough insights for the research. An overview of different projects that are identified, based on the data can be found in Appendix 12. In the appendix, a coarser distinction between projects is made for counting the total number of toilets that is released from demolition projects. This selection is then grouped in three categories that will be used for telling apart the different situations applied to the Market Assessment Method. these groups, are shown in Figure 33:

Small & low buildings

Large & low buildings

Large & high buildings

Figure 33 Category buildings from the example

The Market Assessment Method can be applied to a much more detailed variation of projects but since the Purchase Costs Tool needs to be applied to each individual case, the amount of work would increase as well. for demonstration purposes, three is considered enough. Furthermore, from the transcript it turns out that building height and project size are the only factors with real impact on the costs.

Number of projects. In Appendix 13, a detailed description is given on how the data for counting projects was retrieved. A short summary on using this data is given here. The BAG database contains a list of buildings that were demolished in the year 2017. These data include construction year and user function. It turns out that a bit more than 14.000 buildings were demolished in 2017, housing a larger set of obstacles (VBO). For example, as shown in figure 34, a gallery flat is considered as a single building but it contains multiple houses (VBO).

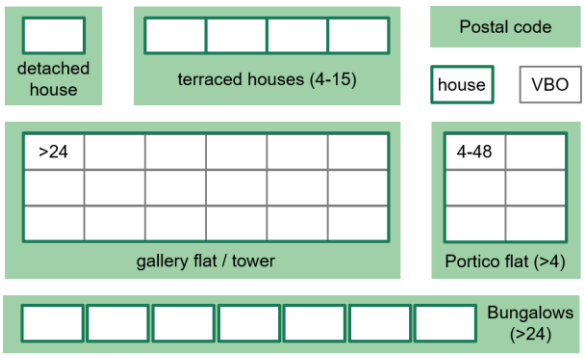


Figure 34 Types of dwellings

An important assumption to note is that the demolition projects from 2017 are representative for projects in other years. 2017 is chosen because the most recent year (2018 at the time of writing) might not be fully up to date and to many years back (2015 for example) would deprive the possibility of using google street view for sampling.

Number of toilets per project. The number of toilets per type of building is estimated. Bear in mind that extreme precision for this aspect is not required to demonstrate the concept of the Market Assessment Method. Appendix 12 demonstrates the estimated number of toilets per type of building. Below, the key numbers are shown (rounded off). note that these numbers only represent standing toilets from demolition (no renovation):

- low & small: *9000* toilets 36%
- low & large: *13000* toilets 52%
- high & large: *3000* toilets 12%
- total *25000* toilets 100%

5.3.2 Step 2 – market size for different contractors

Define different types of demolition contractors and determine their market shares

In step 1, it was determined that the total market for standing toilets from demolition projects is *25000* units and that this number is divided over three categories of buildings. Since the Market Assessment Method also differentiates different types of demolition contractors, the number of situations considered roughly corresponds to the number of project types multiplied by the number of contractor types. These types, and their markets share are determined here.

Types of contractors. Throughout the research, two mayor categories of demolition contractors are observed. These are demonstrated here on the basis of quotes from interviewees.

1. Contractors with or without an interest in reuse. Since interviewees have been selected based on their involvement with reuse, all of them reuses products to some degree. Contractors that do not have an interest in reuse are therefore more difficult to identify. Several pieces of evidence suggest however that a lot of contractors don't show an interest in reusing products:
    a. Interviewed contractors refer to large demolition contractors that care only about recycling. *Contractor 14 - "there are not that many contractors with a shop"*
    b. Some contractors that have been approached for an interview turned out to interpret circularity as being all about recycling rather than reusing
2. Contractors with or without a shop at their yard. there are two types of demolition contractors with regard to their strategy of selling second-hand building products. Some demolition contractors use their yard to store products and sell them. Others don't use their yard like this and only sell products if it is possible for a buyer to pick the products up from the demolition site. *Contractor 6 - "contractors with a yard such as ours"*

On top of these two general criteria, it turns out that a clear distinction can be made between contractors depending on the product or project. Two specific distinctions for toilets are identified:

3. Contractors with or without interest in toilets. Regardless of how active they are in trading other products; some demolition contractors don't trade toilets out of principle. *Contractor 13 – "it is not really typical for this generation to disassemble dirty toilets".*
4. Contractors with or without buyers. Of the interviewed contractors who indicated that they are open to selling toilets, there was only one who can find buyers for the standing toilets from the example. *Contractor 6 – it is confirmed that not many contractors do this – "we do"*

The four criteria are used to divide the Dutch demolition contractors into five groups. Figure 35 illustrates how these contractors are labelled and how they qualify based on the four different criteria.

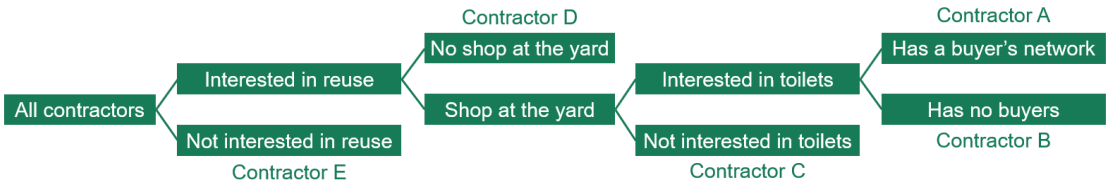


Figure 35 Types of Demolition contractors

Market share of different contractors. First off, it must be noted that the estimation of the market share of the different types of contractors is merely an estimation. No accurate data was available. Statements from interviewees and web research are combined to put together the market share. These are elaborated upon in Appendix 11, part 2 while the results are summarized here:

- Contractor A 2%
- Contractor B 5%
- Contractor C 5%
- Contractor D 18%
- Contractor E 70%

5.3.3 Step 3 – market size per situation

Combine different types of projects and contractors to find different Situations and their respective market sizes

If the different types of demolition contractors were to be equally distributed over the market, determining the market share of each situation would be determined by multiplying the market share of the contractor and the project. However, from the interviews it is deduced that contractors tend to have a preference in projects. Two trends are observed:

- Even though most demolition contractors suggest that they are capable of doing all sorts of projects, most small contractors admit that they seldom demolish high buildings because they don't own large cranes while large contractors indicate that they prefer large projects.
- A pattern that can be recognized in the 14 contractors that have been interviewed, is the fact that generally speaking, the ones that sell products from their yard where smaller companies than the ones that did not do so.

From these observations it is concluded that contractors who sell from their yard (A, B, C) have a relatively high market share in the demolition of small & low buildings while the contractors who don't sell products from their yard (D, E) have a relatively high market share in the demolition of large & high buildings. An estimation is made for small & low projects and it is assumed that contractors A, B and C don't demolish large & high buildings. This results in the distribution depicted in Table 3.

Table 3 Market share of different situations

	contractor	A	B	C	D	E
project	total	2.0%	5.0%	5.0%	18.0%	70.0%
small & low	36.0%	1.5%	3.5%	3.5%	5.5%	22.0%
large & low	52.0%	0.5%	1.5%	1.5%	10.0%	38.5%
large & high	12.0%	0.0%	0.0%	0.0%	2.5%	9.5%

5.3.4 Step 4 – price (E1) per situation – Purchase Costs Tool

Use the Purchase Costs Tool to compute the Contractor's Price (E1) for all different situations

In this step, the Purchase Costs Tool is demonstrated. As shown by step 3, the price needs to be determined for 12 different situations (three of the 15 possible situations are not considered because their market size is 0). To demonstrated the Purchase Costs Tool and to explain the difference in price between the different situations, it is sufficient to take two situations as an example. The first example is contractor B dealing with toilets from small & low buildings. This situation is compared with contractor A dealing with toilets from the same type of building. The first example is addressed in full detail covering the following computations:

1. Determining the current path of the situation
2. Computing the margin (S) corresponding to this situation
3. Determining the most cost-effective path for selling the toilet
4. Computing the price (E) for which margin (R) is equal to or than the original margin (S)

Contractor B – small & low. The conventional path and the reuse path of this situation are illustrated in Figure 36, accompanied with the corresponding prices of the involved processes. The following steps are taken and elaborated in Appendix 11, part 3:

1. Al thought Contractor B sells other products from his yard, Contractor B currently chooses is *demolition – prepare for discard – discard – recycling* (left) because he has no buyer for toilets.
2. The margin of this path is *- €4.00* because it takes time to strip out the toilet. Waste costs are neglected because the toilet ends in the container for stony materials which is cheap to dump.
3. Since contractor B can store products at his yard, the most efficient path for reuse is *disassembly – prepare for reuse – at the yard – sell – reuse*. 30% of all toilets is wasted however because those are found broken and another 7% is wasted because 10% of toilets that are brought to the yard break down during transport.
4. Considering the operational costs, if the middleman buys the toilets from the yard for more than *€11.00*, the margin will be equal to, or higher than *- €4.00*, making reuse a better deal than the contractors normal path. This is how the Purchase Cost of *€11.00* is determined.

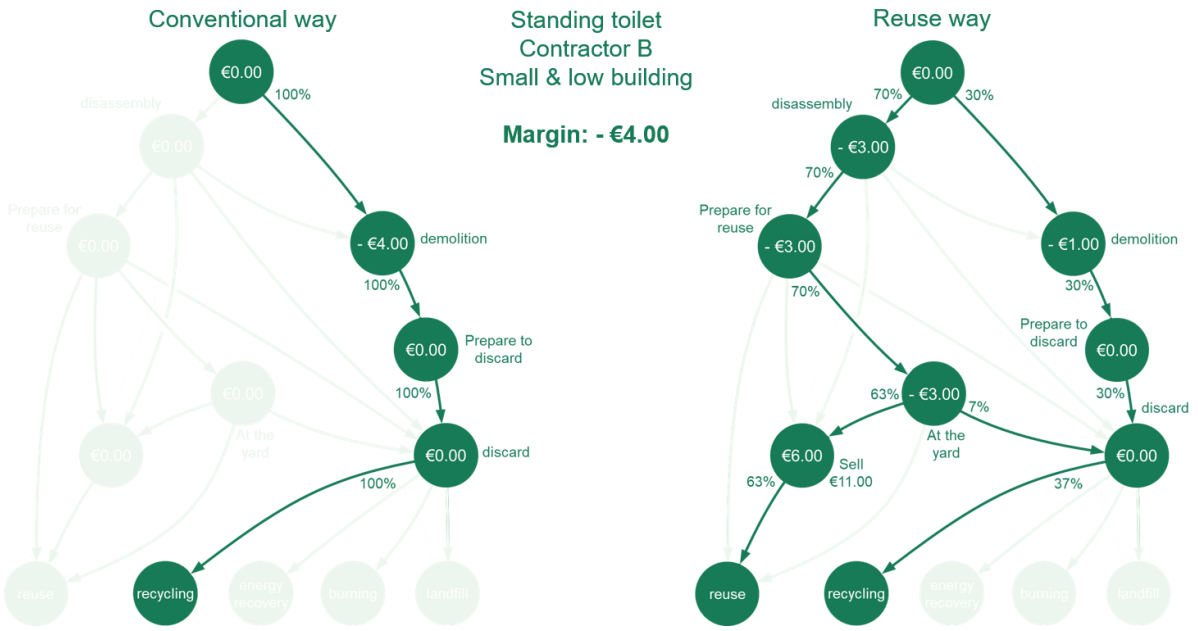


Figure 36 Exemplary use of the Purchase Costs Tool

Contractor A – small & low. Disassembling and selling toilets is conventional for Contractor A when he demolishes small & low buildings. From interviews, it is deduced that he is in a position to charge *€30.00* for a toilet, which results in a margin of *€7.00*, when all costs and broken toilets are accounted for. If Contractor A would be visited by a middleman, he would not accept *€11.00* (like Contractor B) because this would be a setback compared to his status quo. From computation, it turns out that dealing with a professional buyer results in a slight cost reduction leading to a required price of *€28.00*.

Other situations like the way in which the required price from the previous examples differs, the prices for other situations differ as well. The observed price factors are described here to provide a sense for the wide range of prices corresponding to different situations:

- The required price increases for tall buildings because vertical transport is expensive.
- It is reasoned that the price is higher for Contractor C and E because they are not interested in selling toilets. It is *assumed* that they would sell at a premium to compensate their discomfort.
- Because it is expensive to let buyers on the demolition site and because this is the only option for Contractor D and E to sell toilets, they are more expensive. especially for small projects

The computed prices per toilet for all different situations are shown in Table 4. The columns represent the different contractors and the rows correspond to the different projects.

Table 4 Price (E1) per situation

	A	B	C	D	E
small & low	€28.00	€11.00	€25.00	€32.00	€38.00
large & low	€28.00	€10.00	€25.00	€9.00	€15.00
large & high				€14.00	€21.00

5.3.5 Step 5 – purchase costs

Determine the Purchase Costs for each situation by adding the average Pickup Costs to the price (E) and plot these prices to the corresponding market size, from low to high

The third and the fourth step of the method, provide all the required data for plotting the contractor's required price *E1* for different market segments. This is shown in Figure 37. Here, the market segments are arranged from cheap to expensive. Creating this result fills the Research Gap; it allows us to review the most essential part of reuse costs on a macro level at last.

