WP 2 Task 2.3 Facultative educational exploration circular material usage Griffiersveld Apeldoorn

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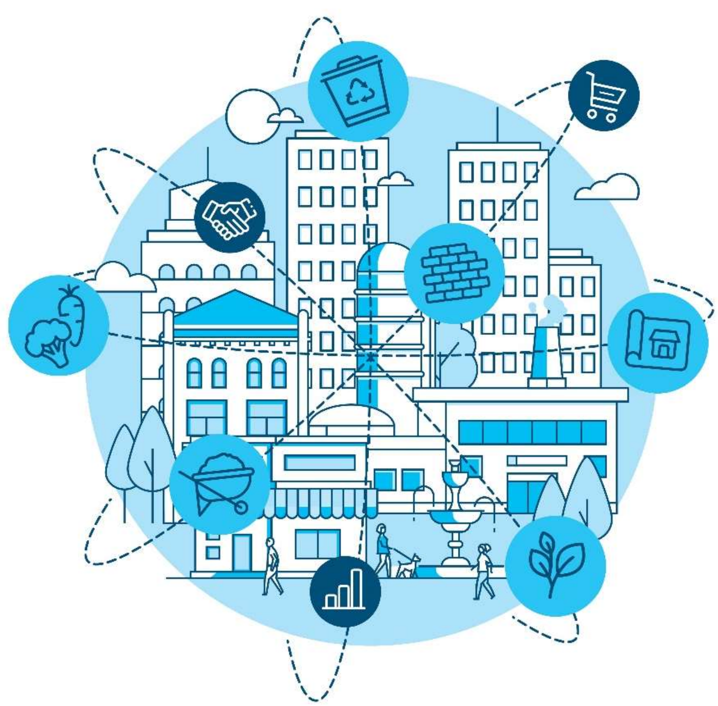

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Abstract	This report was written for the municipality of Apeldoorn as a contribution to Cityloops. It consists of designing and planning tools and provides answers for the municipality of Apeldoorn to enable them to move towards a circular construction economy.
Keywords	Circular economy; Material bank; Circularity; Construction- and Demolition Waste (CDW)
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Designing a material bank to facilitate a circular construction industry

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Preface

This research report was written by three students involved in the course "Industrial and sustainable building" of Saxion University of Applied Sciences. The students were commissioned to conduct a research project for the municipality of Apeldoorn from February to July 2020. The result laying in front of you is their result edited by the involved associate professor from Saxion, Bram Entrop, and by the project manager circular usage of Construction and Demotion Waste (CDW), Sander Lubberhuizen, of the municipality of Apeldoorn.

In the project the students were asked to design a material bank to facilitate a circular construction industry. The insights they gained were used to create opportunities to renovate the road "Griffiersveld” circularly.

The results of the final research are for the municipality of Apeldoorn. However, we can imagine that some elements of this research project are interesting to other members of the H2020 Cityloops consortium. Senja Poutiainen, Nicholas Willoughby and Bas Otten were the researchers and authors of the original report. They, but also the editor and principal, would like to thank everyone who helped us during this research project.

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13-07-2020

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1. Introduction

1.1. Background

The construction industry is responsible for consuming the most materials in the world compared to other industries. In 2016 the amount of total waste generation was 2538 million tonnes in the EU member states. The amount of waste produced in the construction industry was 36.4 %, that equals to almost 924 million tonnes that year (Eurostat, 2019). In this report construction and demolition waste is referred as CDW. Most of CDW consist of concrete, ceramics, gypsum, tiles, wood, glass, metals, excavated soil and masonry. In the European Union 25-30% of total waste are these construction materials, most being recyclable. (WBCSD, 2018). Globally, the amount waste is expected to increase to 70% by the year of 2070 with current actions (Kaza, Yao, Bhada-Tata, & Van Woerden, 2018).

The problem in the construction industry is not only producing waste, it also consumes most of the natural resources. It is estimated that the built environment demands approximately 40% (by mass) of all materials extracted from nature and is responsible for producing the most greenhouse gasses in the world (Heinrich & Lang, 2019). Not only is this an environmental issue, it is also a social problem. The construction industry is risking public health due to biodiversity loss, air and soil pollution and water quality. In high density areas the space for landfills are limited. The few studies available indicate that the saving potential for reusing excavated soil and rock are up to 14 kg CO_2 per ton. For a single construction project, reusing excavated soil and rock can reduce the material handling costs by 85% (Magnusson, Lundberg, Svedberg, Knutsson, 2015).

A solution for decreasing the amount of waste in the construction industry is following the principles of a circular economy. Instead of taking virgin resources materials will be replaced by old materials that have been in the cycle before. A circular economy has a lot of different definitions and visualizations. For example, a circular economy is described as an economy that is based on the principles of designing out waste and pollution, keeping products and materials in use and regenerating natural systems (Ellen McArthur Foundation, 2020).

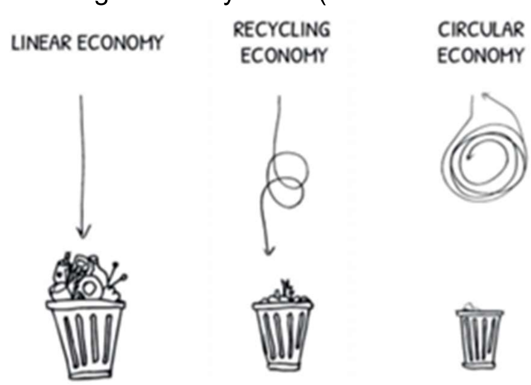

Figure 1. The difference between linear-, recycling- and circular economy (EME, 2019).

It can also be explained by a figure: instead of a linear flow where there is a straight line from use to waste, the materials go in a circular way around without producing any waste. A product can be bought as recycled, but it makes it circular when the product is not thrown away in the end but is kept functional by maintenance and refurbishment. One important aspect to pay attention to is that the products does not lose their value. When a product is recycled but does not maintain the same value it is called downcycling. In road construction a good example of downcycling is using pavement materials as aggregates for roads subbases after recycling, and that is an undesirable situation. A Circular economy is often referred as circularity, but there are some views that prove that circularity becomes circular economy when a product is used in a circular way in every part of its lifecycle (Van Oppen, Croon, & Bijl De Vroe, 2019). Circularity is about minimizing the waste of resources and maximizing value retention of resources and materials (Ellen McArthur Foundation, 2020).

The Netherlands is aiming towards a fully circular economy by the year of 2050 with its own government-wide program. A milestone on the way is achieving a 50% circular economy by the year 2030 (Government of the Netherlands, 2016). At the moment, the Dutch economy is 24,5% circular. The number looks rather good when it is compared to the global economy which is only 8,6% circular. However, the circular gap is still 75,5 % which means that a lot of virgin materials are needed to fulfil societal needs (CGRi, 2020). Construction and demolition waste are a big part of the produced waste, so making a change in this industry makes a significant difference.

This report is written to facilitate a circular economy in the municipality of Apeldoorn. The project is being done in corporation with Saxion University of Applied Sciences and the municipality of Apeldoorn. Apeldoorn is located in the province of Gelderland. In Gelderland alone, about 10 276 tonnes of waste is being produced by the road construction industry yearly. (Jutte, Euler-van Hulst, & Roos, 2019). The municipality of Apeldoorn is participating in the EU-funded project called Cityloops with six other European cities. The goal of Cityloops is closing the loops of urban material flows. Those urban material flows include organic, and CDW. The aim is to embed circularity in urban waste policy to increase the regenerative capacity in the participating cities. The way of executing this project is taking advantage of a real construction site that is the test area. The test area mostly consists of driveways and will be renovated while a lot of concrete, asphalt- and soil waste is being produced. It is an example site used to validate new tools to manage urban material flows in the road construction industry. The test area is called Griffiersveld and it is located in the neighbourhood of De Maten in Apeldoorn. More information of the exact location, materials and pictures can be found in Appendix I.

The tools and possibilities are created and searched to help the municipality switch their manners to utilizing secondary materials as well as possible. This report can help other users and municipalities get ideas on how they could change their economy to be more circular. It must be understood that these tools are in an early stage of their development, and many changes may come up while the tools are put to practical use.

1.2. Research setup

The main problem is that too much CDW is being produced in the construction industry, so a lot of potential materials end up in landfills and new materials are being purchased. The society observes the rules of take-make-waste economy, this means that it is first paid attention to the design and assembling of a product, but then throw it away at the end of its lifecycle. but then throw it away at the end of its lifecycle. This started with the industrial revolution and was amplified in the thirties of the twentieth century, when the principle of planned obsolescence was introduced (Van Oppen, et al; 2018).

The materials are not managed well enough without tracking tools. A lot of materials used in production, products and objects are not registered in detail. Material passports can operate as a tracking device and materials banks can store this information. There are different phases in the circular cycle of materials life, where information is needed, such as procuring, resources-, production-, use- and recycling phases (see Figure 2).

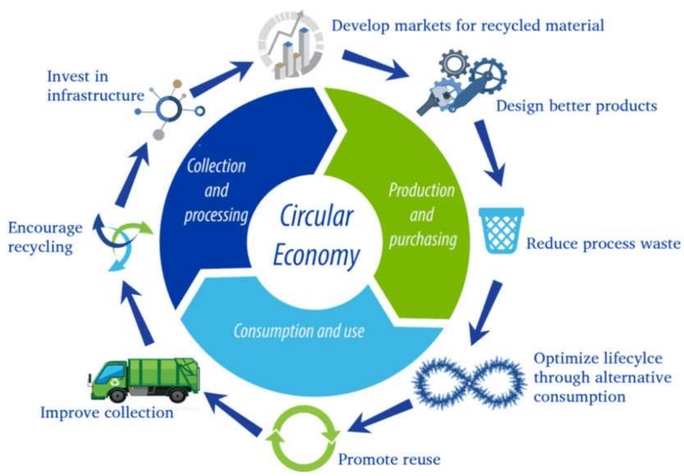

Figure 2: The circular economy model with tasks relating to every phase (Recycling Council of Ontario, 2019).

One of the hurdles to recycle and re-use CDW is the lack of confidence in the quality of and uncertainties about potential health risk by recycled materials (EC, 2018). This produces more problems to the developments of management and recycling of CDW when the lack of confidence reduces and restricts the demand. The more information that is collected on the materials, the more valuable they can be. A more detailed identity needs to be come along with building components, products and materials. However, material prices are often relatively low, which does not encourage users to invest in storing information and aiming for recycled materials (EC, 2018)

For facilitating the management in all of these phases tools need to be available. Tools are for example digital- and a physical material passports and material banks. For this project these tools are designed in order to fulfil the needs of the municipality of Apeldoorn. One of the first problems in the project was that there are not many similar tools in the world so far, which means that the solution is not simply adopting an existing tool or a method. To design functional tools and methods they must be tested to see if they're working. There is not a perfect answer that tells what kind of data must be gathered, or what would be the most efficient way environmentally and economically to reuse and recycle materials as it depends on the materials next destination. If there is no knowledge available on the possibilities of recycling materials, they usually end up in landfills. That is the reason why all possible data about quantities, qualities and recycling options preferably need to be collected and stored.

Gaining knowledge and collecting data are the first steps in a project like this. As already mentioned, qualities and quantities of the materials will have to be sorted together. All this information is needed in order to plan the further use of materials. Knowledge can be gained from papers, design documents and experts. The purpose is to learn more about the properties of the materials and products that are on the site. To find examples of similar projects, to come up with ideas that could be utilized in this project and to learn more of what are the possibilities in order to follow the circular economy's principles were investigated. The quantities of the materials can be collected from old documents and drawings. Sometimes this is not possible, especially for old roads. In this project quantitative data was collected by using road scans. More information of the scans can be found in Chapter 3.

Designing a material passport platform and saving data are the next steps in the cycle. A material passport, often referred to as MP or MPP, is a repository where collected data can be stored systematically**.** The passport makes it easier to get an overview of different qualities and quantities of materials and to plan their further use. The material passport was sketched taking into account the most relevant parts for the materials in the road construction industry. The prototype of the passport designed for Apeldoorn is introduced in Appendix II.

A material bank can either be digital or physical. A physical material bank is a material depot in form of a building or an outside area, where valuable materials are either being stored or processed until they are needed in the future for reuse or recycling. For a circular construction industry to work, one need to find the relationship between the marketplace, the material bank and the material passports and figure out how they play on each other as shown below. The physical material bank is further explained in Chapter 4. Regarding a digital material bank, data from the material passport can be stored in GBI; software designed to provide assistance in the management of public spaces. Developed by the Antea Group, GBI is a database used in Apeldoorn and in multiple other municipalities. The storage place can be called a digital material bank.

Figure 3: Relationships between a Marketplace, Material bank and Material passports.

In this report we also list different ways to use materials. Recommendations on reuse and recycle opportunities are namely also part of material passports. Downcycling has to be avoided as long as possible. New technologies come with an increasing number of possibilities to recycle materials and the construction and waste industry are constantly searching for improvements. In this project the focus is on finding solutions that can be used instantly.

A digital material bank alongside with a material passport and a physical material bank will be designed and implemented for Griffiersveld, a street in the neighbourhood of De Maten in the Dutch municipality of Apeldoorn. The construction industry should increase the use of material passports for all projects to increase the ability to efficiently re-use materials while incorporating this with a physical and digital material bank so that the industry reduces the amount of virgin materials consumed.