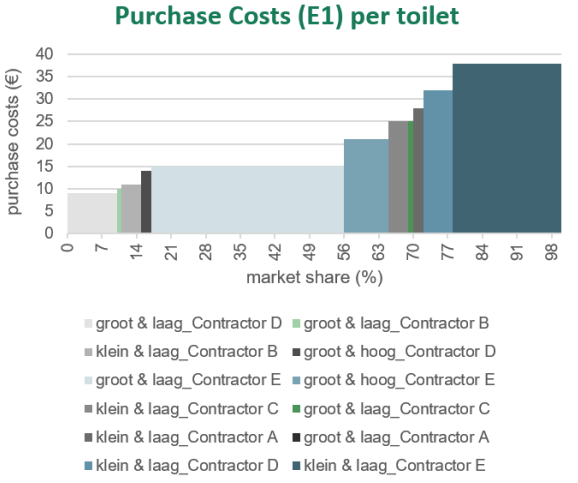


Figure 37 Price (E) per toilet

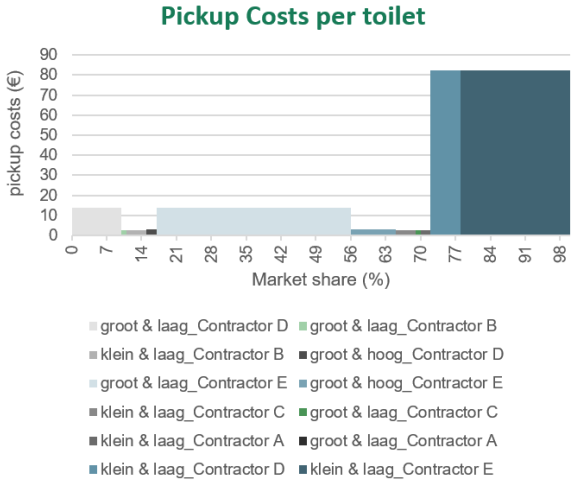


Figure 38 Pickup costs per toilet

Besides the costs that the Hypothetical Middleman needs to make when he buys the toilets from the demolition contractors for price *E1*, he also needs to make costs for picking up the toilets. Just like price *E1*, and unlike the other costs that the middleman needs to make, the Pickup Costs depend on the situation; see Figure 38. In short, the costs per toilet are lower if he can pick up a large batch of toilets, and the batch size depends on the situation. Furthermore, the situations with the lowest price *E1* per toilet don't have the lowest pickup costs per se. When the costs from both graphs are combined to form the improved Purchase costs *E1*, they should be rearranged to be in order from cheap to expensive. this is shown in Figure 39.

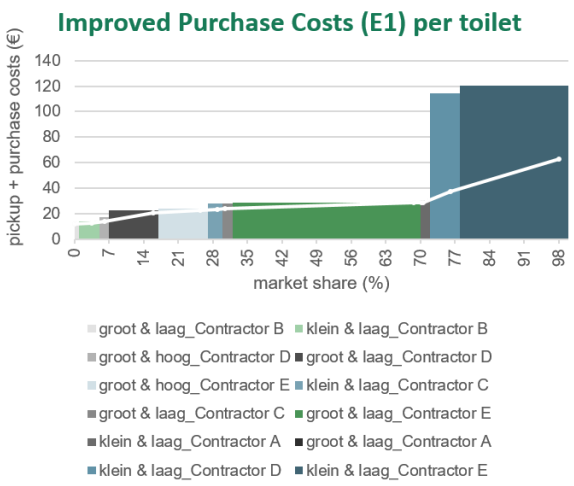


Figure 39 Purchase Costs per toilet

5.3.6 Step 6 – average Purchase Costs

Compute and plot the average Purchase Costs for any production scale

Once the improved Purchase Costs *E1* for different market segments are known, the average Purchase Costs per toilet can be computed. These are represented by the white line in Figure 41. For example, the average Purchase Costs per toilet will be 20 euros if the middleman buys more or less 30% of all toilets while he would only pay 15 euros if he buys 10%. The shape of the curve strongly depends on the assumption of a perfect market that enables the middleman to buy the cheap toilets first.

5.3.7 Step 7 – Middleman Costs

Compute and plot the average Middleman Costs for any production scale

Besides picking up and paying for the toilets, the middleman must make additional costs for running his operation. These costs are referred to as the Middleman Costs. Based on the case study from Appendix 11, part 1, the following fixed costs and variable costs are derived:

- Fixed costs. a plot of land, one full-time employee, yearly costs of a box-truck and other expenses are expected to set the hypothetical middleman back *€85000, - yearly*
- Variable costs. The Purchase Costs are not included with the variable costs. Handling and delivering toilets are considered. Also, toilets need to be washed in order to meet B2B standards. The costs of these activities is about *€14.00* per toilet but the first few thousand toilets are much cheaper because most of their costs are made by the full-time employee.

These costs are combined to compute the average Middleman Costs for any given Production Scale. The result is presented in Figure 40. In the computation, the fixed costs are divided by the number of toilets sold, while the variable costs stay the same. Logically, the costs per toilet are enormous if just a couple of them are sold. If an infinite number of toilets is sold (theoretically), the average costs will converge to the variable costs.

Figure 40 Middleman Costs

5.3.8 Step 8 – Supply Costs

Plot the superposition of the average Purchase Costs and Middleman Costs to arrive at the average Supply Costs for any given production scale

The curve of the Supply Costs for different production scales can be considered the main result of the research. The User of the Market Assessment Method can now see what it would cost the Hypothetical Middleman to supply toilets at any given production scale. It is presented in Figure 41.

Figure 41 Average Purchase Costs per toilet

Since the Hypothetical Middleman theoretically represents all supply in the reuse market for the product, the curve can be used to determine what the supply costs in the market are for any market size. If, at a given market size, the costs are low enough compared to the product price B to leave enough profit for the Hypothetical, a market can arise according to the Theoretical Framework. The only thing required for arriving at this conclusion is determining the appropriate price in step 9.

5.3.9 Step 9 – Evaluate the market

Evaluate whether there is a Production Scale possible for which the Supply Costs are low enough for a profitable business model

Let's finally discuss the options for the Hypothetical Middleman and see whether a market for reusing toilets could arise. From the Supply Costs Curve in figure 41, it can be derived that it is expensive to trade less than 4000 toilets or more than 17000 toilets. However, there turns about to be a production scale between these boundaries for which the average costs are rather constant at a proximately *€40,-* per toilet. At this production scale, the business would break even if buyers would pay this amount.

This brings us to the question what a professional buyer is willing to pay for a toilet. Value is subjective and in principle, the middleman can choose whichever price he likes. However, provided that the quality of the second-hand toilet is the same as new (they are washed), the price of his product must compete with new toilets. Because the market is assumed to be perfect, toilets with a higher price than the new alternative will not be bought. It is decided that the wholesale price of *€50, -* for new standing toilets is a safe estimate. With this price, breakeven is reached if more than 3000 toilets are sold so at least, it is possible for the middleman to make some profit. See Figure 44.

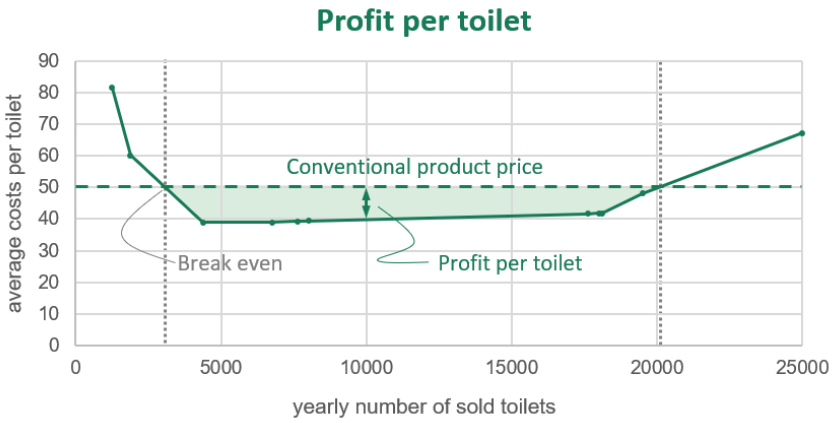


Figure 42 Profit per toilet

Finally, it is the question whether the Hypothetical Middleman would be able to make a healthy profit with his business. With an investment of €85000, - for the first year, a couple dozen grand should be considered a promising return. The fact that the Hypothetical Middleman might have to work himself to get everything up and running, a profit of €50000 is considered generous; he will need to sell somewhere around 5000 toilets to earn that much because at that production scale, he will make a profit of around ten euros per toilet. Furthermore, by selling more toilets, his profit might increase to more than €150000, -. Concluding, according to the Market Assessment Method, a market for reusing toilets may in fact arise. As reader, you might think this is over-optimistic; don't worry, this notion is addressed in the Discussion chapter.

6 Discussion

Can it be concluded that the developed method enables us to determine whether a B2B market for reusing specific products can arise?

This picture was taken at Beijer & zn B.V.

In the Exploration chapter, the Research Gap was introduced. It was described as the missing knowledge that is required for answering the research question; Literature was reviewed in order to find out which knowledge was already available in science and which additional knowledge would have to be obtained in this research. In this chapter, it is discussed what the research has contributed to science, what the limitations of this contribution are and to what extend the new knowledge helps answering the main research question.

In short, four parts of this research can be considered to be a contribution to the current literature on the topic of reusing building products that was found during literature review. *1)* the exploratory interviews led to way of classifying different obstacles that hinder reuse of building products in the B2B market. *2)* a Theoretical Framework has been proposed that describes the metrics by which market potential can be measured. *3)* it has been enabled to calculate the demolition contractors required reuse price for many different types of products and situations by developing the Purchase Costs Tool. *4)* it has been made possible to combine data in such a way that it can be assessed whether a B2B market for reusing a specific product can arise by developing the Market Assessment Method.

Each of the four findings is addresses in a separate subchapter. These subchapters are structured similarly. First it is discussed what is new about the presumed contribution to science and how the findings have contributed to answering the research question. Then, the findings are looked at critically to assess their value by looking into their limitations. Summarizing the discussion, this chapter's sub-question can be answered as follows:

The Theoretical Framework provides metrics, that were not available before, for determining the required price for a reuse transaction to take place and for identifying second-hand building products with market potential, but it should be noted that the Market Size Model is based on assumptions, that leave a part of the research gap uncovered

The Purchase Costs Tool fills a large part of the Research Gap by enabling the user to calculate Purchase Costs E1 for different products originating from different situations but although the validation of the tool make it seem trust-worthy it needs more validation to exclude uncertainty

The Market Assessment Method proves to yield results that meet expectations but for drawing serious conclusions about the market potential of toilets, more reliable input data is needed

6.1 An overview of obstacles

An overview of obstacles led to a broader understanding of different factors that influence reuse feasibility and classifying these obstacles in eight categories allowed for studying these factors

The exploratory interviews were covered in the first part of the research leading to a description of the Research Gap. The overview of obstacles that originated from the interviews provided a way to communicate the influence of different factors on the feasibility of reuse and has been referred to throughout the research. Here it is discussed in which way the overview of obstacles has contributed to science and what possible limitations of the findings are.

6.1.1 Contribution of the different obstacles

Although the appointment of different obstacles is not new, it is a contribution to science to classify the obstacles in eight categories that influence reuse feasibility through different mechanisms

What became really clear after conducting four exploratory interviews was the fact that the number of obstacles that hinder reuse is quite overwhelming. The obstacles mentioned in three of the four interviews are summarized in short sentences to fill an entire page. When going through the additional interviews with demolition contractors, even more obstacles are undoubtedly uncovered.

Mentioning different obstacles that hinder reuse is not a contribution to science. Several scholars mention obstacles in their papers. *(Endicott, 2005)* dedicates a paragraph to limited feasibility of deconstruction, mentioning that most buildings are not designed for deconstructions and that it is labour intensive. On top of that, he mentions limited market demand for different reasons. This is just an example, in all other reviewed papers, references are made to specific challenges with reusing building products as well.

Besides the fact that other papers write about different obstacles for reuse, there is a lot of overlap with obstacles from the exploratory interviews. For example, Endicott's notion that deconstruction is labour intensive corresponds with A van Liempd's remark that reuse is expensive due labour intensity. By conducting a literary review focussed solely on obstacles mentioned in different scholars, all obstacles from the exploratory interviews will probably be encountered. The advantage of conducting interviews was the fact that all discovered obstacles are up to date and that they apply specifically to the Dutch market. However, claiming that the interviews contribute to science is unjustified.

One thing about the uncovered obstacles that can be justified as a contribution to science is the classification of different obstacles. All found obstacles could be distributed among the eight different categories that were proposed. Although it would have been possible to classify the obstacles on the basis of alternative categories, this specific classification system was essential for answering the main question; namely, by applying the different categories it could be identified how specific obstacles influence market development. The result is the Market Development Model which explains how a government's influx can help a stagnant market to develop and remain self-sustaining afterwards.

6.1.2 Limitations of the obstacles overview

there might be issues with the reliability of the interview data but this is not considered noteworthy since the research does not rely on the implications of the individual obstacles

Unlike the other findings from the research it is difficult to devote an entire subchapter to the limitations of the overview. The interview data might have been biased by the subjective opinion of interviewees but this would not have much influence on the outcome of the research since the classification of obstacles is referred to throughout the research rather than the obstacles themselves.

6.2 The theoretical framework

The Feasibility Model provides new insights in the parameters that determine if transactions can occur and the Market Size Model uses these parameters to create new macroeconomic insights

The theoretical framework plays a key role in the research; it would not have been possible to answer the main question without it. The main question of the research is quite abstract. Besides the challenge of making predictions the question is about reuse on a macro economical scale and economist know that macroeconomics is complex. The theoretical framework succeeded to translate the abstract question into the specific task of reconstruction a curve for average Purchase Costs (E1) and Middleman's Costs (E2) for different production scales. This is still challenging (especially E1), but it is very clear what needs be done.

In this subchapter, attention first goes out to the contribution to science of the Feasibility Model and the Market Size Model. The metrics that are used throughout the research stem from these two models. In addition, attention goes out to the Market Development Model because although this model is not referred to much throughout the research, it did contribute to obtaining a deeper understanding of CE. In the second part of this subchapter, it is discussed what the limitations of the different models are with respect to their display of reality. Especially the Market Development Model is addressed here because it represents the answer to the main question.

6.2.1 Contribution of the Feasibility Model

Comparing the value chain of reuse with conventional value chains in order to draw conclusions about the feasibility of reusing a specific product in a given situation is a contribution to science

The model took shape by combining the Cash Flow Model for the respective value chains for reusing or wasting a building product. These models provide insight in the role of different actors in each value chain and they allow for a comparison between different value chains because the actors in the models match one another. Although web research yielded plenty of ways to portrait value chains in a circular economy, no contemporary models were found that allowed for this comparison. Furthermore, the integration of cash flows is a unique feature. Thus, it can be concluded that the Cash Flow Model contributed to the research because there was no alternative available. Although the cash flow models might apear self-evident, they present conventional knowledge in a new way.

Only by combining the value chains for landfill and reuse in the Feasibility Model, insight is created that is essentially new. To summarize, the Feasibility Model illustrates the decision for the involved parties between reuse or no reuse and under the assumption that parties will choose the most profitable option and the fact that all parties must choose reuse in order for the value chain to exist, the model allows for calculating the values of cash flows that are required for reuse to be possible.

Illustrating the difference in profit between reuse and no reuse for the demolition contractor is not new; *(Guy, 2004)* makes the same comparison in his case study about de deconstruction of six homes in Florida. He uses the same cash flows that are illustrated in the Feasibility Tool, to calculate the costs of deconstruction and demolition respectively. His formula (page 6) uses the same parameters as were used in this research, only reorganized, with regard to entire buildings and under different names:

$$(J+H+E2) - (K+E1) = -R \text{ and } (G+H) - I = -S$$

What is new however, integrating the cash flows of all involved parties and deducing that parties in a perfect market will choose the most profitable option. Only by making these steps can it be evaluated which transactions might exist and which ones don't. only these insights allow for *E1* and *E2* to be quantified to be used to answer the main question.

6.2.2 Limitations of the Feasibility Model

When applying the Feasibility Model, it must be realized that the supply chains on which the model is built might vary in practice

At first glance, the model might look to simple to represent a value chain (or value network) that has more involved actors in practice. Especially the 'builder' is overly simplified compared to the real construction industry where an architect, contractor, sub-contractors and multiple advisors are involved in the process of construction. This simplification does not influence the comparison between new and second-hand building products though.

However, the assumption that there will always be a middleman in between the builder and the demolition contractor does in fact influence the outcome. The middleman was introduced to account for processes (such as washing toilets) that allow for products to be suitable for the B2B market and since these are presupposed to be critical, the role of the middleman is justified. However, in practice, it could just as well be the case that this role is fulfilled by the demolition contractor himself, decreasing transportation costs. Luckily, this results in a conservative outcome.

6.2.3 Contribution of the Market Size Model

Displaying the Supply Costs at different production scales by combining middleman costs and purchase costs is a valuable insight for the research

The research not only aims to calculate what the price *E1* is that must be paid to a demolition contractor to make it worthwhile for him to reuse a certain product; it also aims to calculate this price for different market segments, referred to as situations, in order to see how the average production costs for the demolition contractor (*E1*) change when the production scale increases. This relation is plotted in the first graph of the model; it is hypothesized that these costs will increase with production scale. The curve for *E1* is then combined with the curve for average Middleman's Costs (*E2*) to arrive at the Supply Costs Curve. In contrast to the Purchase Costs, the middleman's costs are hypothesized to decrease with production scale. The result is a curve that has an optimum somewhere in the middle. Identifying the existence of this optimum and the comparison to the expected income (*B*) per product is essential for the research.

Although this is probably the first research where an attempt is made to make macroeconomic analyses for reusing building products by taking into account the effect of production scale on production costs, identifying increasing costs and decreasing costs for supplying a product is not a new concept. Although the concept is not a perfect analogy, a comparison can be made with the formula of Economic Order Quantity (*EOQ*) which optimizes the size of inventory. Here as well, an optimum can be found somewhere in between by balancing increasing Holding Costs with decreasing Order Costs when the production scale is increased.

The fact that the average Middleman's Costs *E2* will decrease due to the fact that yearly fixed costs are spread out over a larger quantity of products is not original either. What is in fact a new insight, is the hypothesis that the costs of purchasing second-hand building products will increase if more products need to be purchased. It is intuitive to think that the average Purchase Costs will increase since products will need to be disassembled from places that are harder to reach if demand rises. In fact, a pretty clear analogy for this phenomenon can be found in the oil and gas industry where harder to reach sources such as deep water drilling are tapped into when demand is high. Nonetheless, applying this concept to second-hand products can be considered a contribution to science.

6.2.4 Limitations of the Market Size Model

Since the Market Size Model represents the solution to the research problem, all the assumptions that were made to be able to solve the problem can be considered weaknesses of the model

Since the Market Size Model is proposed as framework for determining whether a reuse market can arise, the main question cannot be answered with full confidence if the model is faulty. Models never simulate reality perfectly which is also the case in this research. Some assumptions have been made in chapter 3.2 (defining the scope) to simplify the process. Here it is discussed what kind of influence the assumptions have on the model. the first two assumptions lead to an overly optimistic result:

- Equal quality (3.2.1). Reuse products can be supplied in the same quality as new products
- Perfect market (3.2.2). market parties act rational and have access to the entire market
- No market obstacles (3.2.2). Supply and demand find each other easily (like normal)

Besides the assumptions that make for an overly optimistic result, some other assumptions have been made that lead to a result that is *conservative* with respect to reality:

- Contemporary capabilities (3.2.3). it is assumed that contractors don't innovate or invest
- Only total demolition (3.2.4). supply from renovation projects is not considered
- Focus on financials (3.2.5). it is rejected that one might pay a fee to help the environment

Equal quality (3.2.1). The model suggests that a market can arise if the costs of production are significantly lower than the price *B* of new equivalent products. This comparison is based on the assumption from chapter 3.2.1 that the middleman is capable of supplying a second-hand product that is similar in quality to the new equivalent product.

This assumption is convenient for the research because it allows the builders obstacles to be left out of the scope but in practice this assumption is hardly realistic. No matter how hard demolition contractors try to be careful and how much effort the middleman does for reparations, some products just decay over time. When applying the model in practice, this aspect can be accounted for by lowering the price that builders are willing to pay. The effect of this aspect is visualized in figure 43. Clearly, the decrease in product price diminishes the middleman's opportunity to make a profit. Less unfortunately still, is the fact that there are products that simply won't satisfy minimal requirements. This implies that the model is not applicable for all products.

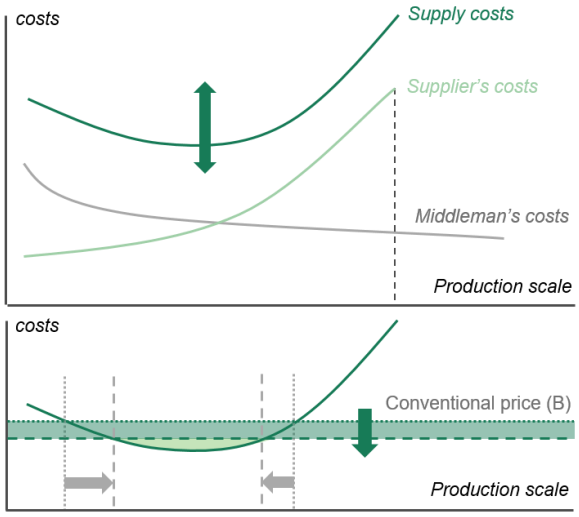


Figure 43 Decrease of product value

Perfect market (3.2.2). The assumption of a perfect market is implemented in the model by introducing a hypothetical middleman who has access to the entire market. If it is accounted for that the middleman does not have access to the entire demolition market, the middleman will only be able to supply a portion of all products in the market. this effect is illustrated in figure 44.

This implies that less revenue from selling second-hand building products can be expected while the fixed costs stay the same. As a result, the potential profit decreases. Furthermore, In the Feasibility Model it was proposed that the price *E1* that the demolition contractor receives AT LEAST needs to be large enough for the demolition contractor to make earn as much as he would earn otherwise. In the market Size model, it is assumed that the demolition contractor will accept the smallest possible payment to make it feasible for him while in reality, the demolition contractor might ask more, simply because he can. This effect is not visualized but it comes down to the fact that *E1* could be higher for any production scale.

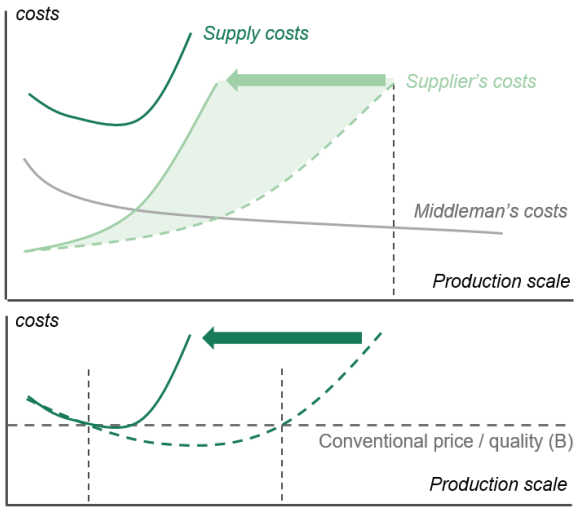


Figure 44 Decreased market access

No market obstacles (3.2.2). Besides the assumption about a perfect market, it was mentioned in chapter 3.2.2 that no market related obstacles were to be taken into account. In the exploratory interviews it was found that reusing products is challenging because demand and supply have trouble finding each other. For convenience, the theoretical framework starts from a hypothetical situation where the market has already arisen to find out subsequently whether such a scenario can exist.

The Market Development Model is then introduced to support the hypothesis that the market related obstacles will decrease as the market develops. It might not be realistic however, to expect that the market related obstacles will fully disappear since this would imply that the reuse market could run just as smoothly as the conventional market while it is clear that there are some permanent issues. Figure 45 shows what the Market Size Model would look like if this difference in 'smoothness' were to be accounted for in the form of additional transaction costs. it is presupposed that these transaction costs would decrease with production scale. As a result, it is clear to see that the selling price would have to be higher in order to make the same profit.

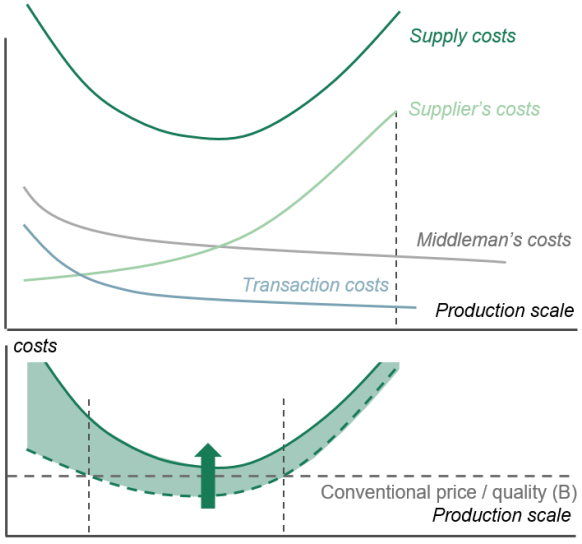


Figure 45 Including transaction costs

Conservative assumptions. Three assumptions made in chapter 3.2 are discussed here. the graphs that are referred to are shown without labels. For reference, the same labels are used as in figure 45. Here follows the discussion about the assumptions:

- Contemporary capabilities. Because of the fact that only contemporary capabilities are considered, it is ignored that demolition contractors can innovate or invest in technologies that allow them to supply products at a lower price. Figure 46 shows what kind of effect this might have on the Market Size Model. here it is presupposed that the most expensive situations in the current situation have the lowest chance of lowering the price.

- Only total demolition. Only total demolition is considered while there are also a lot of potentially reusable products released from renovation products. it can be concluded that the total amount of potential supply increases if renovation is taken into account. This effect is shown in figure 47. As a result, contractors have more opportunities to break even.
- Focus on financials. It was assumed that people are not willing to pay more for circular solution while some might in fact do so because they care about the environment. This effect can be accounted for in the model by increasing the selling price. See figure 48.