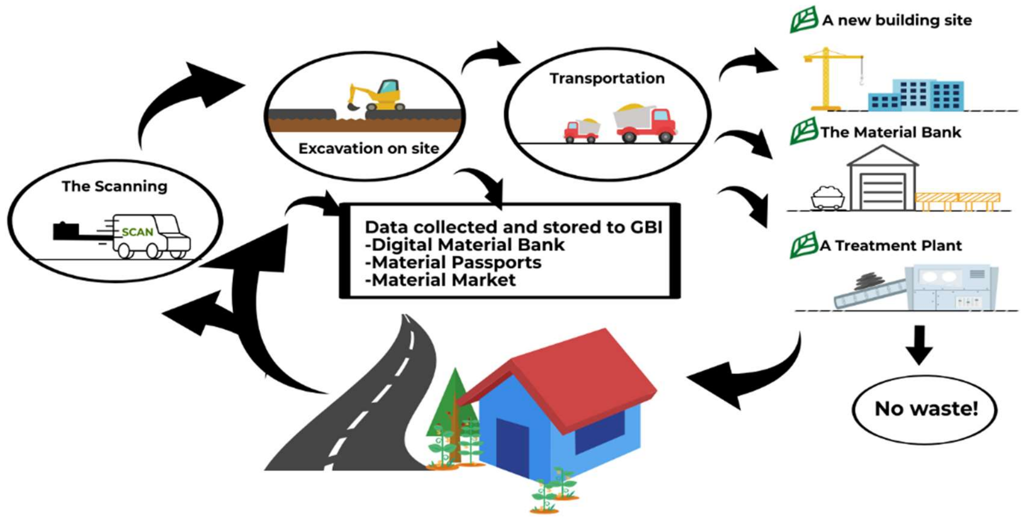

Figure 4. The circular flow in the project of Griffiersveld.

The lifecycle of a circular material should begin over and over again, when a product, like a built object, where it is part of is demolished. However, many buildings and infra structures are being demolished in the end of their life without considering the reuse of components, products and materials with the lowest environmental impact possible. It is not an easy task to maintain the value of materials.

A first problem is collecting data and scanning. One might want to rely on old plans, especially as-built drawings. From those it should be easy to see how much materials have been used in the construction. It is even easier, when those drawings exist in a digital form. There are some drawings from Griffiersveld area from the year of 1977, but there is little detailed information on materials used and their current status. An older plan of Griffiersveld can be found in Appendix I.

From this it is logical to design a material passport and a bank. A new road is designed and built for the area. A new destination will have to be sorted for the old materials. The reason for the renovation is that current concrete slabs are worn out. The old pavement will be recycled but there are multiple minor problems along the way. The aim is to recover all the objects dug from the ground, so they can be used again as whole. This is a great way to avoid downcycling. The main goal is to re-use all the materials as whole. After figuring out where to take the materials and their quantities and qualities, they can be excavated and transported. Ideally this should be known so one does not transport materials longer than needed.

The objective is to design a material bank to facilitate a circular construction industry. The main research question is “how can the construction industry become more circular?”. To answer this main question three research questions were derived:

- What are the logistical and legislative processes in a circular society?
- What are the quantities and qualities considered in this project?
- What is the role of a material bank in a circular society?

Applied research methods are literature study, online internet investigations and interviewing experts; all with a focus on the case Griffiersveld. Interviews are conducted with employees from the Municipality of Apeldoorn and other companies. The interviews with the recycling company Two R Recycling group, demolition company Kamphuis Sloopwerken, conversations with employees of the municipality of Apeldoorn and an interview with a sustainability specialist in the municipality of Oss is found in Appendix III. Two of the employees were interviewed in order to get practical information of GBI.

A lot of knowledge has been gained from experts also by reaching out to them through email. They have either answered questions or linked sources. With Dutch, Norwegian and Finnish backgrounds of the researchers and with documents from those same areas, this study has an international character.

2. Logistics and legislation in a circular society

Processes that manage, move and store the materials are counted as logistics and there is a circular way for planning logistics. All those processes are possible inside the boundaries of logistical resources and legislation.

2.1. Logistics in a circular society

Logistics is all the planning, implementation and control of production, commodity, cash and information flows (Ihalainen, 2014). In this project transportation and storing materials are the biggest questions. Properly planned logistical processes saves time, money and resources. Area planning is an important part of smoothing logistics. There must be indicated clear locations for receiving, unloading, storing materials, driving routes and workstations (Ihalainen, 2014). The designed material bank and area plan can be found in Appendix VIII

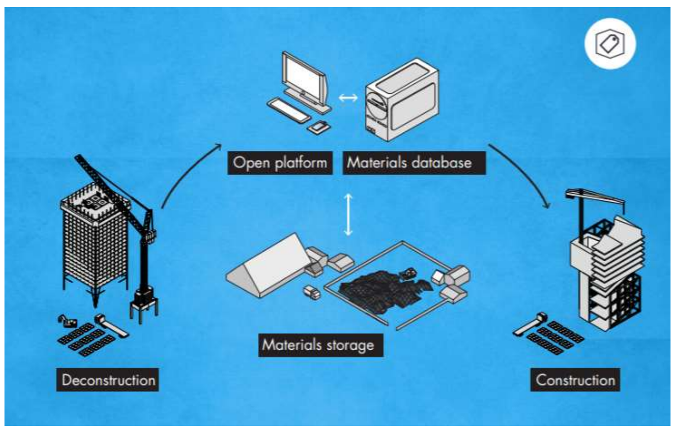

Figure 5. Visualisation of circular material flow processes (Bastein, Verstraeten-Jochemsen, Rietveld, Hauck, Frijters, Klijn, Driessen, 2016).

For moving materials, vehicles such as lorries are needed. Coordination between the site, the material bank and processing plants should be in order, to avoid too much driving with empty lorries. As many co-locations as possible would be ideal in minimizing transportation. This means that for example a material bank and processing plant are in the same area and sites as close as possible. When a lorry delivers new materials somewhere, it should come back with other materials (Carswell, Nicholls, Widyatmoko, Harris, & Taylor, 2010). The size of the loads has to be optimized. The weight of load depends on the car, how much it can carry on official roads. Practical matters are also better to check in order to plan the loads. For instance, the maximum length of lorries is 18.75 m and the maximum weight is 50 tons (Government of the Netherlands, 2020). One must pay attention to organizing truck loads, distances and storage costs. A functional area plan includes clear inbound and outbound areas, storage areas and internal logistic areas like roads.

Regarding logistics by digital means, Apeldoorn is using GBI as a database for storing material passports. The company offering this software is called Antea Group. GBI consists of a collection of apps. App retrieves up-to-date data from a secure database and combines this with validated data from the knowledge base on, for example, prices and packages of measures. This ensures that the results are reliable and substantiated (Antea Group, 2020).

GBI is available for employees who need it in their jobs. It is a back-office application this means that the information in Apeldoorn is not visible to users other than the administrators. Anyone with the correct password can consult the available products and materials. If GBI data is placed in the Cloud, it makes data available for other people than Apeldoorn employees with a correct password (project manager Antea Group, 5.4.2020). This is important for the possibility of making contracts with other companies for the use of the material bank.

The data is also available in RIV viewer and in ArcGIS Online, that are geograhic information systems used by Apeldoorn. One of the concernes was that how well can the material passports be transferred into a marketplace for example, other users have the rights to make mutations and can export files into almost all common formats by means of ETL scripts (employee Municipality of Apeldoorn, 24.6.2020).

The GBI is a viewer to look at the data and thematize it. It is easy and clear to use. The app where all material passports are stored can be called a digital material bank.

2.2. Legislation of construction and demolition waste

The European Union and member states have started to pay attention to reducing waste by different plans and regulations. Ministries plan out their own protocols, following the EU regulations. When people are used to work in a certain way for too long, it is hard to change manners. Sometimes the only thing that works is to change the legislation. The EU Commission intends to set finding landfill abandonment as a binding target to reduce it by 2030 easily 10 percent of all waste. The EU's goals will be achieved by achieving prepared a circular economy package, which is a guide for EU countries to change their behavior from the consumption pattern wiser and more sustainable use of materials and resources (Nordqvist, 2016).

In the European Union, a Waste Framework Directive (2008/98/EC) was made to move the EU towards a recycling society with a high level of resource efficiency. It states that all the member states should take necessary measures to achieve a minimum of 70% (by weight) of non-hazardous CDW to be prepared for re-using, recycling or undergoing to other material recovery. This also includes backfilling operations using waste to substitute other materials. (EC, 2019). In 2016, the EU member states recovered around 90% of overall CDW including backfilling. Although a common model for calculations across the European member states exits, the definition of the EU recovery target for CDW is very susceptible to varying interpretations and consideration of waste and waste recovery by each country. Therefore, it is difficult to compare values between different countries with accuracy, or even within a country (Galán, Viguri, Cifrian,, Dosal, & Andres, 2019).

Since 1st of January 1994, the Dutch legislation on waste can mainly be found in Chapter 10 of the Environmental Management Act. This chapter consists mainly of a framework legislation. This means that a large number of issues are not in the law itself, but are regulated in Orders in Council, provincial environmental regulations or municipal waste regulations. Examples of relevant Orders in Council in this context are the Decree on Landfills and Waste Bans and the Waste Collection Decree (Deloitte, 2015). These regulations mostly lead the Dutch waste management in practise. By following these regulations, the Netherlands are in line with Waste Framework Directive 2008/98. In the Environmental Protection Act are considered following acts: Duty of care for waste, Landfill Prohibition, Municipal Waste Regulation and National Waste Management Plan (Rijkswaterstaat, 2020).

The ministry of Infrastructure and Water Management in the Netherlands has created a National Waste Management plan that sets out the policy for waste management in the Netherlands. The Management Plan is in use from 2017 to 2023. The goals in the plan are issuing collection permits for certain categories of (hazardous) waste and decisions on notification of the proposed import, export and transhipment of waste based on the EU Shipments Regulation.

2.3. Results

In infrastructure projects, on-site handling and hauling of excavated soil, rock and construction materials from quarries, i.e. quarry materials, can be up to 30% of the total project cost and generate significant amounts of CO_2 emissions. (Magnusson, Lundberg, Svedberg, Knutsson, 2015)

If raising awareness of costs savings in a circular economy and other advantages what it has to offer would be added, the industries would start thinking twice. Usually, it is the easiest way to handle waste like it has been used to handle.

By prohibiting some waste acts and increasing the prices of raw materials the production and recycling will turn to rise. New options and knowledge for recycling are then needed, since industries producing waste need answers for what to do with the materials later on.

3. Quantities & qualities in material passports

When planning and managing materials flows, the quantities and qualities must be well known. It would be very difficult to know where the materials can go, if this information is not available. The more information is available, the better the identity of the materials can be assessed and opportunities to reuse them can be better identified. The ideal situation would be that collected data of the products and materials is stored in standardised material passports, that are then saved at a material bank. In order to collect data in Griffiersveld, help was called in from external parties, who scanned the road. In the case of Apeldoorn, the material bank might be developed within GBI. Most of the paving materials in the Griffiersveld area are made of concrete, but some asphalt will also be removed. In this report we mostly discuss about concrete products since those are the main concern in the deconstruction of the area.

3.1. Quantities

One of the most important things to know for managing a circular flow of CDW is knowing the amounts and measurements of materials. If the quantities are known, further use can be planned and managed easily, even long before the deconstruction. The information is needed also for transportation, physical material bank, recycling companies and new potential destinations.

Measurements
- of products, width x depth x hight

Area

Weight

Volume

Figure 6: Possible quantitative properties of materials (Heinrich & Lang, 2019).

The renovation of the Griffiersveld area includes replacing 3700 m^2 of concrete bricks, rebuilding 850 m^2 concrete tiles and possibly disconnecting rainwater (employee municipality of Apeldoorn, 20.4.2020). In Appendix VI the quantities in the test area are further explained. The municipality of Apeldoorn has a soil site, where soil can be stored and its quality and quantity can be assessed. Therefore, the soil excavated during the renovation project will most likely stay in the same municipality .

From the scans that were executed in the area, can be seen for instance how many of the concrete products are unbroken and ready to be reused somewhere else. We may also get information which soil was used for substructures 45 years ago under the pavement before excavating. When it comes to concrete slabs and bricks, the wisest thing to do is to count how many parts there is altogether and separate differently featured parts. When all of this is put into a material passport, it is quick to say how many parts could be taken and where, how much products are there to offer.

3.2. Qualities

Construction materials require specific properties. Especially concretes properties effect on its load endurance and wear resistance, which are usually leads concrete to be an ideal paving material (Rakennusteollisuus RT and Betonitieto Oy, 2006). other properties have impact on the quality, it does not even have to be structural property. Properties filled in a material passport can be for example, matter the material:

Density

Structural data

- Compressive strenght
- Load bearing
- Stability

Building physics

- Porosity
- Thermal conductivity

Optical

- Color
- Surface

Lifespans & durability

Recycling and reuse potentials

Figure 7: Possible qualitative properties of materials (Heinrich & Lang, 2019).

Paving stones are a good choice for roads, since they do not lock up on each other which would lead the stones to break. Tiles are more fragile but good for driveways with light loads and less traffic. Also, their hydraulic conductivity is excellent because of the soil between the slabs. Deconstructed, unbroken slabs and bricks can be reused in many ways, but the optimal way is to recycle them as whole pieces so they value is not lost. This way downcycling is prevented and the value of the materials stays the same**.**

Concrete

With its longevity, recyclability and little need for maintenance concrete is a has a lot of positive qualities. Because it is popular building material, the distances are usually short. It is also fire- and water resistant (Betoniteollisuus Ry, 2019, p. 150). Large concrete slabs, smaller concrete tiles or even smaller stones are used for paving roads and driveways and parking lots. The mechanical strength of concrete bricks and slabs is generally good. They are estimated to last about 50 years in normal circumstances (Betoniteollisuus Ry, 2019). The pavement in Griffiersveld is mainly 45 years old, so the quality might not be at its best anymore.

When new concrete is being mixed, the properties are prompted by controlling amounts and grainsizes of aggregates, amounts and types of cement and mixing additives or admixtures. Compressive strength and stiffness are examples of what will be measured from hardened concrete. Concrete is good for infrastructures for its other qualities too. It also dampens sound, balances temperature and protects from different types of radiation for example radon. The quality needed depends also on what the next destination and purpose will be. Concrete waste can also be downcycled as aggregates after crushing, and then the requirements of concrete aggregates apply to it. Those are for example grainsize, flatness number and shape value of coarse aggregate, fines content and particle density (Väänänen, 2012).

Figure 8 and 9 Pavement in the area of Griffiersveld (see also Appendix I).

When concrete waste and products are taken to further use, a lot of qualities will not be measured with measuring devices. Instead, the appearance: size, tidiness and color make the most difference. Different companies specialized in recycling concrete have they own ways of dividing the materials. For example, the Twee ‘’R’’ Recycling Groep in the Netherlands divides concrete waste into clean, contaminated and mixed concrete. When Rudus in Finland divides, it is mostly by size or mass. Further quality requirements will be measured, when the amount of recycled crushed concrete reaches the limit of 20% of a new concrete mixes aggregate. In that situation, the qualities measured are case-by-case thing and supposedly different in separate cases.

The conditions for concrete recycling are affected by the conditions of use of the concrete structures to be demolished and any consequences of a possible contamination. For recycling in connection with testing related to the production of concrete crushed stone, unsuitable material is separated and used for the structural layers of suitable areas; or disposed of. Demolition concrete is not suitable for civil engineering, if it contains asbestos, sulphates, oils or copper (Nordqvist, 2016).

Concrete can be contaminated with soot when it is been used near or in a chimney, crude oil, acids, sulphates, chlorides (reinforced concrete), magnesium and ammonium salts). Some of those substances can also damage concrete and not only pollute it. In recycling, special attention must be paid to the concrete waste, which should not contain plastic, wood, paint or bitumen (Betoniteollisuus Ry, 2020). This concerns both whole and crushed concrete, which often is referred to as mixed concrete. Most of the recycling companies inform not to bring that kind of concrete to the place, but some offer a cleaning. Cleaning can for example start with manually cleaning the concrete on a conveyor belt and after that there are two mechanical cleaning steps: blowing (wind shifting) and washing. Rebar and other metals can be removed with electromagnets. Contaminated and polluted concrete has to be usually separated from clean material (Twee ‘’R’’ Recycling Groep, 2020). When products are moved to a new destination, they have to be clean as well. It would be ideal that products could be cleaned on-site or in the material bank.

Asphalt

A small part of Griffierveld has also asphalt paving. Recycled asphalt is often referred to reclaimed asphalt as well. Reclaimed asphalt means planings that are intended for recycling and reuse in another pavement layer. It includes asphalt and aggregates that come out of paving the asphalt away from roads. A benefit of concrete and asphalt aggregates is, that the mechanical properties of the aggregate in reclaimed asphalt can be assumed to at least comply with the limit set for the pavement from which it was taken. Properties that have to be measured or known before knowing if the reclaimed asphalt is suitable for use are: aggregate abrasion value, flakiness index, Los Angeles coefficient, magnesium sulphate soundness, polished stone value and water absorption (Carswell, et al; 2010).

Soil

While excavating a road, soil beneath paving materials has also special features. Built areas are not lying directly on natural soil. Roads usually have different layers: surface-, binder-, base- and sub-base courses. Different types and grainsized soils are used as different layers. Soils divide typically into coarse grained and fine grained. In the area of Apeldoorn, natural soil is mostly fine sandy clay.

In recycling, one example of categorizing soil is separating it into four groups. The material is classified as suitable for residential or industrial areas or both. A fourth classification is that of polluted and contaminated soil (Twee ‘’R’’ Recycling Groep, 2020). When soils are brought to a material bank for further use, it is investigated if treatment like soil washing is needed, what are the additional substances (stones, debris) and what are the chemical, geotechnical and physical qualities. Physical qualities can be simply divided for example to wet or dry (Groeneveld, 2013).

Presumably, the soil in this project belongs to residential area soil. Contaminated or polluted soil can be examined after excavation. Naturally, soil is also separated with types and grainsize. Clay is recycled as clay and crushed stone as crushed stone, and all of those different soil types represent their own purposes with certain properties in building industry. To mention some properties, most important in civil engineering are for example structure, porosity, density and consistence (Korkiala-Tanttu, 2019).

3.3. Material passport for Apeldoorn

In this part the material passport of the Griffiersveld is presented. A material passport will be the place in form of a document where all data will be stored from construction or building components, products and materials. Griffiersveld was constructed about 45 years ago, no thought was given to any kind of material passport. It is not exactly known what the qualities of the materials are, what lies under the pavement or where the sewers and electrical pipes run.

Using a material passport is important in order to write down and store the information of which materials have been used in the construction and how they have been processed. This makes the reuse and recovery planning of materials during demolition or disassembly much easier and gives more value to roads. It will be known exactly what the quantities and qualities are and that it is already known what can be done with it in new projects. In short, it is much better to plan ahead in the future with materials for new projects.

The passports are stored in GBI, since the municipality of Apeldoorn prefers to use it for the database. GBI is a program that the municipality of Apeldoorn uses to store data about the infrastructure. The municipality of Apeldoorn, like most municipalities, mainly stores things in GBI such as typologies and quantities of materials, year of construction, years of inspection, places that need to be replaced first, and so on.

Like in this project, a material passport has to be filled in for an existing road. For this situation different investigations were executed. These investigations consisted of interviews with other municipalities, finding existing material passport platforms and two different scans. It is not enough to find a ready material passport platform, but also creating the most functional and optimal tool has been sketched specifically for Apeldoorn's needs. In the Netherlands, several municipalities are in the process of drawing up material passports for their buildings. To date, however, little attention has been paid to drawing up material passports for infrastructure. Nevertheless, there are municipalities in the Netherlands that have already carried out projects in terms of material passports for infrastructure. The municipality where we have done further research is the municipality of Oss.

One of the few available material passport platforms is BAMB, which stands for Buildings as Material Banks. This research project was progressed for three and a half years from 2015 as an innovation action within the EU funded Horizon 2020 program just like Cityloops. Material passports (MP) are (digital) sets of data describing defined characteristics of materials and components in products and systems that give them value for present use, recovery and reuse. MPs are an information and education tool that addresses questions often not covered by other documents or certifications related to building products, especially in relation to the circularity products. MPs do not access the data output and are not an evaluator of data. Instead, they provide information that supports the assessment and certification by other parties and allows existing assessments and certifications to be entered into the passport as uploaded documents (BAMB, 2018).

A Dutch company called Excess Materials Exchange (EME) also offers a kind of resources passport for users, but they don't only focus on construction and demolition waste. Their material passport is introduced in more detail in Appendix II and their marketplace in Appendix IV. The last part of storing data is the actual collecting. Two external companies called The Wegenscanners and Infrafocus executed a road scan in the area. Two road scans were executed in the area during the project. The Wegenscanners and Infrafocus that did the scanning have similar businesses, but slighty different data was received from both of them.

The Wegenscanners scanned the area of Griffiersveld 7th of April 2020. The Wegenscanners drove their car through Griffiersveld about five times. They measured the thickness of element pavement, street layer thickness, crushed stone value. An inspection has also been done visually, so small connections can be recognized. For example, it can be seen that there is a different kind of concrete bricks in the upper and lower part. This confirms the feeling that there has been a number of years of difference between the construction. All the detailed results can be found in Appendix VII (in Dutch). Infrafocus executed a scan on the 17th of June 2020. The results of infra focus are not yet available.

These two companies have similar procedures in scanning. What they both have is a ground radar, what is used for investigating the constructive structure of the road, such as thickness of the asphalt, thickness of the foundation. However, The Wegenscanners also have a gamma spectrometer on their bus, with which they measure the composition of the road. This sensor gives a unique information about the construction history of the road. Infrafocus for its part has a LIDAR that has panoramic HR images. This means they can create a full 360-fold view of the environment, including point clouds. In this way a very clear picture of the environment can be created. But these point clouds can also be measured. By combining these both scans, a good overview of the area will be created. Information of the condition of the paving materials and the type of soil beneath the paving will be received as should.

3.4. Preliminary conclusion

It is possible to receive reliable data from old and existing roads. The data is good enough for the use of material passport and further use planning. Still it is ideal to fill in the material passport in the beginning of new destinations lifecycle, in the building phase. The materials in constructions industry does not vary a lot. Simply, the most important aspect is to know the amounts: how much there is materials to offer to new destination. Qualities depend a lot on the following destination and the materials purpose there. By keeping the materials clean and unbroken will take the materials far. Other things to put into a material passport alongside with qualities and quantities are for example price, location, maintenance instructions, recycling suggestions, history and purpose. These can be found also in the sketch a material passport in Appendix II.

The goal is that all materials of the entire infrastructure in the municipality of Apeldoorn are stored in GBI. Road materials, greenery, benches and playground equipment of the area are known and saved. When it is wanted to be replaced, the users know exactly all the needed data from the products. Then, if it is possible, one material can be transferred directly to the next project if it is needed there, which of course saves logistics and transport costs. If this is not possible, the materials can be stored in a raw material depot (more about this in the next chapter). When figuring out matches to re-use the products, they will be put to an internal marketplace for materials. In that marketplace Apeldoorn will not sell out their products, but the goal is to keep everything that is already owned by the municipality in the loop inside it. In order to be able to work clearly with material passports in the future, it is important that all data is stored properly and processed in an obvious way. Since The Wegenscanners has shared their collected data and Infrafocus will share it soon, a lot of new information can be put down to a material passport for Griffiersveld.

4. Material banks in a circular society

To be able for the construction industry to go circular before 2050, it needs to have a system where materials go to one place before it is being re-used. Also, a way to categorize waste with regards to quality and quantity is needed. A material bank is a great tool to be able to fulfil these needs. A circular material bank can also help to achieve the goals in the waste hierarchy.

Figure 10: The waste hierarchy is defined in the European Union waste frame directive from the 1st of June, 2008

There are different definitions of material banks. For example, one can see buildings being used as material banks. BAMBs vision is to integrate material passports and prefabricated modules so one can make a material bank from a building. By using prefabricated modules, the disassembly of the building is easy, and the passports gives a guide on how to disassemble the building for re-use of the materials used in the building. This gives the building the ability to act as a material bank. By having a material passport for all materials that are being used in a building will make it a material bank following the vision of BAMB.

Another definition of a material bank is: *“repositories or stockpiles of valuable materials that might be recovered”* (BAMB, 2018). The function of a material bank for Apeldoorn should be that it is a treatment facility where materials are being stored and processed until they are needed for reuse. While the definition from BAMB focuses on a definition looking at a building's perspective, it is still an useful definition. A material bank should follow this definition, and in this case it should be defined as a storage/treatment facility which stores materials that are valuable and can be recovered.

In a circular society a material bank is linked to a digital marketplace which shows what materials are available. Each material that is placed in the material bank must have a material passport, so one knows what the materials can be used for and the qualities of the material that is in the facility. The material bank stores and treats the materials. While the material passport gives the project managers the necessary data of what one can do with said materials. Data from the material passport and a digital material bank then give ground to a marketplace. The physical bank is a place where one can easily collect the materials one need based on the specifications the different project manager has for each project.

Treatment at a material bank is necessary if the municipality of Apeldoorn wants to re-use materials within its borders. It is important that the municipality has control over the treatment process. Materials delivered to a recycling company will usually give them the right to choose and sell the treated materials and then move the materials out of the municipality. Treating materials for Apeldoorn means to crush whole materials into aggregates. Polluted materials should be sent to an external treatment facility which can handle polluted materials. The great thing about crushing the materials is that the municipality can use the crushed materials they need, and if they sit on a surplus of materials, they can sell it on the private market using the link to the marketplace. This benefits the municipality economically and the environment by reducing the need for virgin materials.

Another benefit of treating materials at the bank is that one reduces the CO_2-emission from transportation. One saves truckloads, as one does not need to send materials around the municipality to crush and store them. To show the emissions from transporting materials from the test area to the material bank see Appendix IX.

The difference between a circular material bank and a standard material bank is its link to a digital version including the material passports. Before the materials are accepted at a material bank it should be categorized and have a material passport, that was discussed in the previous chapter. This gives the project managers a better understanding of what materials they have available in the material bank. This then reduces the need of virgin materials within the civil construction field as one easily can use materials directly from the material bank. The design of the material bank for Apeldoorn can be found in Appendix VII.