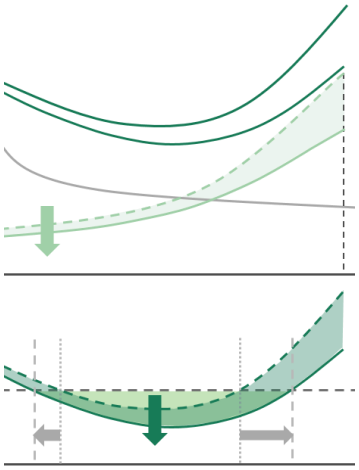


Figure 46 New capabilities

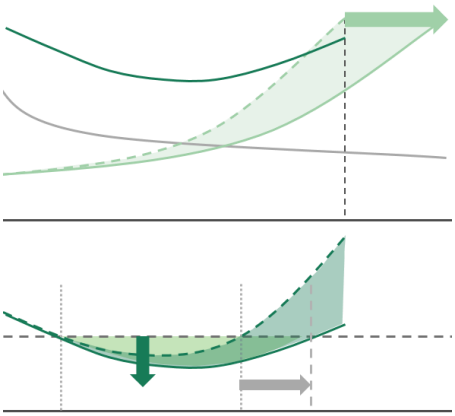


Figure 47 Including renovation

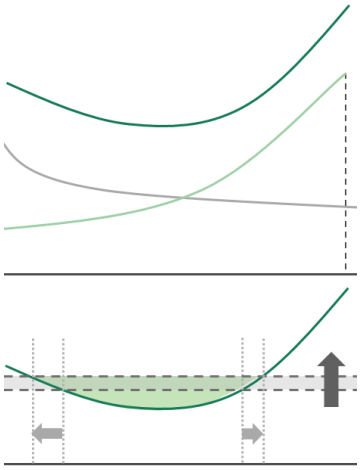


Figure 48 More willingness to pay

6.2.5 The Market Development Model

Although the model only played a minor role in the research, it could be applied for other purposes such as evaluating the impact of different government measures on CE

Contribution to science. The model was only referred to for supporting the hypothesis that stagnant markets may arise with a financial influx from the government and that they maintain self-sustaining after the influx disappears. The model makes this point by demonstrating the interactions between the parameters that were defined in the research. A lot of insights from the research are captured in the model. As such, the model has more to offer than it did in the report.

With the model, it can be traced what the effect of changing certain parameters is on the growth of circular markets. It is interesting to think that this feature of the model is useful for tracing the effect of different government's measures to stimulate sustainable growth. For example, subsidizing the business model of the middleman was proposed in the research but the effect of the following measures could be identified as well:

- Reward demolition contractors for circular demolition. This is equivalent to raising the Reuse Product Price *K*, because of which *R*, and subsequently *U* increases, leading to more supply.
- Raise taxes on demolition waste. This is equivalent to an increase in *H* which has an increase in *U* as result, also leading to more supply.
- Set a standard for the environment impact of new buildings. Reference is made to 'Milieu Prestatie Gebouwen' (MPG). To avoid fines, builders would spend more on circular solutions; equivalent to increasing Product Price *F*, leading to an increase in *Q* which increases apply feasibility *T*, leading to more demand for second-hand products.

Limitations. It should be considered that the model is not validated. All aspects of the model originate from reasoning based on experiences gained during the research. Things might have been overlooked.

6.3 Purchase Costs Tool

This tool allows the user to determine the required price for demolition contractors to reuse and since this knowledge is essential for the research, but absent in literature, it fills the Research Gap

The goal of the Purchase Costs Tool is to generate the most essential data that is required for determining whether markets for reusing certain products can arise, namely, the price *E1* for which it is feasible for demolition contractors to reuse in different situations. The Market Assessment Method also requires other input data such as the number of times certain situations occur or the costs of the middleman's operation *E2* but these data all stems from conventional sources. The knowledge required for determining *E1* was recognized to be the Research Gap. Thus, the Purchase Costs Tool can be considered to the main deliverable of the research, filling the Research Gap. First it is explained what exactly is new about the Purchase Costs Tool. then the limitations of the tool are discussed.

6.3.1 Contribution of the Purchase Costs Tool

Although the communicated knowledge in the tool is not unknown to demolition contractors, it generates potentially valuable new insights for actors outside of the field

The Purchase Costs Tool provides an overview of all operations in the demolition process that have an impact on the demolition contractor's costs and it guides the user to select the operations that are applicable for situations with different products, projects and demolition contractors based on the different chain of events that belongs to these situations. After finding out all required operations in a certain situation, the user of the tool can make cost estimates for each operation which sums up to the total demolition contractor's costs for reusing a building product. In a similar manner, the user can determine the costs of not reusing a product. Once the difference in costs is determined, the price E1 is known since the Feasibility Model suggest that the price should at least cover the cost difference.

To start off, none of the knowledge communicated by the tool. In fact, the process that is run through the tool has been around for decades; it happens automatically in the head of demolition contractors every time they decide on disassembling a building. The knowledge that enables the demolition contractors to do this is referred to as *tacit knowledge*; knowledge that is self-evident for experts. Thus, the research does not generate new knowledge about demolition processes; it merely captures tacit knowledge and makes it available for the user. Therefore, this research is not meant for demolition contractors but it is useful laymen that need insights in the demolition field. For example, architects could use it to determine how reusable their circular design is or, in the case of this research, buyers of second-hand products can calculate how much they can expect to pay for certain products.

Although this tool covers the Research Gap, not all aspects of the Purchase Costs Tool are completely absent in current literature. For example, *(Guy, 2004)* includes sections where an explanation is given about the required steps for deconstruction. What is new about the Purchase Costs Tool is the fact that different steps for disassembly in (almost) all different situations are represented in a single overview. For quickly generating the data that was used in the case study, this was an essential aspect.

6.3.2 Limitations of the Purchase Costs Tool

From all effort to validate the Purchase Costs Tool, no mistakes are found but on the other hand, it cannot be excluded that it is flawless

Since the Purchase Costs Tool is the main deliverable of the research, significant effort is put into the validation of the tool. As was explained, tacit knowledge means that it is self-evident for experts. By interviewing 14 demolition contractors, one actually becomes a bit of an expert oneself. From this experience, confidence originated that the tool reflects the actual situations that are encountered in

practise. The relevant question to ask however, is whether the validation of the tool is solid enough for a third party to trust the tool enough to use it for further research. For that manner, there are some critical points must be addressed; first, the validity of the interview data; then the integrity of the validation process that was gone through in chapter 5.2. Both are discussed here.

Interview data. 14 demolition contractors have been interviewed and some are even visited twice. Moreover, conversation took over one and a half hour on average; that is a lot of data. As mentioned, the nature of the conversations did not allow for a structured transcript. This led to less traceable results; nothing to do about that. However, there were some aspects in the process that could have been executed more carefully:

- Not all interviews were recorded. Extensive notes were made, all interviews were transcribed within 24 hours and shared with the interviewee afterwards but in fact, only the last seven interviews were recorded. The traceability of the other transcripts is lower.
- Not all sentences were written down literally. Even when interviews were recorded, not all sentences were written because it costs a lot of time. In defence of the fact that it might be less pure, the original recordings (for the last seven interviews) are still available.

The validation process. In an attempt to validate the Purchase Costs Tool, three aspects have been evaluated separately, namely, the way of interpreting elements from written text with a key, the presence of all elements in the transcript, and the overall coherence of the tool. the conclusion from the validation process is that it is not proven that the developed tool is incorrect but that it cannot be excluded based on the validation process that there are errors in the tool. For reference, here the weaknesses in the three aspects of the validation process are discussed.

- Validating the key. As was mentioned, the keys that were used to identify certain elements from the transcript require some human interpretation. Because of this, it is tested whether a volunteer could reproduce similar results. Limitations of the approach are addressed here:
    1. although the volunteer did surprisingly well, she did miss some of the elements and also identified one unintended element. Missing elements is considered harmless; because data from the transcript is not limitless it is also not expected from the tool to cover all possible scenarios. However, the situations that are covered, ought to be covered correctly so it is not a good sign if unintended elements can be identified. This particular case was blamed on misinterpretation of the assignment
    2. the volunteer only got to work through a small sample of elements.
    3. Just one volunteer was used. Therefore, there might have been luck involved.
- The present of all elements. Although the interpretation of the transcript turned out to not be fully traceable, it has been made traceable which parts of the transcript have been cited to arrive at the different elements that make up the tool. In Appendix 6 you can see for yourself if you agree with the applied interpretation of the transcript. This actually provides a useful alternative for interpretation with a key.
- Overall coherence of the tool. The question is whether the tool describes the contractor's processes exclusively and fluently, meaning that each element is relevant and in the right place. From the reaction of the interviewed contractor this seemed to be the case. However, this discussion aims to assess whether the validation method can actually exclude the chance that there Are issues with the tool. Aspects that make question the validation are:
    1. Due to the nature of the conversation, it was not possible to cover the entire tool.
    2. Furthermore, during the interview, a slightly older version of the tool was presented.

6.4 Market Assessment Method

Since the outcome of the Market Assessment Method can be considered the end result of the research, a critical look is taken to the input data that was used for the case study

Whereas the Purchase Costs Tool can be considered to be the main deliverable of the research, the Market Assessment Method really is the end product. The method uses the results from the Purchase Costs Tool as input and combines it with relevant market data to recreate the Supply Costs Curve from the Market Size Model. By comparing this curve with the price that a buyer is willing to pay, it can be determined how much profit can be made off the business. Since the potential profit was adopted as threshold for potential market development, and other factors were left out of the scope, the method therefor results in an answer to the main question whether a B2B market may arise.

Because the Market Assessment Method is just a step-by-step plan for recreating a curve, not much can be concluded about the scientific value of the method. In that respect, this subchapter will just be used to share some interesting insights that were gained. Special attention is paid to the limitations of the Market Assessment Method however. After all, in line with this chapter's sub-question and based on the outcome of the Results chapter, it must be determined whether the Market Assessment Method provides a solid answer to the main question. In the Methodology chapter, it was presupposed under the assumption that the theoretical framework is correct that the outcome of the case study could be considered valid as long as the input values are valid. Since the theoretical framework has already been covered, focus goes out to the validity of the method's input values in this subchapter.

6.4.1 Contribution of the Market Assessment Method

While using the Market Assessment Method, several interesting insights in the demolition market where gained and based on the model, an analogy with the oil and gas industry is confirmed

The interviews with 15 contractors were primarily used to synthesize the Purchase Costs Tool but it was used again to gather input data for the Market Assessment Method; especially during step 2 where contractor profiles were formed and step 4 where the Purchase Costs Tool was applied. Of all the interesting information from the transcript, the findings from the case study are presented here:

- There seems to be a clear distinction between demolition contractors who bring building products to their yard and the ones who don't. from research it follows that there are several ways to sell products. For example, one could invite buyers to disassemble products themselves or one could allow them to pick them up at the project site. However, success rates are low with these sales strategies because there is almost never enough time for it. In contrast, contractors who sell products from their yard don't have this problem because they just bring home the products after a day of work. Only a small number of contractors operates like this but it is them who dominate the B2C reuse market.
- From the case study it turns out that, for most buildings, it would actually be more expensive for the middleman to buy toilets from the demolition contractors who sell products from their yard because, in contrast to the majority of contractors, they have existing sales channels in the B2C market. Ironically enough, by selling to a middleman, the contractors who currently reuse less building products in fact have the most potential for reuse in the B2B market.
- Finally, it turns out that prices for the middleman skyrocket when picking up building products at small projects simply because he has to drive all the way up and down for only a small number of toilets. In those cases, it is actually cheaper to purchase products from contractors who bring products to their yard because they can hoard the products in order for the middleman to pick them up all at once

Apart from the additional findings from the transcript, it is worth to mention the findings from step 5 where the purchase costs for different market segments are plotted. It was already mentioned that the oil and gas industry poses a fitting analogy for purchasing second-hand building products but in hindsight it was found that analysts in the oil and gas industry use exactly the same visualisation to demonstrate the fact that there is a difference in costs depending on the source of the product. This is shown in figure 49 where the costs of production is plotted against the cumulative production.

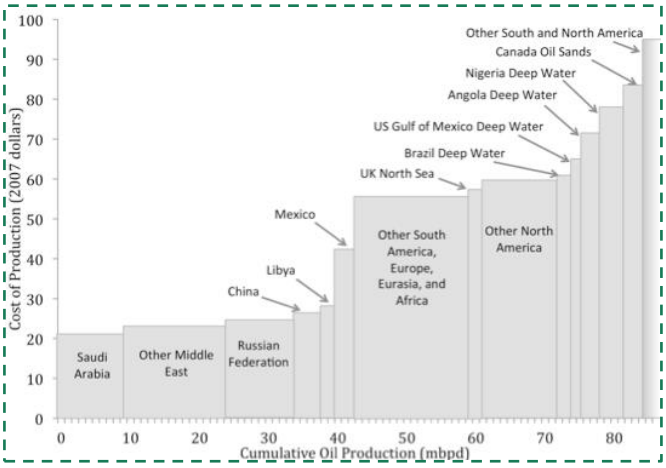


Figure 49 Oil costs curve

Similar to the proposed model in this research, it becomes unattractive for a middleman to purchase from oil from expensive reserves if there is not much demand for the product. logically, he would only tap into more expensive sources when the oil price is (demand) is high. The analogy between the circular economy and the oil and gas industry (or mining in general) is a valuable insight because it suggests that more lessons could be drawn from the comparison.

6.4.2 Limitations of the Market Assessment Method

From an assessment of the input values of the case study it can be concluded that there is a chance that the investigated toilet business will be less successful in practice due to biased input value

Since the Market Assessment Method ought to provide an answer to the main question, the case study must show realistic results unless the input data was biases. Here it is assessed whether de input data is biased or no. distinction is made between *random* error, where the real outcome might be more or less optimistic, *conservative*, where the real outcome may be more optimistic and *overly optimistic*. the different data that are considered are discussed below. The conclusion from the assessment is that it is less likely that a toilet business can be successful than the case study suggests. This is shown in figure 50. When it is ever proven wrong that a second-hand toilet business can exist, at least some of the error can be attributed to the input value and not to the model itself.

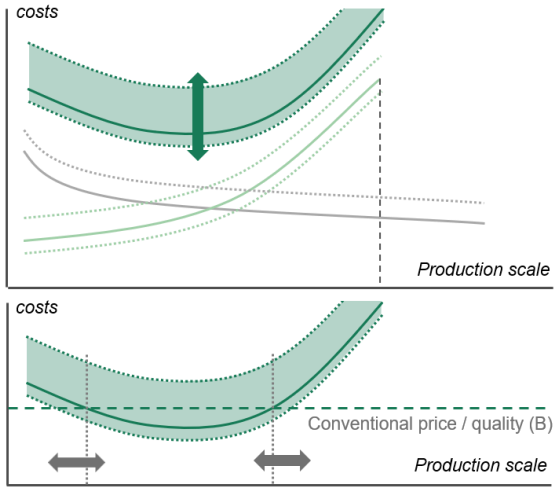


Figure 50 Inaccuracy of the input values

- Market size of different types of projects. The number of toilets that was attributed to each type of building was based on estimations. It would have been way beyond the scope to many toilets there are in different types of buildings so it was necessary to make an estimated guess. This inaccuracy is *random* since the real number of toilets could be more or less.

- Market share of different types of contractors. Web research was conducted to determine the market share of different types of contractors but since there are no reliable sources for such data if you're not willing to pay, here as well there is inaccuracy. Once again, this inaccuracy is *random*, not biased.
- Costs per situation. This is where the Purchase Costs Tool is applied. The reliability of the tool itself is in the previous subchapter. The quality of the input data for the tool is discussed here. the tool helps decide which operations are required for reuse but the costs of each operation need to be estimated. In general, estimations are more accurate if they consist of more elements but still there is inaccuracy involved without a doubt. In contrast to the previously mentioned costs, these costs may be *over-optimistic*, here is why: e.g. estimating the time needed for transporting a toilet out of a building involves estimating the required time for all parts of this operation such as walking down the stairs, the hallway etc. Estimation the costs of these known steps might be random but it is certain that the costs can only increase when steps are overlooked
- Middleman's costs. In line with the other values discussed here, there will be inaccuracy in the estimations for the middleman's costs and just like the input costs for the Purchase Costs Tool, the actual costs are likely to be higher in reality, making the case study's result *over-optimistic*.

7 Conclusion

How can we determine whether a self-sustaining B2B market for reusing specific building products can arise?

This picture was taken at Beijer & zn B.V.

Here follows the conclusion chapter of the research; This is where the question is answered how we can determine whether a self-sustaining B2B market for reusing specific building products may arise. The sub questions of the subsequent chapters each peeled off a layer of the problem to arrive at this subchapter; together these chapters answer the main question. This final chapter addresses the conclusions from each chapter. In addition to the conclusion, the chapter is wrapped up with three suggestions for follow-up research. But first, the conclusion of the research:

It is useful to investigate which second-hand building products have market potential because the government can use this knowledge to stimulate circular business models in order to reduce the CO2 emitted in the production of building products

Current literature does not provide answers to any of the challenges that are expressed by market parties in the context of reuse potential of products but because there is already tacit knowledge available about disassembly, it is decided to approach the problem from the supply side

The Feasibility Model has been proposed to determine the costs of reusing individual products and the Market Size Model is proposed to evaluate if the sum of all transactions for a product leaves a large enough profit for middleman to facility market development

The Purchase Costs Tool, that can be used to determine the demolition contractor's costs for supplying a product in different situations, is synthesized by interviewing 15 demolition contractors, validated, and used as input for the Market Assessment Method which is used to identify potential self-sustaining B2B markets for reusing a specific product

In a case study it is demonstrated how the Market Assessment Method, supported by the Purchase Costs Tool, is used to assess whether a self-sustaining B2B market for second-hand toilets can exist

At last, it is found that the developed method provides a solid basis for evaluating market potential of different second-hand products but that additional research on application costs, together with more extensive market data is required to give the full answer to the question how it can be determined if a self-sustaining B2B market for reusing specific building products may arise

7.1 Background

Why should we determine whether a self-sustaining B2B market for reusing specific building products can arise?

Around the time of writing, no extensive explanation should be required about the impact of CO2 emission on our living environment. Many scholars have shed light on the challenges we face and besides the fact that the risks have been demonstrated by scientists, politicians and citizens seem to be really aware of the problems. A survey by the EU shows that 93% of citizens consider climate change a serious problem and governments from all around the world agreed that they would reduce their CO2 emission during the famous UN Climate Change Conference in Paris in 2015.

One way of reducing CO2 emission is the circular economy or CE in short. CE aims to reduce the initial use of materials and tries to increase the functional lifespan of materials with the goal that less materials need to be produced. Besides other advantages such as independence on finite resources, less CO2 is emitted in the production process if less products are produced. As well as for CO2 emission in general, the government made plans for the transition to a circular economy in 2050, recorded in five transition agendas including one for the construction industry. The latter is of interest since this is a graduation research in the field of building engineering.

Based on this explanation, it can be concluded that circularity in the construction industry contributes to the higher goals that humanity is engaged in at the time of writing. Central in CE, is the distinction between different strategies for treating materials throughout their life-span; Reduce, Reuse, Recycling, Energy Recovery, Incineration and Landfill, according to Lansink's Ladder, in order from low environmental impact to high environmental impact. It is logical to focus on the Reuse of building products, instead of other waste strategies because Recycling, which is one step below Reuse on the ladder is the status quo in the construction industry; 95% of materials is reused while only an estimated 0.24% is reused. Concluding from this, potentially, huge ecological savings can be achieved by reusing.

While reuse has great potential for reducing ecological impact in the construction industry, almost no products are reused because it appears to be uneconomical (expensive) to do so. Furthermore, a lot of specific building products probably never will be suitable to be traded in a self-sustaining reuse market. It is hypothesized however that there could be a market in trading some specific products if the government would support these markets to arise by temporarily investing in market development. As is mentioned in the transition agenda for the construction industry however, it is not clear which products could potentially be traded on a larger scale so in order for the government to invest her resources in developing the right markets, it is worthwhile to assess which products have market potential and which ones do not. In order to do this, a Market Assessment Method is required.

From reading the transition agenda for the construction industry, it becomes clear that the government seeks out collaboration with companies in the construction industry, referred to as the B2B market in this research. This research recognizes that there is also a B2C market, referring to private parties buying building products, which is currently responsible for most existing reuse (0.24%). Since this research is done in context with the transition agenda however, it is decided that the research question should be focussed on B2B market for reusing building products.

7.2 Exploration

Which knowledge must be gained for identifying second-hand building products for which a self-sustaining B2B market can arise?

There would be no use for the research if the answer to the main question was already known. Thus, provided that this is a useful research, there is a lack of knowledge that hinders the main question from being answered. The question which knowledge must be gained throughout this research is address in four parts. *1)* It is investigated which knowledge is relevant for identifying second-hand building products with market potential. This is done by conducting Exploratory Interviews with market parties. *2)* It is determined which knowledge with respect to the main question is still lacking in contemporary literature on the topic. This lack of knowledge is referred to as the Research Gap. *3)* It is established which part of the Research Gap will not be look into throughout the research (due to limited time and resources). These parts of the Research Gap are described in the Scope of the research. *4)* In a Theoretical Framework it is clarified which knowledge is needed based on the Research Gap and the Scope, and what should be investigated to acquire this knowledge.

Exploratory interviews. Since it is not immediately clear what makes reuse of different products uneconomical, exploratory interviews have been conducted with market parties. It was identified that conventional products are chosen over second-hand products because it is more economical. It is reasoned that this difference as to how economical reuse is compared to conventional products, is caused by different Obstacles. In the interviews it is found what these obstacles are. The obstacles are classified in eight categories; to summarize, there are four categories related to supply and demand. The categories provide a new way of identifying the effect of many factors on the feasibility of reuse.

The Research Gap. In the context of reusing building products in the construction industry, literature has been reviewed. About the supply of building products, some interesting papers are written. In the United States there have been several researches on comparing the costs of deconstructing typical American houses compared to the costs of conventional demolition. From these sources it can be concluded which building products are typically disassembled in the deconstruction process and that, in multiple specific cases, deconstruction of a building is cheaper than conventional demolition if salvage value is accounted for. In contrast to supply, almost no useful sources are found on the topic of applying second-hand building products in buildings.

Based on the different types of obstacles from the exploratory interview, it is evaluated which knowledge is lacking. Literature about applying different second-hand building products in construction projects is lacking all together. In context with the obstacles for supplying building products it is still unknown what the additional costs for supplying specific products are since the reviewed papers only spoke of total disassembly costs per project. Also, it is not clear how these costs would vary for different projects or different contractors in the Dutch demolition market. Concluding, knowledge is lacking about all obstacles that hinder specific products to be traded on a large scale.

The Scope. Since there is not enough time to fill in all the gaps in the missing knowledge, the scope is restricted to covering only part of it. This implicates that the resulting answer to the research question will not take all aspects into account that are relevant for identifying market potential for reusing specific building products. As a result of the scope restriction, the research only looks into the feasibility of supplying different building products on a macro scale. This is fit to answer the main question by presuming that the supplier makes costs in order to supply products with the quality and convenience that the builder is used to, therewith cancelling out demand related obstacles.

In addition, the market is modelled as if it has already arisen, meaning that demand is plentiful and therewith cancelling out the market obstacle for the supplier. besides these two main restriction to the scope, it is assumed that demolition contractors won't innovate, that perfect market conditions apply, and also, environmental costs are not accounted for and only supply from total demolition is considered. Concluding from these restrictions, the research basically aims to come up with a method that helps to assess for which costs and in which quantities a certain type of second-hand building product can be supplied for a normal price, at quality that the builder is used to, in order to evaluate if enough profit is left for a market to sustain itself.

The Theoretical Framework. The main elements of the Theoretical Framework are the Feasibility Model and the Market Size model. The Feasibility Model demonstrates the comparison between cash flows in a linear value chain and cash flows in a value chain where demolition contractors disassemble building products and a middleman upgrades the product to sell it to a builder subsequently. Under the presumption that demolition contractors in the reuse value chain want to be at least as profitable as contractors in the linear value chain, it can be formulated which the price *E1* the contractor must receive for reusing a certain product. Since the middleman must pay the price *E1*, has to make his own costs *E2* and wants to make a profit *E3*, it can then be formulated which minimal price *E* the builder must pay the middleman in order for the middleman to facilitate the transaction. Clearly, no transaction will occur (in line with the scope) if price *E* is higher than the price *B* for conventional products because, as well as the other parties, the builder at least wants to make his normal profit. Thus, by means of the Feasibility Model it can be assessed which transactions can or cannot take place. In order to do so, prices *B*, *E1*, *E2* and *E3* must be known.

Whereas the Feasibility Model provides a way to assess whether reuse (B2B) transactions are possible, the Market Assessment Model can be applied to evaluate whether a B2B market for reusing a certain building product can exist. For the model to work it is proposed that a reuse market can exist if enough transactions (with a profit margin) can occur in order for a Hypothetical Middleman, who facilitates all transactions, to make enough profit to run his business. Whereas the conventional product price *B* and a desirable profit *P* are single values that can easily be determined, the price *E1*, referred to as Purchase Costs, will be different for different transactions since there is a variation in projects and contractors (different project- and contractor related obstacles). The Market Assessment Model proposes that costs *E1* per transaction will increases if the number of transactions increases because, just as in the oil and gas industry, harder to reach products will be sold only if demand is high. On the other hand, the model proposes that the average operation costs per product *E2* will decrease when the number of transactions increases because this spreads out the fixed costs. By plotting *E1* and *E2* to production scale *n* and combining them, the model demonstrates how the average costs per product (*E1+E2*) compare to price *B* at any production scale *n* to evaluate if there is a production scale at which the middleman makes enough profit and if this is the case, it can be said that a B2B market for reusing the product can exist. Concluding from the model, a method must be developed for shaping the cost curves for Purchase Costs *E1* and Middleman Costs *E2* in order to answer the main question.

In light of the scope restrictions of the research, the Market Assessment Models only helps determine whether a B2B reuse market can exist under the earlier discussed assumptions. To account for the most important assumption that demand will be plentiful, a final model is proposed; the Market Development Model. This model demonstrates how market related obstacles, causing the fact that demand and supply don't find each other, may disappear if the government temporary stimulates a market. Concluding from that notion, the Theoretical Framework covers the entire Research Gap.

7.3 Methodology

How do we synthesize and validate a method for determining if it is possible for a B2B reuse market for certain building to exist?

The method that is developed aims to recreate the curve of average Purchase Cost *E1* for different production scales as well as the curve of the average Middleman Costs *E2* for different production scales because, in line with the Market Size Model, these curves can be used to answer the main question. The method is referred to as the Market Assessment Method. The most challenging part is determining the Purchase Costs *E1* for the same type of product originating from different types of products, supplied by different kinds of demolition contractors; this challenge covers most of the Research Gap. A special tool is developed for this purpose. It is referred to as the Purchase Costs Tool.

The Purchase Costs Tool. By conducting semi-structured interviews with 15 different demolition contractors that have experience with circular disassembly, enough tacit knowledge is gathered to simulated the processes of supplying many different types of building products from several different types of buildings by a lot of different kind of demolition contractors. These insights are used to synthesize the Purchase Costs Tool. To cover Project- and Product- related obstacles, pictures of different types of products are shown in the context of different types of projects to provoke stories about disassembly or demolition. Contractor related obstacles are covered by portraying each contractor that was interviewed on the basis of standard questions.