To make a circular material bank it is vital that there is a sort of marketplace that is linked to it. This is so the materials aren't forgotten by the municipality and isn't stored away for too long. A marketplace helps to match materials to projects. There are different companies that deal with the matchmaking. One of them is Excess Material Exchange (EME). EME uses the material passports to track and trace materials in real life assets and follow them through the value chain. They have made a tool which quantifies the economic, environmental and social value of the materials. By combining these three tools they find a high value circular match across industries (EME, 2019, p21).

A material bank can save money for the municipality; in Rotterdam € 12,500,000 was saved in 2011 by having a soil bank and by doing matchmaking for different projects (Groeneveld, 2013, p15). A material bank in Apeldoorn could be based on the same principles, but might handle more materials than just soil. The goal of a material bank in the municipality is to get a similar flow of materials as was achieved in the municipality of Rotterdam, but also will deal with asphalt and concrete. To summarize the role of a material bank for the municipality; it is a place where materials are stored, treated and categorized before it is being re-used again within the municipality. The primary focus should be handling CDW, matchmaking through the marketplace and the integration of material passports from all the materials stored inside the bank.

5. Discussion, conclusion & recommendations

5.1. Discussion

The Netherlands have come quite far in regards of a circular construction industry compared to the rest of the world. Even though the recycling rate is quite good, circularity has still got a way to go before it is a fully viable method in the construction industry. Putting into use tools like material banks, material passports and a marketplace to match materials is going to be the next steps for the industry on closing the loops in a circular economy.

Although different opportunities exist to structure and store material data, the municipality of Apeldoorn, just like the rest of the Netherlands, has not yet a generally accepted structure up and running to facilitate circular material processes in building projects. In this project different structures were explored and GBI seems to offer a possibility to facilitate these processes. However, investments are necessary to find out how GBI exactly can encompass all characteristics in correct units and store this information widely and easily accessible over long time spans.

In is also necessary to point out that the project described in this report is the work of three Saxion students, who were willing to work at and with the municipality of Apeldoorn. Due to the Covid-19 outbreak a lot of planned physical visits and data gathering had to be done online, which negatively influenced the internal and external collaboration, as well as the project planning. The project team had to make new plans, therefore some practical examples are lacking. The second company hired to do a scan in Griffiersveld did not had the time within the educational time frame of this project to analyse the data. Therefore, it was not possible to compare the different data regarding qualities and quantities of materials within the test area.

5.2. Conclusion

In this study it was found that how circularity is defined and measured, that settled material passports and that the presence of an actual case, all three play a major in designing a material bank. A material bank can reveal itself in a digital or physical form. The first one is preferably directly linked with material passports. The second one is often called a material depot, which might operate as a shop for used materials, as well as an entity that stands for the quality of the materials offered, like the sand site of the municipality does.

With regards to logistics and legislation one needs to optimize the flow of lorries to and from trucks to cut down emissions. Within this project a tool is offered to assess the environmental impact of transporting building materials.

By implementing circularity in procurement, offering material banks in both forms, and searching for new purposes for used materials, the municipality can facilitate a more circular construction industry. By doing this the construction industry can reduce virgin material usage and cut back on CO_2 emissions.

5.3. Recommendations

Based on the findings in this report the recommendation to the municipality is to develop a material bank where the goal of the bank is to be a place where materials are recovered and then re-used. To achieve this effectively material passports should be made for municipal projects, so that the materials being stored in the material bank can be linked to a digital material bank and stored in GBI. The data stored in GBI will show the quantities and qualities of materials present in the material depot. GBI can then link what projects Apeldoorn will have in the future and then show where the materials are needed. By implementing this the municipality can contribute to a more circular construction industry by reducing waste and re-using materials.

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Appendix I: Area of Griffiersveld

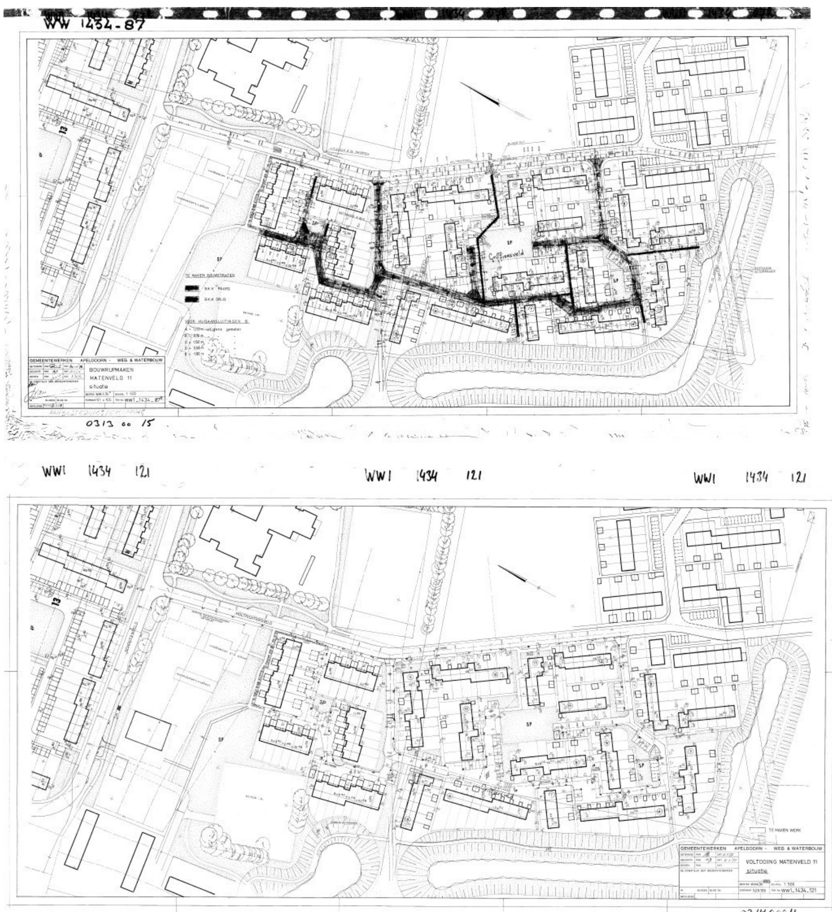
Griffiersveld is a residental area in the neighbourhood of De Maten in the city of Apeldoorn. De Maten is located in the south-east of Apeldoorn and Griffiersveld area and street are in the south-west side of the neighbourhood. De Maten neighbourhood is also called ''Zuidoost'' in some sources. In total seven areas make up De Maten, namely Matendonk, Matendreef, Matengaarde, Matenhoek, Matenhoeve, Matenhorst, and Matenveld. Griffiersveld is located in Matenveld (Postcodebijadres, 2020).

De Matens population is 26 255 and altogether there are 11 275 households in the area. Theres 1 205 companies in the area as well, mostly business services and trade and caterings companies. Only 1% of the area has been built after the year 2000, so a lot of the buildings, streets and municipal infrastructures are over 20 years old (Postcodebijadres, 2020).

The current pavement in Griffiersveld was built in 1977. There are still existing some drawings from that time. The data know of pavement materials is that there is 3690 m² of concrete slabs and 850 m² concrete bricks. Not every slab or brick is clean and unbroken, so further investigation is needed. The measurements of concrete slabs are 300 mm x 300 mm x 65 mm and the bricks are 105 mm x 210 mm x 80 mm. (Employee of the Municipality of Apeldoorn, 20.4.2020).

Figures 1 & 2. Map of Apeldoorn and the area of Griffiersveld. Limited area on the left figure is the neighbourhood of De Maten and the red dot is in the street of Griffiersveld, and on the right Griffiersveld is bordered (Google Maps,2020).

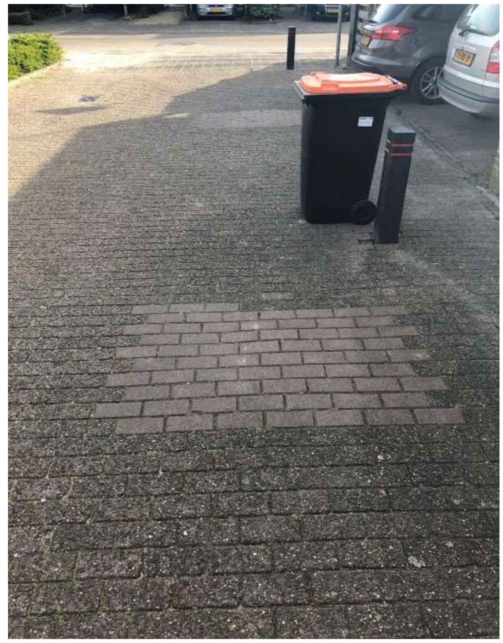
In old areas like Griffiersveld there is not much information of which materials was used there and their amounts. There may be some drawings available, but it only shows which areas were planned to build. If the exact amount of materials and their condition want to be investigated, then best way to do that is a roadscan. In Griffiersveld area the scanning was also executed, see more in Appendix VII.



Figures 2 and 3. Drawings from Griffiersveld in 1977. First picture shows the road construction areas and the second shows building construction areas without roads. Nowadays these would be in digital form and easier to share with others (Employee of the Municipality of Apeldoorn, 20.4.2020).

For this project, Apeldoorn’s employees with more knowledge of the area and the planned renovation were interviewed. An interview with an employee of the municipality of Apeldoorn will follow here. He is responsible for the ''grey part'' of the entire district of De Maten. This includes all road work and sewerage, not greenery. They have a special hotline for the entire district where anyone can make reportages. If there is something wrong with the street work, the respondent makes sure it is solved as soon as possible.

The respondent indicates that there are two things that really cause the big problems, namely: the district was created about 45 years ago, at that time they tried to create a lot of greenery in the district (trees, shrubs, grass, etc.). Because of the trees, they have a lot of trouble now. The most common problem is that the roots of the trees are destroying the roadwork. This is a permanent problem, they cut the street loose as well as possible and then build it again. However, the tree continues to grow and there is a very good chance that within 3-6 years they will face the same problem again. More pictures can be found below.

Figures 4 and 5. Places where a tree has been cut down. This tree continued to cause extra work every few years after which they decided to cut it down. You can still see this in the newer tiles with which they replaced the old ones.


Figures 6 and 7. Another problem is the trucks, 45 years ago the streets are certainly not calculated on these big trucks that are getting bigger and heavier.

The most common problem because of this are subsidence and broken tires. The respondent advises not to lay stones like brickwork pattern, but preferably like fishbone pattern. This spot is located exactly between the two wells where a sewer pipe runs. Probably there is a very small hole under the sagging in the sewer pipe through which the pavement can sink.


Figures 8 and 9. Sagged places in the street.

The respondent recommends using IT sewerage when renewing the street. It is a good sustainable solution. This is because the system does not then automatically send relatively clean rainwater directly to the sewage treatment plant. But it ensures that the water infiltrates as groundwater. Water can come out of the sewer pipes, but preferably any sand would not enter. The only disadvantage is that people are no longer allowed to wash their cars in the street because of the soap.

Figure 12. A piece of new street work. This road was so bad a few years ago that they laid it again. The broken bricks have been thrown away and for this last piece they were short of stones which they later supplemented with new ones.

Figures 10, 11 and 12. Water sewerage in the Griffiersveld area. All the rainwater is lead to a canal nearby.

Other remark that the respondent pointed out, is that parking spaces are being counted for 0.75 cars per household. That is far too small space nowadays. Putting the concrete tiles instead of clinker bricks have no functional difference, this was purely architectural choice. He also adds that speeds bumps are very important in the area.

Figure 13. Example of a proper speed bump

The renovation process will take place in the year 2021. The area will be designed to look more lively and that way that there will be no structural movements because of trees or the drainage system. New materials for the area will also be recycled products, otherwise the project would not be following the manners circular economy. Listening to the respondents' advice is also important, since he is one of those who knows best about the problems the area is facing.

Figure 14. New plan for the renovation of Griffiersveld. The green parts are only renovated lighty by changing the pavement, but the red parts will the completely renewed with new drainage system etc.

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Employee of the municipality of Apeldoorn

Figure 1. Google Maps,2020

Appendix II: Material passports

Since materials passports are part of circular industries fulfilment, it is important to design a material passport for that would be most suitable for Apeldoorn's use. A ready material passport platform will be given for users, so they can be filled and taken into practice. All material passports are stored in material bank in GBI. They are stored there as long a deconstruction for example buildings or roads is starting to be planned. Then they will be transferred to Material Market, where users can see directly all the information of the materials or products that have been stored to the material passport earlier. Material Market and the business model are introduced in Appendix IV.

Material passports should be able to fill in new projects, such as the construction of new roads. Of course, it is easy to immediately keep track of which materials are used. But so far this is of course unknown in most roads. In the Netherlands, some roads are from before the 19th century and a lot of changes and widenings has been executed in past 50 years that are not recorded anywhere. (The Wegenscanners). How can a material passport be set up despite the fact that the roads are old.

Some things are easy to find out such as the amount of benches, bins or wells. But the most important and common things like the stones and the underlying soil are much more difficult to determine. Completely invisible from the top are of course the sewerage and electricity lines.

Material passport, also shortened as MPP or MP, is a tool used for storing materials, components and product information. In this document material passport is referred as MP. Different organizations and companies may have their own definition of an MP. They also plan their own platforms to suit their needs the best. There are not too many MP platforms in the world, and those that are, are usually companies secret since they include data.