Validation of the Purchase Costs Tool is done in three steps. *1)* It must be demonstrated that there is a clear relation between the stories from demolition contractors in the transcript and the way they are interpreted to synthesize the Purchase Costs Tool. To do this, a linguistic key is developed for translating sentences in the transcript to elements of the tool. It is validated if the key works correctly by comparing the interpretation of the transcript by an independent volunteer with the interpretation that is used for developing the tool. *2)* An overview is made that includes all elements of the Purchase Costs Tool, accompanied with sentences from the transcript where the elements are based on. This allows the reader to judge for herself whether the elements of the tool are grounded in the transcript. *3)* A demolition contractor is asked to use the tool to find out if it yields the same results that he would expect. By these steps, the individual elements and the overall coherence of the tool are validated.

The Market Assessment Method. The main challenge for the model is to create the curve for the average Purchase Costs *E1* per product at different production scales *n*. Situation for which price *E1* differs are defined on the basis of different categories of contractors crossed with different categories of projects; each combination between a type of contractor and a type of project represents a situation. To plot the curve, each situation has a price *E1* corresponding to it, which is found with the Purchase Costs Tool, as well as the number of transactions *n* that correspond to the situation. The number of transactions for each situation is found by doing research into the market share of different kind of contractors and by calculating how many products are released from different kind of buildings. The curve for *E2* must be created as well; this is done by making a plan for a hypothetical business to assess what the required fixed and variable costs would be for a business that transports, stores and possibly upgrades a certain building product.

Validating the Market Assessment Method is considered trivial because it is merely a step-by-step plan for creating two curves. Since the method is copied from the Market Size Model, the outcome of the model is considered valid if the input data is accurate, presuming that the Market Size Model is correct. Rather than validating the model, a case study is done to demonstrate how it works.

7.4 Results

How can it be determined whether a self-sustaining B2B market for reusing toilets can arise by using the developed method?

The two main results of the research are a functioning Profit Cost Tool and a case study in which the Market Assessment Method is demonstrated. To summarize the results; both were delivered successfully. With help from the Purchase Costs Tool it became possible to generate the Purchase Costs *E1* corresponding to many different transactions with relatively little effort and the tool was successfully validated. The result of the case study is a diagram for evaluating the market potential for second-hand toilets that resembles the envisioned curve from the Market Size Model perfectly, as was hoped for. Here, the Profit Costs Tool and the case study are evaluated individually.

The Purchase Costs Tool. The stories from the transcript were used to recreate the chain of operations for different situations in which different building products are disassembled. By combining these so called 'paths' in a single overview, a diagram resembling an upside-down tree is formed. By using data from the transcript, individual paths for different situations can be filled out in the diagram and by adding up the costs of all operations on a path, the costs for disassembling a product can be determined. Similarly, the path for demolishing the same product can be filled out to compute the corresponding costs. In line with the Feasibility Model, the operational costs for disassembly and demolition are then compared to determine the Purchase Costs *E1* for the given situation. In the case study, this process is repeated for 12 different situations which went smoothly because all computations are automated in a spreadsheet. See Appendix 14 to inspect the user interface.

The three steps for validating the Purchase Costs Tool all led to the conclusion that the tool can be trusted to generate valid input data for the Market Assessment Method. *1)* the volunteer who was given the assignment to interpret the transcript by using the prescribed key only made a few mistakes even though she had no prior knowledge. From this it is concluded that the transcript is interpreted correctly for synthesizing the tool. *2)* all elements of the tool are supported by references to the transcript; in Appendix 6 you can see for yourself. *3)* upon showing the rather complicated looking tool to a demolition contractor, he easily understood how it worked. When walking through the tool, the contractor was able to identify different paths for two different products without hesitation. Finally, when asked whether the paths correspond to his process in practice, the answer was a convincing YES. This shows that the tool is coherent and applicable in practice.

The Market Size Model. The model consists of nine steps that lead to a diagram that demonstrates the market potential of toilets. The steps from the case study are summarized here. *1)* A distinction is made between high and low buildings as well as small and large buildings because these project properties turn out to influence the Purchases Costs. Most toilets originate from large, low buildings *2)* Variables that are used to distinguish demolition contractors are; their interest in reuse; whether they sell from their yard; if they consider toilet; whether they have buyers for toilets. Web research shows that most contractors are not interested in reuse to begin with. *3)* by combining the variety in projects and contractors, 12 situations are defined. *4)* the Purchase Costs Tool is used to compute *E1* for all situations. *5)* The middleman's costs for picking up toilets is included in *E1* because these costs depend on the situation. The data is used to plot the market share n and Purchase Costs *E1* for each situation. *6)* From the market segments, the curve for average *E1* is plotted. *7)* A hypothetical business for the middleman is evaluated to plot the average Middleman Costs *E2*. *8)* The two curves are added up to arrive the Supply Costs Curve. *9)* the curve from step 8 is compared with the new equivalent product price *B* to conclude that a B2B market for toilets can arise. The real conclusion is that the method seems to work since the result perfectly meets the expected shape of the curve.

7.5 Discussion

Can it be concluded that the developed method enables us to determine whether a B2B market for reusing specific products can arise?

First of all, it was demonstrated that the developed Market Assessment Method results in an answer to the question whether a B2B market for reusing toilets may arise. By evaluating the method in light of the Research Gap it is concluded that this answer cannot be given without the knowledge that was gained in the research. Whether the method satisfies the main question depends on the question whether the answer about the toilet is correct. Since the Market Assessment Method makes a prediction, the result cannot be compared with the real life situation to draw this conclusion because the real life situation does not exist (yet). Instead, deductive reasoning is used; the outcome of the method depends on the Theoretical Framework, which forms the basis for the method, and the input values that were used, provided by the Purchase Costs Tool and market research. Thus, if the Theoretical Framework, the Purchase Costs Tool and the market data are correct, the method satisfies the main question. These three aspects are address separately but the main conclusion is that more accurate market data is needed to provide a solid answer; that the Purchase Costs Tool can be considered valid although the validation is not yet water tight; and that follow-up research is required for complementing the Theoretical Framework to include factors that were left out of the scope.

The Theoretical Framework. Three separate models contribute to an answer to the research question; the Feasibility Model, the Market Size Model and the Market Development Model:

1. The Feasibility Model sheds new light on the way in which cash flows for demolition and disassembly can be compared by proposing that these cash flows can be put in context with the cash flows of other actors to assess whether a reuse transaction can occur. The fact that the cash flows in the model are referred to in other publications, supports their validity.
2. The Market Assessment Model. Because the model is limited to the restrictions of the scope, it is concluded that the Market Size Model is not fully capable of demonstrating the market potential of second-hand products. It does however provide a solid basis, including the most essential variables, that was not available before conducting research. The incompleteness of the model provides room for the follow-up research that is discussed in the last subchapter.
3. The Market Development Model. This model addresses the market related obstacles that were left out of the scope of the research. By demonstrating that there are mechanisms by which these obstacles can be overcome through temporary government financing, the model attempts to convince the reader that the Market Assessment model can answer the main question without accounting for demand. The model does give valuable new insights in the influence of government influxes but it is over-optimistic to assume that demand is really accounted for by the model since it only provides a qualitative analysis.

The Purchase Costs Tool. All attempts to validate the tool pointed in the direction that it reflects the real processes of demolition contractors so it is fair to say that it is a valuable tool for using in practice. However, the rigidity of the validation method can be questioned because little sample sizes were used. Because of this, it is proposed to do more tests before considering it a full contribution to science.

The Market Data. When evaluating the outcome of the case study to conclude whether the Market Assessment Method gives a realistic result, it must be taken into account that the conclusion about the market potential of second-hand toilets can be over-optimistic due to biased input data. If the method is ever applied in practice, more effort should be put in generating reliable input data to prevent over-optimistic expectations about the market potential of certain products.

7.6 Follow-up research

Based on the assumptions that have been made to make the research manageable and based on interesting insights from the interview transcript, three ideas for follow-up research are proposed

From the assumptions that have been made to allow the research to be completed in the available time, several suggestions for follow-up research originate. Covering these limitations will result in an addition to the Market Size Model which helps to fully address the question whether self-sustaining B2B markets for reusing certain products may arise. Chapter 6.2.4 already demonstrated the effect of the assumptions on the Market Size Model. Some suggestions for follow-up research have been inspired by these effects. Furthermore, some additional suggestions for follow-up research are provided that originate from researching the 130-page transcript with demolition contractor's stories.

1. Research on application costs. in this research, the Purchase Costs Tool has been developed to compute the price *E1* that a demolition contractor needs to receive for supplying a certain building product, depending on the type of project and the way he is used to operate. Similarly, a tool could be developed to compute the additional costs (*D-A*) that a builder needs to make in order to apply a second-hand building product, depending on the product, the type of project and the type of consortium that represents the builder. In this research, it was assumed that the middleman can supply second-hand products similar to new products but this is not realistic. Only by investigating the additional costs that builders will have to make for reusing products, can it really be determined which products have market potential. An interesting dimension to such a research will be the fact that a single second-hand building product can be applied in many different ways; finding out which repurpose is most economical for different products will increase the chance for reuse markets to arise.
2. The effect of product properties. The 130-page transcript contains knowledge about dozens of different building products and the Purchase Costs Tool allows the user to determine the Purchase Costs E1 for all of them if the transcript is consulted; it really is a shame that only the market potential of toilets was assessed. Only by assessing all other products can it be found out which products have market potential and which ones don't and on top of that, it would provide the required data for a related research in the field of designing for reuse, namely: The Purchase Costs Tool provides all operations for disassembling a product and the transcript can be used to figure out the costs of each operation. By mapping these costs for different kinds of products in different kind of buildings, it can be traced down what the effect of different product properties is on the supply costs. these insights can be used to produce products and design buildings that are more suitable for disassembly.
3. The supply costs of entire products. In this research, the Supply Costs Tool was applied to determine the required price for supplying a single product without considering what the reuse potential is of the adjacent products. A toilet was a convenient example since it can easily be regard independent of the rest of the structure. In contrast, when disassembling wooden roof boards for example it is relevant to consider if the roof tiles will be sold as well because for disassembling the roof boards, the tiles need to be carefully removed first; this becomes a less interesting option if the tiles are discarded anyway. By creating a model that accounts for the interrelation between products, the Purchase Costs Tool can be applied to find the most economical way of taking down a building conform current market prices of second-hand building products. Such technology can be used to assess if circular designs are really reusable to advise clients of demolition projects in circular tenders.

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Appendix 1,2,3,6,12,13 & 14

These appendices contain sensitive information and have been left out of this version for commercial reasons. Please contact me by email if you have questions about the content: hermenvandeminkelis@gmail.com

Below it is summed up what the content of the missing appendices is. The pages thereafter contain Appendices 4, 5, 7, 8, 9, 10 and 11.

- Appendix 1 contains exploratory interviews with Repurpose, Imix projecten, A van Liemd and Veras. It covers their vision on the obstacles that hinder reuse in the construction industry
- Appendix 2 contains an interview with Architecture firm Roosros about their experiences with realizing a building project with reused building products.
- Appendix 3 contains interviews with 14 demolition contractors about the disassembly of many product from numerous types of projects.
- Appendix 6 contains an explanation of all individual decisions and operations that have been applied in the Purchase Costs Tool joined by a reference to the stories from appendix 3.
- Appendix 12 contains a count of different types of buildings that were demolished in in 2017 accompanied by the corresponding number of toilets in these buildings.
- Appendix 13 contains a report covering the process of extracting required data about the demolition of buildings in 2017 from BAG.
- Appendix 14 shows an overview of the Purchase Costs Tool.

Appendix 4. interview format

8.1 Interview format

8.1.1 Inleidende vragen

- Hoeveel projecten / omzet per jaar?
- Hoeveel renovatie / totaalsloop?
- Wat voor materieel en transport middelen hebben jullie?
- Hoeveel / wat voor personeel hebben jullie in dienst?
- Wat voor afzetkanalen gebruiken jullie voor de verkoop van producten?
- Proces rondom de verkoop van een product?
- Worden er weleens producten gestolen?

8.1.2 Vragen over Type gebouwen

- Welke panden slopen / renoveren jullie voornamelijk?
- Om welke redenen worden de verschillende panden gesloopt?
- Uit welke panden valt het meeste te verdienen aan geoogste producten?
    - Waar ligt dit aan?
- Op wat voor soort project kan je het beste concurreren?
- Hoevaak gebeurt het dat een particulier iets mee neemt?
- Waar neem je pot. Opbrengst mee in bestek? / inventarisatie?

8.1.3 Algemene product fotos

- Demonterende partijen of particulieren / installateur opkopers / aannemer opkopers
- Hoeveel producten kan een persoon op een dag online zetten en verkopen?
- Wat voor producten verkoop je die anderen niet snel zullen doen?

8.1.4 Vragen over Productfotos

Gele gedeelte

- *Waar vind je dit product allemaal?*
- *Hoevaak is het product daar?*
- *hoe oud is dit product meestal?*
- *Demonteer je dit voor verkoop?*

Nee:

- *Waarom niet?*

Ja:

- *In welke gevallen doe je dit?*
- *Wat voor gebreken kom je tegen in het product? – hoevaak?*
- *Wat voor problemen kom je tegen bij demontage? – hoevaak?*
- *Hoeveel % van alles wat je kan verkopen wordt verkocht? – prijs?*
- *Hoe wordt het product vervoerd en opgeslagen*
- *Wat is de doorlooptijd van het product?*

Appendix 5. paths of the tool

Here, the processes are referred to as start and end of a path. The reason for taking the different paths is explained.

Start	end	Reason for taking the path
1	2a	• The product is disassembled for the client of the project • The product is disassembled for a buyer found during project preparations • The product is disassembled without having searched for a buyer • The product is disassembled by a buyer found during project preparations • The product is disassembled by a specialized sub-contractor
1	2b	• Asbestos is found in or on the product • The contractor has the habit of demolishing the product • The project is not suitable for disassembling and reusing • The product turns out to not be suitable for reuse • No buyer for the product is found beforehand
2a	2b	• An unexpected discovery of asbestos prevents a buyer from disassembling the product because only certified people are allowed inside
2a	3a	• The contractor successfully disassembled the product
2a	4a	• A buyer has disassembled the product • A specialized sub-contractor has disassembled the product
2a	4b	• The product is damaged during disassembly by the contractor
2b	3b	• The product is demolished and converted to debris • The product (if containing asbestos) is carefully removed
3a	3c	• The product is transported to the yard of the contractors
3a	4a	• The product is being picked from location by a buyer
3a	4b	• No buyer is found who can pick up the product
3a	Reuse	• The product is handed over to the client to be reused (mostly at site)
3b	4b	• The debris is sorted and processed at location • The debris is sorted and processed at the yard of the contractor
3c	4a	• The product is picked up from the yard by a buyer • The product is delivered to a buyer
3c	4b	• The product is damaged during transport and handling • After a long time, no buyer is found for the product
3c	Reuse	• The product is reused by the contractor himself
4a	Reuse	• The product is donated to a ‘buyer’ • The product is sold without registration to a buyer • The product is sold after registration to a professional buyer • The product is sold after registration to an individual
4b	Recycling	• The product is picked up by a recycling company • The product is brought to the recycling plant to be recycled
4b	Energy Recovery	• The product is brought to the recycling plant to be burned in a process where energy can be retrieved
4b	Burning	• The product is brought to the recycling plant to be burned
4b	Landfill	• The product (mostly asbestos) is brought to a dumping place

Appendix 7. linguistic analysis

8.1.5 Operations

Verbal predicate, adverbial clause, subject, direct object, nominal predicate, sub clause

1 The operation is described by the *verbal predicate* (possibly accompanied by an *adverbial clause*) of a sentence in which the *subject* is the building product (or otherwise a part of the product or a compassing element such as the entire building)

"de wc moet worden ingeladen"
- *'inladen'* describes the operation

2 The operation is described by the *verbal predicate* (possibly accompanied by an *adverbial clause*) of a sentence (or otherwise a *subordinate clause* or *subject clause*) in which the *direct object* is the building product (or otherwise a part of the product or a compassing element such as the entire building) and the *subject* (if present) is the demolition contractor (or someone substituting his role)

"slecht hout knijpt hij fijn met de grijper"
- *'fijnknijpen met de grijper'* describes the operation

"een andere optie is om delen van het product er uit te slaan"
-

"om delen van het product er uit te slaan"
- *'er uit slaan'* describes the operation

3 The operation is described by a *nominal predicate* or *verbal predicate* or *nominal predicate* and/or the related *subject* or *direct object* that is not a building product in a sentence (or otherwise a *subordinate clause* or *subject clause*) that is accompanied by (or can be supplemented with) an *adverbial clause* that describes another operation

"voor het slopen van hoge flats moet een grote kraan worden gehuurd"
- *'huren'* describes the operation

"om granulaat te maken is een gecontroleerd proces nodig"
- *'een gecontroleerd process'* describes the operation

"tijdens werk op het balkon moet men valbeveiliging dragen"
- *'valbeveiliging dragen'* describes the operation

"de sloper heeft contact met een pannenhandelaar"
-

"(voor de demontage van dakpannen) heeft de sloper contact met een pannenhandelaar"
- *'het hebben van contact met de pannenhandelaar'* describes the operation

8.1.6 Circumstances

Verbal predicate, adverbial clause, subject, direct object, nominal predicate, finite verb,

conjunction, compliment

1a The condition is indicated by a specific *adverbial clause* as condition indicator accompanied by a *nominal predicate* describing the condition

"De schroeven van een wc zijn bijna nooit verroest"

-

"De schroeven van een wc zijn bijna nooit verroest (waardoor ze meestal worden los geschroefd)"

-

"(waardoor ze meestal worden los geschroefd)"

- *'bijna nooit'* is the circumstance indicator
- *'verroest zijn'* describes the circumstance
- *'waardoor'* is the consequence indicator
- *'losschroeven'* describes the operation

1b The condition is indicated by a specific *adverbial clause* as condition indicator accompanied by a *verbal predicate* together with an *adverbial clause* and/or a *subject* describing the condition

"meestal zien wc potten er niet uit"

-

"meestal zien wc potten er niet uit. (dan gaat de hamer er tegenaan)"

- *'meestal'* is the circumstance indicator
- *'er niet uit zien'* describes the circumstance
- *'dan'* is the consequence indicator
- *'de hamer er tegenaan'* describes the operation

2 The condition is indicated by a specific *finite verb* as condition indicator accompanied by a *verbal predicate* with a *compliment* describing the condition

"een wc pot moet er wel een beetje goed uit zien om hem mee te nemen"

-

"om hem mee te nemen"

- *'moet'* is the circumstance indicator
- *'er een beetje goed uitzien'* describes the circumstance
- *'om'* is the consequence indicator
- *'mee nemen'* describes the operation

3a The condition is indicated by a specific *conjunction* (opening a *sub clause*) as condition indicator accompanied by a *verbal predicate* accompanied by an *adverbial clause* and/or a *subject* describing the condition

"als er asbest in de radiator wordt gevonden mag deze niet meer worden verkocht"

-

"als er asbest in de radiator wordt gevonden (,dan) mag deze niet meer worden verkocht"

-

"als er asbest in de radiator wordt gevonden"

- *'als'* is the circumstance indicator
- *'er asbest in wordt gevonden'* describes the circumstance
- *'dan'* is the consequence indicator
- *'verkopen'* describes the operation

3b The condition is indicated by a specific *conjunction* (opening a *sub clause*) as condition indicator accompanied by a *verbal predicate* accompanied by a *direct object* describing the condition

“wc potten zou hij niet verhandelen als hij tijd had”

-

“als hij tijd had”

- *‘als’* is the circumstance indicator
- *‘tijd hebben’* describes the circumstance
- *‘zou’* is the consequence indicator
- *‘verhandelen’* describes the operation

Appendix 8. key interpretation

8.2 Opdracht 1 – een handeling identificeren

Een zin of bijzin die **iets**[1] beschrijft dat gebeurt met een **product**[2] door toedoen van de **sloper**[3]

1. Een handeling (werkwoordelijk gezegde)
2. benoeming van / verwijzing naar het product (verwijswoord), deel van het product
3. verwijzing naar (onderwerp) / geen vermelding (product is dan het onderwerp)

opdracht: markeer het **iets**[1] groen

toilet	
Van Rijswijk	ze willen alleen merkpotten (Joop / Spynx) – zo'n praxispot kost nieuwe 2 tientjes, en kost teveel moeite (die moet worden ingeladen, voorzichtig worden vervoerd, uitgeladen, trap op, op marktplaats, trap af). Verder zijn alleen hangende potten interessant {staande potten zijn uit de mode lijkt uit de reactie daarop} – de hangende potten kunnen gewoon worden los geschroefd en omlaag worden gedragen – schroeven zijn bijna nooit verroest (9/10), bij staande potten soms wel – dan gaat de hamer er tegenaan. {een beetje vies maarja}
TN	Marijn geeft gelijk aan dat de pot op de foto te ouderwets is. om hem los te maken moet de kit worden doorgensneden (met een normaal mes) en moet de fitting er uit getrokken worden. Wat voor soort pot zou het meest interessant zijn? – hangende pot. Later, tijdens de rondleiding wordt ook een ingebouwde spoelbak aangewezen in de loods {suggestief als lucratief product}
Heezen	wat hij zou vermarkten als hij tijd heeft: wcs niet. Frank antwoordt dat er bijna nooit genoeg tijd is. ... moet ook met de hand maar dat zijn simpele dingen – die kan je losschroeven.
Schimmel	Toiletten doet Eddie bijna niet – die dondert hij gelijk weg. Reden? – meestal zien ze er niet uit. Vies wordt bevestigd – die wil hij niet eens verkopen. De mogelijkheid om hem door te spoelen {schoon te maken} wordt niet beantwoord. "meestal is dat spul zo oud" alleen af en toe kom je op een locatie dat er toevallig iets in zit wat er nog goed uit ziet – meestal puinbak ... pispotten haalt de machinist er NIET uit met de grijper, dat is allemaal puin.

8.3 opdracht 2 – een omstandigheid identificeren

een zin of bijzin die de **mogelijke**[1] **toestand**[2] omschrijft met als gevolg wel of juist geen **handeling**[3]

1. een omschrijving van voorkomendheid (‘soms’, ‘meestal’, ‘vaak’, etc.) / voorwaarde (‘als’ bv.)
2. omschrijving van het (deel van het) product of een omschrijving van de situatie
3. een handeling als gedefinieerd in opdracht 1: (Een zin of bijzin die iets beschrijft dat gebeurt met een product door toedoen van de sloper). Soms wordt de handeling niet expliciet genoemd maar valt het uit de context op te maken dat een toestand invloed heeft op wat de sloper doet

opdracht: markeer de **toestand**[2] geel

toilet	
Van Rijswijk	ze willen alleen merkpotten – dan volgt de handeling ‘sloop’. (Joop / Spynx) – zo’n praxispot kost nieuwe 2 tientjes, en kost teveel moeite (die moet worden ingeladen, voorzichtig worden vervoerd, uitgeladen, trap op, op marktplaats, trap af). Door deze situatie, volgt de handeling ‘sloop ’niet. Verder zijn alleen hangende potten interessant {staande potten zijn uit de mode lijkt uit de reactie daarop} – de hangende potten kunnen gewoon worden los geschroeft en omlaag worden gedragen – Door deze situatie, volgt wellicht de handeling ‘sloop’. schroeven zijn bijna nooit verroest (9/10), bij staande potten soms wel – dan gaat de hamer er tegenaan. {een beetje vies maarja} – Als de schroeven verroest zijn, dan volgt de handeling ‘hamer er tegenaan’.
TN	Marijn geeft gelijk aan dat de pot op de foto te ouderwets is. om hem los te maken moet de kit worden doorgensneden (met een normaal mes) en moet de fitting er uit getrokken worden. Door deze situatie volgt de handeling ‘sloop’ niet. Wat voor soort pot zou het meest interessant zijn? – hangende pot. Dan zou hij wellicht de handeling sloop uitvoeren. Later, tijdens de rondleiding wordt ook een ingebouwde spoelbak aangewezen in de loods {suggestief als lucratief product}
Heezen	wat hij zou vermarkten als hij tijd heeft: wcs niet. Frank antwoordt dat er bijna nooit genoeg tijd is. Door te weinig tijd volgt de handeling ‘sloop’ niet. ... moet ook met de hand maar dat zijn simpele dingen – die kan je losschroeven.
Schimmel	Toiletten doet Eddie bijna niet – die dondert hij gelijk weg. Reden? – meestal zien ze er niet uit. Vies wordt bevestigd – die wil hij niet eens verkopen. De mogelijkheid om hem door te spoelen {schoon te maken} wordt niet beantwoord. “meestal is dat spul zo oud” Omdat het oud en vies is, volgt de handeling ‘sloop’ niet. alleen af en toe kom je op een locatie dat er toevallig iets in zit wat er nog goed uit ziet – meestal puinbak ... pispotten haalt de machinist er NIET uit met de grijper, dat is allemaal puin. Omdat het puin is, volgt de handeling sloop niet.

toilet	
Van Rijswijk	ze willen alleen merkpotten (Joop / Spynx) – zo’n praxispot kost nieuwe 2 tientjes, en kost teveel moeite (die moet worden ingeladen, voorzichtig worden vervoerd, uitgeladen, ~~trap op~~, ~~op marktplaats~~, ~~trap af~~). Verder zijn alleen hangende potten interessant {staande potten zijn uit de mode lijkt uit de reactie daarop} – de hangende potten kunnen gewoon worden los geschroefd en omlaag worden

	gedragen – schroeven zijn bijna nooit verroest (9/10), bij staande potten soms wel – dan gaat de hamer er tegenaan. {een beetje vies maarja}
TN	Marijn geeft gelijk aan dat de pot op de foto ~~te ouderwets~~ is. om hem ~~los te maken~~ moet de kit worden doorgensneden (met een normaal mes) en moet de fitting er uit getrokken worden. Wat voor soort pot zou het meest interessant zijn? – hangende pot. Later, tijdens de rondleiding wordt ook een ingebouwde spoelbak aangewezen in de loods {suggestief als lucratief product}
Heezen	wat hij zou vermarkten als hij tijd heeft: wcs niet. Frank antwoordt dat er bijna nooit genoeg tijd is. ... moet ook met de hand maar dat zijn simpele dingen – die kan je losschroeven.
Schimmel	Toiletten doet Eddie bijna niet – die dondert hij gelijk weg. Reden? – meestal zien ze er niet uit. Vies wordt bevestigd – die wil hij niet eens verkopen. De mogelijkheid om hem door te spoelen {schoon te maken} wordt niet beantwoord. "meestal is dat spul zo oud" alleen af en toe kom je op een locatie dat er toevallig iets in zit wat er nog goed uit ziet – meestal puinbak ... pispotten haalt de machinist er NIET uit met de grijper, dat is allemaal puin.

Operation	14
Circumstance	10
~~Missed out on~~	5
Falsely identified as operation	0
Falsely identified as circumstance	1

It does not matter that elements are missed out on. This merely makes the tool less complete and since the tool does not cover all possible situations to begin with, this is not a problem.