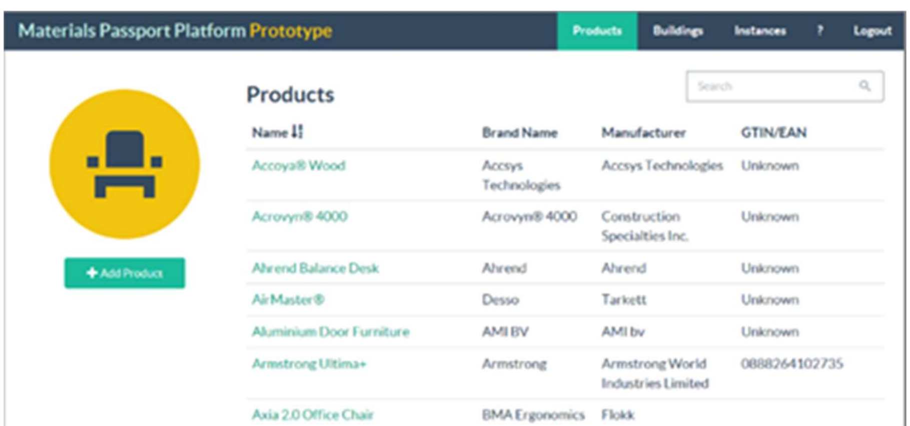

Figure 1. Product list MP platform, a prototype (Seinäjoki UAS, 2019).

The BAMB prototype sums up the purpose of an MP very shortly but concisely. Most of sources of an MP is received form BAMB deliverables, but also some information was received from small companies working with their own MP. For example, a company called Excess Material Exchange (EME) introduces their own resource passport. EME is a company that works with materials ''matchmaking'', which means that they aim to bring together used materials and their new users and destinations. When introducing their resource passport, some terms such as transparency, track & trace and valuation come up. The circular economy needs data transparency in order to make more matches between different companies. Like said, some companies do not want to share all their information. EME offers an environment where organisations can securely share information about the resources they need or would like to sell without revealing business sensitive information. The ability to track & trace materials has a huge importance in the circular economy. When knowing how much materials will be available and where, this makes it easier to get in touch with new, reusable and potential materials. It is important to evaluate the financial, environmental and social impacts of materials in order to keep new destinations high-valued in further uses. That is why valuation process is important in an MP as well. Matchmaking is the last part of finding a new home for materials. When there has been made a clear MP of which material with which qualities, quantities, possibilities and values they have, it is easy to find a perfect match for them for further use (EME, 2019).

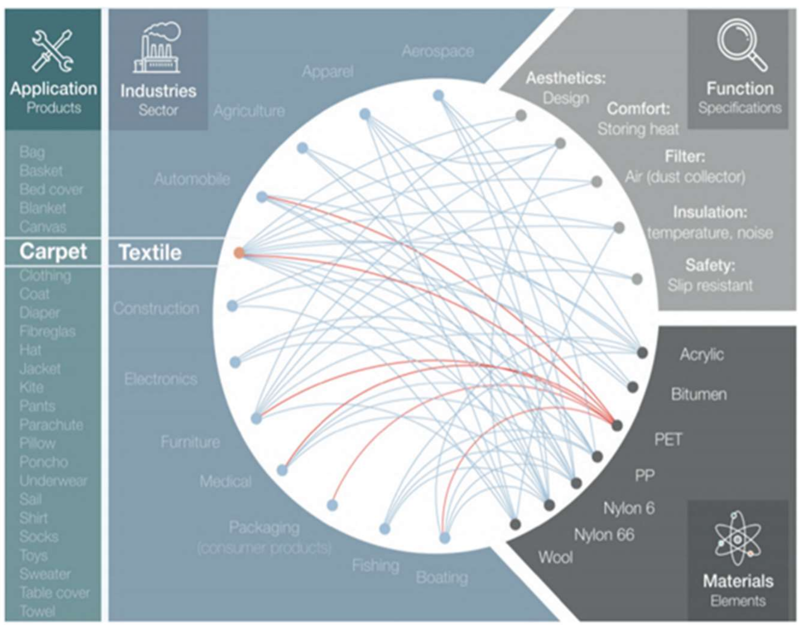

Figure 2. How match making is done. (EME, 2019).

In EME's words, the passport creates more transparency in the exchange of excess materials. The passport is a data structure that records information on product, component and material level and their various attributes throughout their life cycles. It offers a clear and uniform format in which organisations can log the characteristics of their streams (origin, composition, toxicity, embedded energy, carbon emissions, etc.), thereby providing anonymous excess materials with an identity relevant for reuse. The structured and standardised format enables scalability in the exchange of materials. By mapping the availability and characteristics of resource flows, we will make high-value matchmaking possible.

The sketch of an MP for Apeldoorn will hopefully find its way to a good and functional platform in the end, but so far it is been designed in Excel. Below you can see pictures of the sketch.

Material passport for road construction - The municipality of Apeldoorn		
	1. General information	
1.1.	**Contact information**	
1.1.2.	Company	
1.1.2.	Address	
1.1.3.	Contact person	
1.1.4.	Phone number	
1.2.	**Site information**	
1.2.1.	Company	
1.2.2.	Site address	
1.2.3.	Contact person	
1.2.4.	Phone number	
1.3.	**Transport information**	
1.3.1.	Company	
1.3.2.	Machinary	
1.4.	**Content information**	
1.4.1.	Amont of produtcs	
1.4.2.	Amount of different soils	

Material passport - The municipality of Apeldoorn

Apeldoorn

2. Quantities and qualities

Help

2.1.1. Product = Short product info like "paving product"
2.1.2 Description = Short description of condition
2.1.3 Material = concrete/asphalt/other stony material
2.1.4 Shape = square/rectangular tile/slab/brick/stone, asphalt paving

2.1.5. Location
2.1.6. Available since
2.1.7. Amount of products
2.1.8. Past use
2.1.9. Recycling options
2.1.10Maintenance
Storing instructions
2.2.1 Measurements = length*widht*(hight)
2.2.2 Total weight [tons]
2.2.3. Total volume [m3]
2.2.4.Density [kg/m3]
2.3.1 Color
2.3.2. Surface [smooth/coarse]
2.4.1. Compressive strenght [Mpa]
2.4.2. Tensile strenght [Mpa]
2.4.3. Elasticity [Gpa]
2.4.4. Max grainsize
2.4.5.Porosity
2.4.6. Concrete mix

Figures. 3 & 4. The general information and help page

	PRODUCT 1 - Paving tile Griffiersveld	
	General	
2.1.1.	Product	*Paving stone*
2.1.2.	Description	*Clean whole tile*
2.1.3.	Material	*concrete*
2.1.4.	Shape	*slab*
2.1.5.	Location	*Apeldoorn, materialbank 1*
2.1.6.	Available since	
2.1.7.	Amount of products	
2.1.8.	Past use	*40 years paving material*
2.1.9.	Recycling options	
2.1.10.	Maintenance	*Cleaning etc.*
2.1.11.	Storing instructions	
	Dimensions (one product)	
2.2.1.	Measurements	*300*300*65*
2.2.2.	Weight one product [kg]	*13,25025*
2.2.3.	Volume [m3]	*0,00585*
2.2.4.	Density [kg/m3]	*2265*
	Optical	
	Optical	
2.3.1.	Color	*Grey*
2.3.2.	Surface	*Coarse*
	Structural data	
2.4.1.	Compressive strenght	
2.4.2.	Tensile strenght	
2.4.3.	Elasticity	
2.4.4.	Max grainsize	
2.4.5.	Porosity	
2.4.6.	Concrete mix	

Picture

Map

Figure 5. The concrete tile sketch with relevant data, that will also be useful information in the marketplace.

	PRODUCT 2 - Paving stone Griffiersveld	
	General	
2.1.1.	Product	*Paving stone*
2.1.2.	Description	*Clean whole brick*
2.1.3.	Material	*concrete*
2.1.4.	Shape	*brick*
2.1.5.	Location	*Rectangular*
2.1.6.	Available since	*Apeldoorn, material bank 1*
2.1.7.	Amount of products	
2.1.8.	Past use	*40 years paving material*
2.1.9.	Recycling options	*Paving stone, aggregate*
2.1.10.	Maintenance	*Cleaning etc*
2.1.11.	Storing instructions	
	Dimensions	
2.2.1.	Measurement	*200*100*80*
2.2.2.	Weight one product	*4*
2.2.3.	Volume [m3]	*0,001764*
2.2.4.	Density [kg/m3]	*2268*
	Optical	
2.3.1.	Color	*Grey*
2.3.2.	Surface	*Coarse*
	Structural data	
2.4.1.	Compressive strenght	
2.4.2.	Tensile strenght	
2.4.3.	Elasticity	
2.4.4.	Max grainsize	
2.4.5.	Porosity	
2.4.6.	Concrete mix	

Picture

Map

Figure 6. The concrete brick sketch with relevant data, that will also be useful information in the marketplace.

Clean	
Weight in [tons]	
Amount of whole	
Amount of broken	
Polluted	
Weight in [tons]	
Amount of whole	
Amount of broken	
Mixed	
Weight in [tons]	
2.1.5 Amount of whole	
2.1.6 Amount of broken	

Figure 7. A useful data for Apeldoorn's own use, especially linked to the material passport. This would not necessarily be shared for anyone else than one material site's personnel at a time in order to keep track of one specific product.

These Excel sketches have what will have to be included in a material passport for industry are general information, product description, quantities, qualities, functionality, deconstructability, recycling possibilities, location and a map and financial value. A material passport should give users a wide view of the materials and sort of instructions to plan ahead. The best way of filling a material passport, is in the beginning of materials lifecycle when it's in fresh memory of what has been put to the building or road for instance. This example sketch is made especially for road construction materials. Products can be for example concrete tiles, stones, natural stones, asphalt, soil and gravel.

Additional references used in this appendix

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Appendix III: Interviews

In this document the overview of interviews external interviews are being presented. All the experts were eager to help, since circularity is an important topic. The interviews were an important source for this research.

1. Interview with the Two "R" Recycling Group

What do you think 100% circularity means?
In my opinion something is 100% circular if you can take out all the raw materials of that product as they have ever been made. So for example with concrete if you can use the gravel, sand and cement all over again to make new products.

What are the best materials to use if we renew the streets? Just put the existing (whole) concrete tiles back in? Or take them out and use them for something else?
The respondent indicates that as long as the concrete clinkers still meet the requirements of the municipality of Apeldoorn we should always reuse them. According to him, this is optimally sustainable and circular.

How can we best deal with the broken concrete tiles that cannot be reused?
According to Respondent we have to take them to the demolition depending on the exact quality, we will then see if it can be used to replace them as a whole (removing all the original materials). Or as a replacement for gravel in concrete or that it would be better to use it as a foundation under the roads.

Do you recommend recycling old paving concrete bricks as whole bricks or is it better to crush them for further use? Let's say it's a 20-year-old stone from a driveway.
The respondent advises us to reuse the concrete tiles if they meet the requirements of the municipality.

What are the places where we can use whole concrete bricks / slabs? In a new pavement possible? As building material?
In principle, the concrete tiles can be used in all places where they are normally used. But again, they must meet the requirements of the municipality.

What qualities do you measure from asphalt, concrete, sand and baked bricks?

Concrete:

- polluted concrete (concrete with soot, e.g. near and chimney)
- clean concrete
- mixed concrete.

Asphalt:

- Asphalt laid before 1994 tar Asphalt (PAX substances) may be accepted and crushed but not machined goes to thermal cleaning plants (which burn it clean).

- Clean asphalt is either put back as asphalt or underneath the road as a foundation (this happens with marked asphalt think of the lines or coloured asphalt of e.g. bicycle paths).

<u>Fried products:</u>

- One category satisfies or does not satisfy, the baked products are highly sought after if they are still good re-use otherwise as foundation under the road.

<u>Sand:</u>

- Four categories of sand are distinguished.

Are you trying to avoid downcycling for as long as possible?
Respondent is clearly striving to do everything he can to postpone downcycling as long as possible. However, the techniques are still a long way off and most building materials are used directly as downcycling foundations under roads.

What is the most difficult material to deal with?
Concrete, because we would very much like to remove the cement but this is very difficult. They are fully developing it but so far only 4% of the concrete is completely reused. However, Respondent recycles 16% concrete. Clean rubble includes: concrete debris and concrete mortar, roof tiles, masonry and paving stones, floor tiles, sand-lime brick, the waste serves without contamination.

So what can't you offer as clean rubbish?
Plaster products, rubble with soot (chimneys), rubble with asbestos, stucco rubble, aerated concrete, tar Asphalt, gravel, roof waste (bituminous/tarry), other contaminants such as plastic, paper, wood and other non-stone materials. If the above material is enclosed, the rubble offered will be refused.

Questions one week after the interview:
Just for the record, we don't accept land. Only the stony fractions from construction and demolition waste, except gypsum and asbestos.

We are not allowed to receive soil, permit technically. Our permit states that we may accept rubble with up to an x% contamination and also with an x% soil. This differs a bit per province, but assume only about 5% for soil and pollution, think of insulations, foils, wood, plastics, etc. This applies to the acceptance of mixed rubble. In the acceptance of concrete rubble we have much stricter requirements. There must be no soiling and only adhering soil with a maximum of 5%. Of course we sometimes get concrete rubble with some pollution such as PVC tube, formwork wood, tempex insulation material, but again this is in principle forbidden with us.

You separate contaminated concrete and soil. Do you have a cleaning system for them and do you clean them? Or do you have a plan for contaminated material and do you not clean it?

We clean contaminated concrete in several steps. The first step is by manual removal. Coarse dirt is manually removed by an employee on a conveyor belt. After the debris has broken, we have a 2nd and 3rd cleaning step. This can be by means of wind shifting. In this step we blow, very directed light parts out of the rubble. These 2 steps are used for all types of materials, i.e.

for the mixed flow of rubble and the concrete rubble. For the concrete rubble we have a washing process as an extra cleaning step. In this washing process, the concrete rubble is stripped of light (floating) pollution and adhering dust. In addition, we always remove the rebar and other metals from the debris streams. This is done by means of electro magnets.

How do you distinguish contaminated material? Do you somehow separate contaminated material that cannot return to good condition and contaminated material that can be cleaned?
See my remark above about our acceptance process. We only accept a small amount of dirt. If it is above that, it will not be accepted by us. This material first has to be taken to a sorter and there it has to be stripped of the excess pollution. Then the debris comes to us and is further processed.

Are there general quality requirements for, for example, concrete and soil? What standards do you follow?
We do not accept soil. We have different quality requirements for concrete. For example, there is a BRL, the BRL 2506, which we have to comply with in order to be able to deposit the materials. If you take a look at our website. www.puinrecycling.nl or at the website of our trade association the BRBS, you can find more information about quality requirements.

2. Interview with Kamphuis sloopwerken

Do you invest in recycling after your demolition work? And if you do, how?
Kamphuis does not really invest in recycling after their demolition work. What they often do is put a rubble crusher in it. They then throw an X number of m3 of rubble through what is needed for the new project. For example, if a house is demolished, part of the rubble is broken into the machine and then a layer of 20cm is laid under the future driveway of the new house. They don't recycle any further themselves, but a part is stored at a raw material depot of their in Tubbergen, before it goes to the recycling companies.

If we strive for circularity in the future, the buildings will be built in such a way that they are not demolished and crushed, but carefully demolished one by one, so that we can use complete pieces of buildings again. Do you see this as a threat to your business model or do you plan to specialise in that kind of demolition work as well?
This is what Kamphuis hopes to achieve in the future because it is really circular in their eyes. They certainly don't see this as a threat but more as an opportunity for the future. So they are also sure that they plan to specialise in this in the future.

Are you more specialized in: conventional demolition, where the building is converted into waste; fully selective demolition (also called deconstruction) or where construction steps are reversed to recover as many materials as possible; or partial selective demolition, which is a combination of the other two?
They can both be said to be a combination of conventional demolition and selective demolition. However, because customers often didn't value the old building, and they only hope that it will be demolished as quickly and cheaply as possible. Kamphuis often can't compete with other demolition companies that directly put the demolition ball against it.

So we can say camp house can carry out the demolition very accurately and sustainably if the client cooperates. However, if they don't have the money for it, Kamphuis can do it just like other demolition companies also very quickly (conventional demolition).

What are the best materials to use when renewing the streets? Just put back the existing (whole) concrete tiles? Or take them out and use them for something else?
He indicated that the best solution is to just reuse the same concrete tiles. However, he clearly indicated that spraying the tiles with high pressure is not a solution. You make them very rough and then a year later they will certainly be just as green again.

You separate contaminated concrete and soil. Do you have a cleaning system for them and do you clean them or do you have a plan for contaminated material and don't clean it? How do you distinguish contaminated material?
When camp house delivers demolished material to recycling companies it may contain a percentage. For example, when they deliver concrete it may contain (I'm just saying) 3% contaminated material such as baked bricks, sand, etc. As long as it meets these requirements they can't get fines. Kamphuis never cleans demolished materials itself.

What is the best way to deal with broken concrete tiles that are not reusable?
Trying to see if recycling companies like 'Twee R Recycling' can do something with them after we 'stole' the different bricks. If recycling companies can't do anything with them, they can put them in the rubble crusher.

What is the hardest material to demolish? (What do you work with the most? Soil, asphalt, concrete or baked goods)
In principle, concrete is the most complicated to demolish, especially if you have to have pure concrete. In homes, there is often a cement screed on top, and reinforcement, sewerage and electricity in it. This makes it very difficult to demolish pure concrete. However, camp house indicates that it is easy to do just takes much more time. Simple concrete tiles are of course easy to demolish.

Do you do a lot of roads or do you only demolish buildings?
Kamphuis mainly does buildings, but also infra they do not shy away from. Think of a very large industrial building with its own roads and parking spaces. The demolition of the infrastructure they do therefore completely at

What happens to your materials?
If there are no direct ideas for the time by the customer or contractor. They often go on to the raw materials depot in Tubbergen. They also sell part of their products online to private individuals.

3. Conversation with the municipality of Apeldoorn

How big is the area being excavated?

- Concrete paving stones 3690 m^2
- Concrete tiles 850 m^2
- Concrete tires unknown m^1

How old is it? -How old is it? Does it have renewed parts? Where does the material possibly come from?
The Griffiersveld in sizes was built in 1976. It hasn't really been renewed until now, but of course it has been serviced several times if necessary. Think of replacing street work that has been shifted.

From which type of place do you get the most materials?
The municipality of Apeldoorn obtains all materials from their contractor HOFMAN INFRA B.V. However, when they can reuse existing stones or soil of course not.

Do you prefer the kind of stone?
We always buy a through-and-through concrete mix stone (door en door betonmengsel steen), which is a stone with a slightly lower quality. The reason for this is that nicer bricks such as covering bricks (deklaagstenen) have had a lot of damage to them.

Do you recommend recycling old paving concrete bricks/ slabs as whole bricks or is it better to crush them for further use?
The municipality of Apeldoorn has a framework contract with Aterro B.V. in Voorst. Here all bricks from the municipality go into the rubble crusher. What the respondent indicates, is that they always try to take the rubble back to use as a foundation in the municipality of Apeldoorn. He also indicates that at Attero B.V. they try to keep the concrete granulate separate from the mixed granulate. Concrete granulate has a higher stiffness and is therefore more valuable for reuse. The respondent also indicates that, if possible, as much rainwater as possible should be disconnected directly so that it does not end up in a sewage treatment plant (WWTP). Especially for the court clerk's office this is easy to do because there is a stream running behind it.

4. Interview with the municipality of Oss

Function	Advisor/specialist sustainability manager
Organisation	Municipality of Oss
Date of purchase	11-5-2020
Time decrease	09:00
Location reduction	Online meeting

The municipality of Oss uses a material passport. What is a material passport according to your definition?
What we consider to be a materials passport is a digital register or library of materials and/or products. Its purpose is to give an identity to materials. In this way you can monitor the value of waste as well as its residual value. In terms of design, it is ideal if you can do that with a 3D overview of materials within projects. It is not an impact cycle for materials, you have the life cycle for that. It is also your marketplace for second or third hand materials. It's not an asset management system either, you have engineering consultancies for that.

Is it possible that we can gain some insight into this?
Esther indicates that we cannot get the materials passport for privacy reasons. In the case of concrete or asphalt, for example, we can then derive entire recipes from it, which is too

sensitive information in her opinion. However, she would like to send me the specifications of their materials passport.

Do you use material passports for the management of the CDW in your municipality for infrastructure projects? If not, do you see any possibilities for this in the future?
No, they have only used it for their project the sustainability square. Furthermore, she indicates that for her the term CDW is unknown and that they most likely call it BIG DATA. It is an important data tracking tool, so it is certainly useful. So at the moment she certainly sees possibilities for the future in this, only they are not yet so far that she can give clear views on this.

Is there a system for controlling maintenance of public spaces, green spaces and/or roads?
As they work with GBI in Apeldoorn, they work with 'obsurv' in Oss. A programme with, in their own words, the first real integral management system for public space: planning and budgeting in a single process (http://www.obsurv.nl). They also work with a data square in which they keep track of the data of the materials. Such as the types and quantities of materials.

Can you say how much of the total CDW in the municipality of Oss is recycled?
They do not want to make any statements about this in relation to privacy within their municipality.

Do you use a digital materials bank? And in what way?
Yes, only so far they use it on a higher level as just mentioned in question they have a data square which contains all types and quantities of materials. Such as trees, benches, asphalt, roads, lighting, etc.

How do you deal with sustainability, do you strive to re-use everything within your municipality? Or does it sometimes go to other municipalities as well?
In the first instance they obviously try to reuse as many materials as possible within their municipality. When they are left with materials that they can no longer use, such as benches or lighting. Do they put this on www.gemeentewerf.nl a kind of marketplace for materials within the municipalities with which we are already in contact.

Do you have companies that specialise in recycling concrete and asphalt that you work with?
The municipality of Oss engages external companies for their recycling of concrete and asphalt which companies are these has not become clear to me.

Do you already have fully circular districts/streets in Oss?
In Oss they have developed a circular square, which is also the subject of the article on madaster (which brought me in contact with Esther). Furthermore, they do have circular parts such as the recycling of asphalt and the recycling of concrete sewer pipes. I will tell more about the latter in question 11.

Do you have resource depots within the municipality of Oss?
They do have many soil depots where yellow and black sand is separated. However, this is only sand; they do not have large resource depots where all the different infrastructure materials are located.

How do you deal with concrete recycling? And what requirements do you have for the quality of this?
The recycling of concrete is handled via the BRL2506: (https://www.brl2506.nl/). Esther indicates that they do not want to use old concrete under roads as a foundation. But that they use old concrete as much as possible in new concrete products. However, she also told me another interesting news, in the municipality of Oss they are reusing old concrete in new concrete sewer pipes under the roads. These concrete sewer pipes are almost always finished when the street is replaced. These can no longer be recycled, they can then be used as a foundation under roads.

Guidelines for the materials passport for a construction-wide approach see https://platformcb23.nl/downloads. Guidance on detachable building www.duurzaamgebouwd.nl/artikel/20190725-handreiking-losmaakbaarheid-geeft-aanbestedingsadvies. BRL2506: https://www.brl2506.nl/. Metabolic Studies: https://www.metabolic.nl/publications/. More information about Obsurv is on http://www.obsurv.nl

5. Interview with the Abbink road construction company

Function	Owner and managing director
Organisation	Abbink wegenbouw Boekelo
Date of purchase	14-5-2020
Time decrease	09:00
Location reduction	Online meeting

What is your function within ecofalt? What is ecofalt part of?
The respondent works for Abbink Boekelo road construction. He is responsible for their establishment on Terschelling. He is also director and founder of Ecofalt. Ecofalt was founded 10 years ago and has always been part of Abbink Boekelo road construction, but since last year it has become a company of its own.

Is it possible to use ecofalt asphalt in the court clerk's office? Is this real and optional? Is this really useful? Does this solution also yield the most circular profit?
Of course, it could certainly be an option. Up to now, Ecofalt has been used on all sorts of streets/paths except regional and motorways in connection with CE certifications. There are two types of Ecofalt that can be applied:

- Ecofalt with old asphalt
- Ecofalt with old debris such as concrete and masonry debris.

The advantages of Ecofalt with old asphalt are, that when the end of life of the asphalt is reached, this type of asphalt is then much easier to recycle. In terms of costs, it does not really matter which of the two options is used. The advantage of Ecofalt with old rubble is that you actually deal with the old rubble waste in a very sustainable way, which is normally difficult to get rid of. However, if this has to be recycled again in, say, 50 years from now, it will be a lot more expensive than recycling with Ecofalt with old asphalt.

Is it possible to make an asphalt road with the old stones out of the way?

Yes, that is certainly possible, the pros and cons I have mentioned in the question above. Respondent really does indicate that he doesn't think it's the right way to process old concrete is asphalt. He indicates that he would rather see concrete recycled back into new concrete. He has also told us about new horizons in Amsterdam. A company that specializes in the recycling of concrete. He also indicated that he might want to make contact with new horizon for us.

In short, it is possible but Ecofalt with old asphalt is more sustainable and more effective according to the respondent.

Do you have a cost indication?
Giving a really good cost indication per square meter is very difficult for Respondent. Because it is very complex and is related to many factors. What he indicates is that when production gets going a little better, he can meet about the same price as normal asphalt. Respondent also gave me amounts per ton of Ecofalt. For example, the price of Ecofalt is between 45 and 65 per ton.

What is his problem to market this product well? If something is good, how come it doesn't really seem to break through? Isn't it good enough?
The respondent indicates that he has been taking it very seriously for 8 years and that his patience is also running out. He says that Ecofalt is always measured on real asphalt. Ecofalt complies with the application and construction of real asphalt, but ecofalt is not real asphalt because it is more durable. At the moment, Ecofalt does not yet have all the CE tests that are available for normal asphalt. Because of this, many companies or municipalities often get rid of it. That problem he constantly runs into. According to Respondent it is just as strong on asphalt, but according to him this is not demonstrable. Costs also play a small role, because it is not yet produced as much as Respondent would have liked, they cannot currently meet the costs of normal asphalt.

What alternatives are there for us besides ecofalt asphalt? Which one is the most sustainable? Which one is the most expensive? What is standard, and therefore cheap, and how does his product fit into this list?

Do you have a contact for a concrete bike path maker?
Respondent is familiar with concrete bike paths. He has realized many projects on Terschelling in which they recycled concrete to such a high level that all they had to do was add a little sand and cement. If I have any questions about this I can put them on the mail.