It is an issue that a circumstance was falsely identified. The mistake can be explained though: the word "possible" in the key is not considered. The falsely identified circumstance does describe a condition of the product but only conditions should be identified about which it can be derived from the text that can occur but not always.

Appendix 9. validation int.

8.4 Validatie_Vermeulen

mestroosters - Vind je het leuk om er een paar producten doorheen te halen? – “ja, ik wil er wel 1 of 2 doen” – heb je weleens mestroosters verhandeld? – NEE, weleens tegengekomen? – JA. Als je ze tegen komt, doe je dan een inventarisatie als je een stal gaat slopen? – uuuh, “daar kijk ik niet naar om ze te hergebruiken...dat gaat bij ons zo bij de puin”. Geen inventarisatie? – Jawel, een inventarisatie – “ze zitten er in” – maar ze gaan gewoon bij de puin. Dus je overweegt het niet? – NEE. Kijk je nog of ze kapot zijn of niet? – NEE, zoals je al zei is die handel gewoon te moeilijk. Dus eigenlijk, voordat je gaat kijken weet je al dat het niks wordt? – JA, “historisch besef zegt dat de handel te moeilijk is”. dus dan worden ze gesloopt? – JA. Als je ze er uit haalt, maak je ze dan kapot of schep je ze er uit? – “ze hoeven niet heel te blijven dus ze kunnen kapot – ze gaan kapot”. Hoe doe je dat? – “machinaal”- met een machine worden ze er uit gepakt. Worden ze er wel volledig uitgepakt? – JA. Hoe vervoer je ze naar de stort? – “vaak zijn het wat grotere projecten en wordt de puin op locatie gebroken” – dat komt op een grote berg terecht en op het moment dat het uitgesorteerd is komt er een puinbreker, wordt het gebroken en wordt het granulaat afgevoerd. Wordt er altijd lokaal gebroken? – niet altijd maar vaak wel. Het kritisch punt zit hem een beetje (hang ook van de locatie af) bij projecten waar minimaal 3000 ton puin vanaf komt.

Dus als ik het goed begrijp: het wordt gesorteerd, staal moet er uit – het wordt verwerkt, want het wordt op locatie gebroken – JA. Het wordt machinaal gedaan. sommige gaan kapot – JA. Anderen niet – JA. Hoevaak gaan ze kapot ongeveer? – 98%. Vervolgens worden ze ingeladen – is het containerwerk? – NEE, als het gebroken is wordt het op een trailer geschept, kiep trailer. Breng je het vervolgens zelf weg? – het wordt menggranulaat. Wordt het opgehaald? – JA, of we hebben zelf de handel of we hebben een tussenpersoon.

Dus soms zelf, soms opgehaald – JA. En jij slaat het hier ook op toch? – JA. Heb je het gevoel dat hier nog stappen uit ontbreken? Uit deze route...je komt het wel tegen, je inventariseert het niet, je treft het heelhuids aan, JA, vervolgens ga je het niet hergebruiken, bijna alles gaat kapot als je het er uit haalt, je doet het machinaal, het wordt gesorteerd, het wordt gebroken op locatie en dus verwerkt, JA, en vervolgens gaat een deel mee en een ander deel gaat met jou mee, JA, “JA dat is het”, “dat is het”

Toilet. Ik denk dat ik de route al wel weet, want je gaat dus: ga je inventariseren? – JA, dat is een automatisme – jongens gaan naar binnen om te kijken wat er goed is. als het goed is wordt het gedemonteerd en gaat het mee naar huis. Dit geld voor alle gebouwen. Vervolgens tref je hem aan, hoe vaak is ie dan kapot? “durf ik niet te zeggen” – komt wel voor dus? – ongeveer 30%. Als ie heel is ga je hem dus hergebruiken? – JA. Je gaat hem er ook zelf uithalen denk ik? – JA. Schroef je hem met de hand los? – JA. Moet ie worden gesorteerd? – NEE, hij wordt gewoon losgedraaid, dan gaat ie op de bus, de jongens komen hier ’s avonds en die zetten hem in de stelling zegmaar. En wij doen niet sorteren op achteruitgang etc – ze zetten hem gewoon weg, thats it. Zijn er een paar die stuk gaan tijdens demonteren – JA, dat zal ongetwijfeld. JA, of tijdens transport. Kan ie ook op andere momenten breken? – NEE, of nou ja, in principe, bij alle handelingen. Als ie hier eenmaal staat gebeurt er niet veel meer mee. Hij komt dan dus op de werf, je bewerkt hem niet, NEE, niet schoonspuiten, NEE. Maak je er een advertentie voor? – JA, op marktplaats hebben we wel geregeld complete sets staan, hang toilet met installatie...zou je demontage kosten voor een pot verwaarlozen? – JA, spoel bak kost minimaal een uur. Hoeveel vraag je voor het framework met pot? – minimaal 100, tot 150.

Appendix 10. toilets transcript

Toilet	
Weba 1	**General** heel veel, weinig vraag, makkelijk los te maken, onhygienisch - zelfs als het verkocht zou kunnen worden wilt het slooppersoneel het niet graag doen - dan wordt 'per ongelijk' het breek ijzer er in gezet
Van Rijswijk	**Terraced house** ze willen alleen merkpotten (Joop / Spynx) – zo'n praxispot kost nieuwe 2 tientjes, en kost teveel moeite (die moet worden ingeladen, voorzichtig worden vervoerd, uitgeladen, trap op, op marktplaats, trap af). Verder zijn alleen hangende potten interessant {staande potten zijn uit de mode lijkt uit de reactie daarop} – de hangende potten kunnen gewoon worden los geschroeft en omlaag worden gedragen – schroeven zijn bijna nooit verroest (9/10), bij staande potten soms wel – dan gaat de hamer er tegenaan. {een beetje vies maarja}
Vermeulen	**General** In de loods staan vooral veel wc potten – Patrick geeft aan dat hij vooral verkoopt aan particulieren.
TN	**Portico appartment** Marijn geeft gelijk aan dat de pot op de foto te ouderwets is. om hem los te maken moet de kit worden doorgensneden (met een normaal mes) en moet de fitting er uit getrokken worden. Wat voor soort pot zou het meest interessant zijn? – hangende pot. Later, tijdens de rondleiding wordt ook een ingebouwde spoelbak aangewezen in de loods {suggestief als lucratief product}
Weba 2	**General** "daar moet je er gewoon drie van hebben liggen en that's it". Je komt er heel veel tegen maar er is geen vraag naar. Mensen kopen voor 2 tientjes een nieuwe dus waarom zouden ze voor 5 euro een tweedehandsje doen "mensen worden er panisch van, een gebruikte plee" maargoed, in een wegrestaurant zitten ze wel op een plee waar al 600000 man op hebben gezeten. Bij het demonteren en bij het transport kan het makkelijk kapot gaan. Je kunt ze los schroeven, dikwijls zijn de schroeven wel verrot (30%).
Venus	**detached house** makkelijk te demonteren; 1 of 2 bouten losdraaien – dat is echt niet het probleem. De vraag is of het een mooie is of niet. De standaard wc kan je voor een vergelijkbare prijs bij de gamma kopen – hier gaat het er om of je iets bijzonders tegenkomt. ... **gallery flat** Je kan er wel waarde uit halen als er bijvoorbeeld een herbestemming is voor 100 wcs maar dan moet je wel iemand hebben die akkoord gaat met een wc die oud, maar vaak ook vies is. "het is toch een gebruikt ding". Hoelang het duurt {demonteren} is hetzelfde voor hergebruik als voor NIET hergebruik. Als je hem stuk slaat moet je staan opruimen – dat kost meer werk. ... Het wordt bevestigd dat de toilet in de container stuk gaat. ... 10 sanitair {wcs of wasbak} op een dag per persoon inclusief transport naar beneden. Wellicht doe je er 8 als ze heel moeten blijven omdat je beneden meer nazorg nodig hebt om het netjes weg te zetten. Het moet netje in een container worden opgeslagen of op een pellet.
Heezen	**Gallery flat** wat hij zou vermarkten als hij tijd heeft: wcs niet. Frank antwoordt dat er bijna nooit genoeg tijd is. ... moet ook met de hand maar dat zijn simpele dingen – die kan je losschroeven.
Schimmel	Toiletten doet Eddie bijna niet – die dondert hij gelijk weg. Reden? – meestal zien ze er niet uit. Vies wordt bevestigd – die wil hij niet eens verkopen. De mogelijkheid om hem door te spoelen {schoon te maken} wordt niet beantwoord. "meestal is dat spul zo oud" alleen af en toe kom je op een locatie dat er toevallig iets in zit wat er nog goed uit ziet – meestal puinbak ... **detached house** pispotten haalt de machinist er NIET uit met de grijper, dat is allemaal puin.

Vd Heijden	**Detached house** “nee, nemen we niet meer mee”. Is er een tijd geweest dat het nog wel voorkwam? – ooit wel. Sinds wanneer is dat? Het is niet echt van deze tijd om een vieze pot los te schroeven en op een auto te zetten. Het wordt bevestigd dat je er eigenlijk geen zin in hebt. “Gewoon met de hamer er tegen, kort maken, vlug weg” – dit wordt gedaan bij renovatie en sloop. Dus ook bij totaalsloop. is dat sneller dan losschroeven? – dit wordt bevestigd. Komt het uberhaubt voor dat je het doet? Nee, ook niet als het een hele mooie pot is. het maakt niks uit of het een hangende of een staande is.
Repurpose	**General** Bas heeft gehoord van een gast: een handelaar die ten onder is gegaan omdat hij van alles en nog wat heeft opgeslagen op zijn terrein waar toe en wist niet wat hij nog had. Ook had hij deals gesloten met afnemers die zich terug trokken – dan ga je kapot – uitgaven aan mensen en opslag (echt lang geleden, gesprek voor bouwkringloop) – deze gast heeft allemaal potten staan schoonspuiten maar dat was te duur, Bas denkt dat je daar sociale arbeid voor nodig hebt. Demonteren is het probleem niet volgens Bas. Aan schoonmaken wordt het verhaal toegevoegd – “als wij het schoon gemaakt hebben is het schoner dan een nieuwe pot” – dat soort stomme argumenten moet je verzinnen. Lelijk wordt ook genoemd. Ook: iemand anders heeft er al op gezeten – Bas heeft het in het begin een keer genoemd maar merkte dat mensen meteen gaan stijgeren, hij noemt het niet meer. {het wordt gesuggereerd dat het de naam “hergebruik” besmeurt}.
Schijf	**Detached house** Bij een huis (buiten de stad) dat tegen de vlakte moet, wat voor producten kom je dan tegen bij totaalsloop die de moeite waard zijn om te hergebruiken. Een wc ... Vraag: ik heb weleens gehoord dat slopers een wc stukslaan omdat ze dat sneller vinden, ben je het daar mee eens? – Nee! – Tristan zou hem in zijn geheel wegpakken en in de puinbak gooien. Waarom zouden slopers hem kapot slaan? – “zodat ze hun aggressie kunnen botvieren denk ik”. Omdat het leuk is wordt bevestigd. Er wordt aan toegevoegd dat het ook zou kunnen omdat het water er dan uit is. theorie van Tristan: ze willen niet dat het er uit loopt als ze hem optillen (zwanenhals).

Appendix 11. middleman costs

8.4.1 Part 1_middleman costs

Middleman properties

- Because he is just a hypothetical middleman who has no competition, he aims for buying all toilets from demolition if the market allows for it
- Demolition contractors contact him when they have toilets and because he operates in a perfect market, he plans to buy the cheapest toilets first before buying more expensive ones.
- He has a network of professional buyers that approach him when they need toilets and because reused toilets are popular (hypothetically), demand is plentiful
- In order to get the toilets from the demolition contractor and sell them to the professional buyers he has to pick up, wash, store and deliver the toilets

Cost drivers in order to figure out if the business might be fruitful, the middleman first maps all cost drivers that he can think of:

- The *purchase costs*, or in other words the price that he has to pay demolition contractors for a product. The middleman realizes that demolition contractors might charge more once they notice that the middleman is making money off of it but for his first calculations, the middleman uses prices for which it is feasible for demolition contractors to sell
- The middleman is friends with a demolition contractor who is located in on a rural plot at a central location in the Netherlands. He is willing to lease an unused part of his property:
    - 800 m^2 of paved area with an old barn standing on it
    - Yearly payment of €15000 to use the plot
- The middleman can get his hands on a second-hand box truck which he will amortize linearly:
    - an expected remaining service life of 7 years
    - payed for by using €15000 from his savings account
    - fuel costs are €0.25 per km (1:6, €1.5/km).
- the middleman needs staff for his operation. He decides upon the following composition:
    - one full time employee with a yearly cost of €62700, - working 1900 hours per year
    - all additional work will be taken care of by hired workers from an employment agency with a cost of €45, - per working hour.
- All other costs are expected to be around €5000, - per year
- Because toilets are sold to professional buyers from nearby cities, the expected time and distance for a round delivery trip are 1.5 hours and 60 km respectively
- It is expected that preparations for an order will take about 3 hours on average
- Because toilets are purchased from all around the country, the expected time and distance for a round pick up trip are 3 hours and 120 km respectively
- Professional buyers will order full loads, bringing each delivery to 60 toilets (truck capacity)
- The size of the truck load for picking up toilets will depend on the contractor:
    - Contractors who use their yard for storing products are willing to hoard toilets up until the moment they are picked up. This allows for a truck load of 60 toilets each time
    - Contractors who don't use their yard for storing products expect toilets to be picked up from location which means that the truck load will depend on the project
- With the system that the middleman has in mind, washing and handling toilets is expected to cost 15 minutes each