So concrete debris can also be reused as a foundation, but that's downcycling. So less sustainable, but how much less sustainable?
Reuse concrete rubble under roads is far from achieving the desired sustainability effect when concrete is recycled again into new concrete. In terms of costs, however, in the short term it is cheaper to use old concrete as a foundation under roads. In the matrix that we are going to make, we will pay attention to the following aspects

Do you have a material passport for the cycle paths you have already built?
The respondent provides the material passports for his landscaped bike paths. However, he keeps the material passport in a logbook. In which it is clear to himself but not directly to others. In addition, there are now private things in it, so he can't send it to me at the moment. He is

going to work it out further and he can send it to me later but fear that that will be too late for us.

6. Questions for civil servant on road maintenance about GBI:

How can the municipality of Apeldoorn make practical use of GBI? Is there an GBI channel that contains all the data of the municipality? Where users can access it when they need it? Or how does it work in the basics?
GBI is available for employees who need it. In addition, the data is also available via the RIV viewer. The RIV viewer is available for all employees of the municipality of Apeldoorn. The data is also available via the arcgis portal. The data is also available through a number of arcgis-online projects.

For example, do other municipalities use GBI to store their data?
GBI is used by more than 100 municipalities.

Is it easy to add and move data in GBI? As an example, we would like to have an easy transition from GBI to a kind of marketplace for materials (e.g. gemeentewerf.nl). Would it be possible to create such a direct transition? Or should we first download the files from GBI and then add them to the marketplace.
People who have access can, if they have the right rights, make mutations. If the data has to go to some kind of marketplace, it depends on how this portal should deliver the data. By means of ETL scripts we can export in almost all common formats.

Can we get an example of what it looks like inside GBI (possibly through a few pictures) It will help us to get a better picture.
You have had an Excel list as an example. Here you can see what the data model looks like. GBI is actually a viewer to look at the data and thematise it. Below you can see an example of the legend road maintenance. We can set up these legends the way we want.

Appendix IV: Business models

The marketplace is a platform for exchanging materials inside the municipality. Basically, it is a public platform for all users inside Apeldoorn. Since it is namely about exchanging and not selling materials and products, it is a non-profit marketplace. The goal is to save money and resources, not to make financial profit and getting rid of owned materials.

The benefits of having an internal marketplace for a municipality are said to be easier comparing and transparency between the municipalities construction sites and possible local companies, customers reliability, being able to reserve materials for future projects and integrating products already in designing and planning phase. (Excess Materials Exchange, 2019) Also, maintenance requirements and recommendations and exact quantities and qualities can be listed to the marketplace just like to a material passport. It is in planning, that the material passports would be directly transferred into the marketplace. Generally, it helps closing local loops and to extend products life and to facilitate circular city's ambitions.

Excess Materials Exchange has a great example of using their Resource Passport and Internal Marketplace, which they offer for municipalities to use. They have a functional platform where it has been made easy to share and move the passports between storage and the marketplace. The thought at the moment is that Apeldoorn would combine EME and GBI, not to create an own marketplace. So far, the exchange will only be between the municipality's own destination. Practically, it would work in following steps in Apeldoorn:

1. A material passport is transferred from GBI and shared to the marketplace whenever it is wanted to put back to recycle. All the users in Apeldoorn who have access to the GBI have also access to the platform where a material passport can be filled up and to the marketplace. The marketplace offers all the information than what is in the passport itself. The more information is available, the better it is.
2. Since the user has uploaded material passports into the marketplace system, he/she has a possibility to manage those products on the platform. On dashboard you can see which passports are complete and which need more information. It is an overview that shows the products name, status, location, market value, end-of-life cost, distance and actions.
3. Using your Internal Marketplace. Assests you want to be published, will be securely transferred to an Internal Marketplace. The customer looking for certain products can also you search on specific items and make a wishlist. Also additional services for EME can be requested, such as ValuationbModule ot Matchmaking Module. Now the customers can exchange products within the municipality. (Excess Materials Exchange, 2019)

The CEO of Excess Materials Exchange, Christian Van Maaren, was interviewed for this research. Some practical information was received from him regarding the use of the marketplace platform. Here is an example: In Griffiersveld there may be hundreds of similar produts, that will be available for others inside the municipality to use. If in the marketplace are informed for example 100 similar concrete tiles, how does it work if a some user wants to have only half of them. Christian answered, that it is possible to split the material passport and half of the products go directly to the next owner and rest of the products stay where they were. The platform has been made simple like that, and there is no need for creating a new passport and filling all the data there again. The passports are designed to be modular like that.

Christian also told, that customers may only see their own products and all products that are shared with them, for example in an ecosystem where multiple customers are present. This kind of ecosystem is for exapmple the municipality of Apeldoorn.

When a users are looking for new materials and equipment while planning a new project, they can make a wishlist to the marketplace. According to Christian, certain people like superusers can see the wishlist. The superusers are the ones who are doing thr matchmaking inside the marketplace.

Result of utilizing an internal marketplace

If a municipality decides to utilize the platform with material passports and marketplace, or only marketplace, regarding to EME the municipality can now:

- Strategically plan on the release of certain products/materials on your Internal Marketplace to optimize your assets' value retention;
- Strategically share the release of certain products/materials on your Internal Marketplace to chosen third parties.

Material Market

Together with International Business students from Saxion University of Applied Sciences, a Material Market business model was created. The business models come always to question when new business is being established. Even though Apeldoorn's plan is not to make the most financial profit, some kind of business models are still good to give thought to. Business model is a description of what are the main authors in the business and the relations between them. Non-profit organizations of course have their own business model then, too. Below can the business model called Material Market be found. It was designed especially for Apeldoorn. The slides were made in co-operation with Dennis Hekman, Joost Agazzi, Jonatan Bunskoeken, Zoë Haas and Nadea Bogdan

Material Market
Sharing building materials from waste streams
How can a platform be provided for secondary material exchange between all users inside the municipality
Exchanging materials
One step closer to a circular economy
Construction companies
Munincipality Construction
The material market
Private construction projects
Crushing low-grade materials for repurpose

So how does it work?

The material market is a combination of 3 types of business-models

Community

The material market works as a community business model as it provides a common ground for multiple stakeholders to store and collect secondary raw materials.

Resource recovery

All construction projects within the municipality can use the market to deposit waste materials for repurposing. When a new project is started, those materials can then be recovered and used again.

Product life extension

Materials that are considered to be unusable can be crushed up into aggregates and can then be reused again via product life extension.

The community business model

And how a material passport can enable the community business model to function

Material passport

A material passport is filled in for each material that enters the market place.

It contains information about the quality, quantity, and other general information such as location date of entry and much more.

The material passports are then stored in an online databank hosted by the municipality.

Whenever someone then wants to use or find a material this databank can then be consulted.

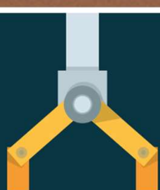
Those material passports can then be seen by anyone active in the Material Market

Resource recovery business model

The resource recovery model involves the production of secondary raw materials from waste streams. Whenever a building, road or other construction is demolished, all waste materials that can be repurposed will be recovered

Those recovered materials will get their own material passport and get sorted. Materials that can be used immediately will be moved towards the material market while materials that currently don't have a second purpose will be stored in a storage facility that functions as a physical material bank.

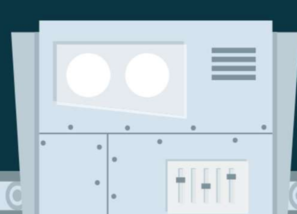
Lastly, materials that are unfit for both the material market and the material bank will flow towards the final business model which is the product life extension model.



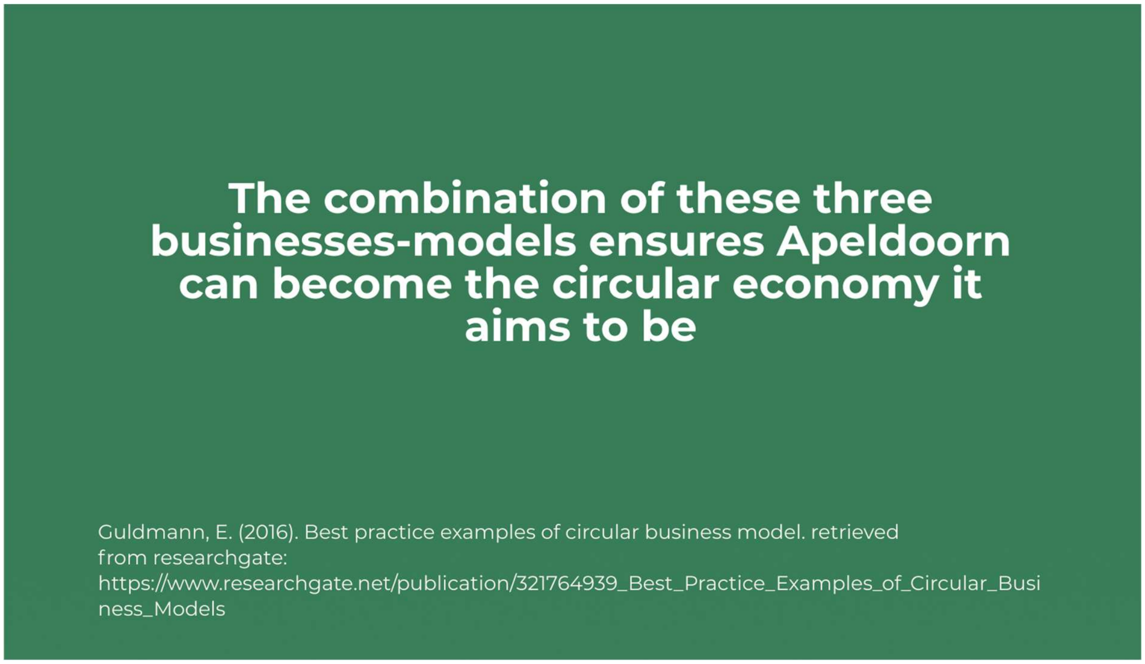
Product life extension

The materials that would usually end up in a landfill are now remanufactured into actually useable construction materials via product life extensions

Materials that have been deemed unfit for repurposing will be crushed up into aggregates



Those aggregates can then be repurposed again as raw material for new construction destinations



References:

Excess Materials Exchange (2019), *Internal Marketplace*

Appendix V: Recycling of road materials

One of the main actions in circular economy is recycling. After a product is not needed any longer but it has remained in good condition, it has to be made sure that it stays in cycle by recycling and not ending to a landfill. It is a remarkable part of a material passport to write down the recycling possibilities, too. In this Appendix some recycling possibilities of concrete, soil and asphalt are introduced.

1. Concrete

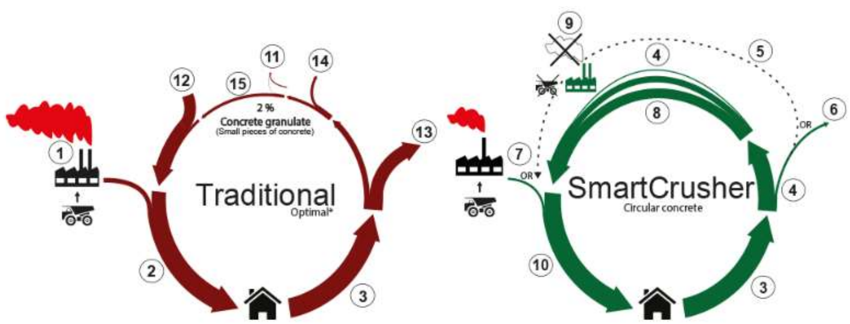
In European union and in the Netherlands, one of the largest part of construction and demolition waste is concrete. Whole concrete produtcs are not easy to recycle unless they have been disassemblied carefully without braking anything. Most of the deconstruction work still happens by demolishing, since earlier in construction industry producing concrete waste was not alarming like it is now. That is why most possibilities in recycling concrete is to recycle it as concrete aggregates. Of course it would be ideal to desing all the buildings and structures to be disassemled well and designing new high-class destinations for aggregates as well. Since separating cement and aggregates is found to be demanding and expensive, it is quicker to crush the concrete products and recycle it as crushed concrete aggregate. This is only bad, since those materials end up mostly in civilworks and is that for, downcycled. Avoiding downcycling is important, since the value of the products will want to be saved.

At the building demolition site a first step is to seperate reinforcement steel from concrete structures. Steel will be melted again for new purposes as recycled metal. Concrete will be prepared for reuse. Recycled concrete aggregates have a lot of possibilities. Some possibilities of recycling concrete are listed here:

- When demolished and crushed, former concrete elements can be used as a bed for new asphalt directly at the same location;
- Crushed concrete makes a good substitute for gravel, which can be used for example as subbase (bearing) and dividing layer for roads. Most of recycled concrete is used in earthworks: in pipe trenches, environmental construction, and in foundation and other building fillings;
- In some cases recycled concrete can be used as aggregate for new concrete instead of new aggregate, depending of the purpose;
- A paving material for example for walkways and driveways. Pavings will be permeable and promotes same kind of effect than open graded asphalt. Rainwater then goes trough the paving without causing runoff water;
- Larger parts of concrete can be used for controlling erosion in streambanks
- Properly crushed and well sorted concrete pieces can be used as river rocks and ground covers and mulch;
- Wire gabion fills, that are used as decorative or functional wall;

- Material for building new oceanic reef habitats: large pieces of concrete carefully positioned offshore can form the foundation for coral to build new reefs (Rodriguez, 2019).

The Netherlands is one of the most succesful countries in Europe in recycling construction and demolition waste (Eurostat, 2019). A dutch company called SmartCrushers offers a possibility to recover sand, gravel and cement from concrete. It makes it possible to create almost climate nerutal new concrete from concrete waste, and its technologies are under development that will make the concrete completely circular. A SlimBreken technique, developed by SmartCrusher takes in to account the fact that concrete is composed of very hard and strong sand and gravel and much weaker cement stone. The cement stone is therefor the only ground, the rest remains undamaged. The cement in old concrete has never fully hardened and can partly be recovered as new unused cement and immediately used to make new concrete. This results in a 100 % CO2 reduction (SmartCrucher BV, 2018).



(1) Making 1 kg of Portland cement from marl/limestone = 1 kg of CO_2. (5 Billions tons in 2017) (2) For concrete construction, roughly 3x as much CO_2 as all aircraft! (3) In all the concrete rubble is still roughly 50% new, reactive cement! (4) SmartCrushers free that new cement from concrete rubble and is immediately usable again. (5) The cement used (cement hydrate) is a CO_2-free marl / limestone substitute for the production of new cement or (6) to be worked up as a binder or mixture improver. (7) SmartCrushing: Without marl / limestone quarry; dust-free and without harmful emissions new cement and concrete. (8) Sand and gravel from SmartCrushers is directly on location and ensures better concrete with less cement! (9) SmartCrushing reduces roughly 2.5 billion tons of CO_2 per year. (10) Urban mining with SmartCrusher halves the cost of new concrete! (11) Worthless sludge by washing. (12) Large amounts of valuable sand and gravel with a lot of CO_2. (13) Downgrading as road foundation. (14) Worthless crushed sand. (15) Concrete granulate in concrete requires more cement.

Figure 1. Closing the Loop of concrete production industry (SmartCrusher BV, 2018)

Excavated material can be rock, stones, gravel, sand, clay, organic material and materials from previous constructions or industrial activities. Excavated soil and rock are used in 5 different ways in urban building: as 1) use on-site 2) use in other projects 3) pretreated before use in other projects 4) store for later use, 5) use as landfill cover or dispose at landfill. Meaning, everything that is dug for one project, it's doesn't necessarily go to use on-site or for landfills.

Generally, the knowledge about the quantities and fate of excavated soil and rock is low even though the amount of excavated soil is large. Reuse of excavated soil and rock has the potential to reduce climate impact. There is a need to evaluate management improvements and environmental gains. Estimating, quantities and quality of excavated soil and rock can facilitate recycling. There could be benefits from using excavated soil and rock as a construction material. Conclusions drawn are that there is little knowledge about the quantities and the fate of excavated soil and rock in urban areas. There is a need to evaluate the potential for an increased use of excavated soil and rock as construction material. Excavated soil and rock are often disposed at landfills and the recycling rate for high quality purposes is low, which leads to downcycling.

Soil is defined as: “the upper layer of earth in which plants grow, a black or dark brown material typically consisting of a mixture of organic remains, clay, and rock particles». Soil is important for building stabilization and for making materials like bricks and cement. Everything that is built is built on soil. Understanding the soil properties at the construction site is vital for a good outcome for the building that is being built.

Soil has many properties. For civil engineering the most important properties of soil are that the soil:

- has a **neutral PH**;
- is **stable** when it’s wet and when it dries off. This is to prevent cracks in roads;
- has enough **strength** to support the road/building that’s a top of it;
- has a **drainage effect** so water does not collect under or on the construction and corrodes it.

It is important to know the properties of the soil in a building area before you start building. If the soil is to be reused it’s important to know where it can be used, and what it can be used for. It is vital for the environment that soil finds new use in different projects, so it doesn’t have to be deposited in a landfill. To keep emissions down soil should be used locally.

Soil that has the right properties and is not contaminated, can be used on site. While contaminated soil, or soil without the right properties must be transported for treatment or to a different sight. Soil that has undergone treatment can be used again in a project where the soil has the suitable properties. Soil that is not contaminated but lacks the right properties can be used as fillings and drainage to lead water away from the building site.

Soil can be used in:

- fillings for landscape engineering;
- creating drainage at a building sight;
- used for farming purposes;
- used in civil constructions;
- used in cement and brick production.

2. Asphalt

The Netherlands has one of the most dense road networks in the world. More than 10 million tonnes of asphalt are laid each year, 80% of which is a replacement for old asphalt. Usually asphalt can only be recycled to be new asphalt.

It is often possible to use RAP (recycled asphalt planings) as a significant proportion of the aggregate input. As well as avoiding the use of virgin aggregate this also utilizes the bitumen on the reused stone. Use of such material is dependent on its availability, the type of processing plant and the performance (Carswell, et al; 2010)

A system called The HERA (Highly Ecological Recycling Asphalt) was developed by a Dutch construction company called VolkerWessels in collaboration with a Swiss company Ammann. The new system was taken to use and by that, the reuse of old asphalt increased to almost 100 percent. The systems allows the asphalt to be recycled three to five time more often than with the current method. An energyefficient drum used in this recycling process also emits fewer harmful gases than active production lines and does not cause olfactory nuisance. VolkerWessels is the first company using this system. It saves costs as well: heating costs are lower due to the reduvtion of energylosses and fewer raw materials are needed. With the current recycling system, only from 50 to 60 percent of the old ashalt is used. The rest is supplemented as sand, gravel and fillers. While usinf this new technology, one hundred percent recycled asphalt goes into the new recycling drum and only less than one percent of the mixture is rejuvenating liquid (VolkerWessels, 2019).

Additional references used in this appendix

Rodriguez, J. (2019). *Ways to Recycle and Reuse Concrete.* Retrieved from: https://www.thebalancesmb.com/recycling-concrete-how-and-where-to-reuse-old-concrete-844944

SmartCrucher BV (2018). *Concrete recycling.* Video retrieved from: https://www.slimbreker.nl/smartcrusher.html

VolkerWessels (2019). *Using 100% recycled asphalt at Schiphol business park reduces CO2 emissions by 75%.* Retrieved from: https://www.volkerwessels.com/en/news/

Appendix VI: Quantities infrastructure Griffiersveld

Figure 1. Borders of the district in black and blue districts are playgrounds. The green and red parts will be under renovation in 2021.

Concrete tiles/stones

I measured and weighed the concrete tiles and stones I took from the clerk's office. So that I could then calculate the density, and also the total weight of concrete.

Tiles: Volume: 0.3 x 0.3 x 0.065m = 0.00585 m^3

Weight: 13.25 kg

Density: 13.25 kg / 0.00585 m^3 = 2,265 kg/m^3

Stones: Volume: 0.105 x 0.21 x 0.08m = 0.001764 m^3

Weight: 4 kg

Density: 4 kg / 0.001764 m^3 = 2,268 kg/m^3

The densities of the products were surprising. It was expected that the densities between the products would differ more. It was assumed that the density would be 2270 kg/m^3 for both. Now that the density is clear, the total volume and mass can be calculated. Condition & Maintenance: by researching what has been done we have found out that the street can last for a maximum of 10 years at a good level (Apeldoorn, 2016).

Figure 2. The concrete tiles and bricks

Asphalt

It was discovered a little later that there is a small part of asphalt in the area. The measurements of asphalt turned out be approximately 128 m^2. The density of asphalt is on average 2500 kg/m^3.

Figure 3. The asphalt part in Griffiersveld

Sand

While the project group visited Griffiersveld, there was going on a construction of laying optical fibre. The workers said, that the thichness of the yellow sand was, 1.2 m. This also seems to be correct in the drawing where the water levels are, because numbers between 1150 and 1250 occur each time the sand track is constructed.


Figures 4 and 5. Laying of cable

Street well's

The wells in the street are most likely as old as your street itself, which is 43 years.


Figures 6 and 7. The wells in the area


Figures 6 and 7. The posts with and without reflection

Figure 10. Traffic signs

Figure 11. Big trees >6m

Figure 12. Tree's > 2m < 6m:

Figure 13. Small tree's < 2m:

:

Figure 14. Lampposts: **Figure 15.** Wastebaskets

Figure 16. Benches , OLD (77) **Figure 17 & 18** .Parking spaces NEW (4)

Figure 19. Electrical centre

Figure 20. Fire hydrant

Figures 21 to 23. Play equipment in three places:

Quantity					Qualities					
Category	Name product	Material	Quantity	Entity	Density (tons/m3)	Total mass (tons)	Total volume (m3)	Age (years)	Condition (1 t/m 10)	Maintenance (within ... years)
Concrete	Tiles	Concrete	850	m2	2,27	125,4175	55,25	43	3	10
	Stones	Concrete	3690	m2	2,27	670,104	295,2	43	3	10
	Bands	Concrete	-	m1	-	-	-	43	3	10
Baked products	-	-	-	-	-	-	-	-	-	-
Asphalt	Asphalt road	Asphalt	128	m2	2,5	32	12,8	-	6	20
Soil	Yellow sand	Soil	5448	m3	1,5	8172	5448	43	10	Unlimited
	Black Sand	Soil	???	m3	-	-	-	Unlimited	7,5	Unlimited
Metals	Street well small	Iron	46	units	-	-	-	43		10
	Street well big	Iron	16	units	-	-	-	43		10
	Traffic signs	Iron		units	-	-	-	-	9	35
Plastics	Reflector posts	Plastic	13	units	-	-	-	-		
	Posts	Plastic	14	units	-	-	-	-		
Green products	Big tree's > 6m	Wood	11	units	-	-	-	43		
	Tree's <6 >2m	Wood	10	units	-	-	-	25		
	Small tree's <2m	Wood	8	units	-	-	-	10		
	Bushes < 1,5m	-	-	m2	-	-	-	43		
	Grass	-	-	m2	-	-	-	-		
Other products	Lampposts	-	35	units	-	-	-	-		
	Wastebaskets	Iron	4	units	-	-	-	-		
	Benches		3	units	-	-	-	-		
	Parking spaces	Concrete	81	units	-	-	-	45		
	Electricity house		3	units	-	-	-	-		
	Fire hydrant		3		-	-	-	-		
	Play equipment		3	places	-	-	-	-		

Figure 24. Excel document with the Quantities:

Additional references used in this appendix

Gemeente Apeldoorn (2016). *Meerjaren onderhoudsplan wegen 2017 - 2019.* Retrieved from: https://apeldoorn.raadsinformatie.nl/document/3831480/1/03_-_Meerjaren_Onderhoudsplan_Wegen_2017-2019

Appendix VII: Results road scans

de Wegenscanners

We rijden, we scannen.We weten alles van:

de Wegen scanners

Status	***Concept***
Titel	**Verhardingskartering Griffiersveld**
Locaties	**Griffiersveld Apeldoorn**
Projectnummer	**2020-W-505**
Opdrachtgever	**Gemeente Apeldoorn**
Inloggegevens APP	***app.dewegenscanners.nl*** **Projectnummer: 2020-W-505** **Wachtwoord: daredo49**
Datum rapportage	**26 mei 2020**
Auteur(s)	**H.K. Lenting**
Collegiale toetsing	**W. Bouwmeester**
Datum uitvoering metingen	**7 april 2020**
Operator	**M. Abbink**
Gebruikte Meetsystemen	**IDS grondradar 400 MHz**
	IDS grondradar 2 GHz
	MS-4000 Gammaspectrometer
Positionering	**RTK-GPS met surveywiel**
Contact informatie	**www.dewegenscanners.nl**

Inhoud

1 Inleiding

In opdracht van gemeente Apeldoorn hebben de Wegenscanners een wegkartering uitgevoerd. Het doel van het onderzoek was het in kaart brengen van de verhardingsdikte, de funderingsdikte en de homogeniteit van de verharding. Het wegdek is gescand met twee grondradarsystemen om de dikte en de opbouw van de wegconstructie in kaart te brengen. Ook is de natuurlijke achtergrondstraling gemeten, wat informatie geeft over de gebruikte soorten steenslag.

Het onderzoek betreft de volgende wegen:

Weg	# lijnen	Grondradar (GPR)	Gamma-spectro-meter	Wegopbouw	Verhardings-samenstelling
Griffiersveld	4	ja	ja	ja	ja

2 Meting en gebruikte meetsystemen

De Wegenscanners onderzoeken de wegconstructie op een unieke, non-destructieve wijze. Onze meetbus is uitgerust met twee technische meetinstrumenten: de Ground Penetrating Radar (GPR) en de Gammaspectrometer.

De GPR meet de reflectie van radarstraling in de bodem. Bij het meten wordt een hoogfrequente radiopuls door de zendspoel uitgezonden en gereflecteerd op bepaalde lagen of objecten in de bodem, die andere elektromagnetische eigenschappen hebben dan de bodem eromheen.
De meting legt de looptijd van de radiopuls vast tussen het moment van uitzenden en het moment van ontvangst van een reflectie. De looptijd wordt bepaald door de diepte van het object waarop de reflectie plaatsvindt, waarbij de voortplantingssnelheid van de radargolf in de grond afhangt van de diëlectrische constante van het materiaal. De methode is enigszins vergelijkbaar met seismische metingen, waarbij een uitgezonden geluidsgolf weerkaatst op bodemlagen of objecten met verschillende dichtheden. Deze meting levert informatie over de *opbouw* van de weg. Het geeft bovendien schades onderin het asfalt weer of laat zien of er kabels en leidingen onder de weg voorkomen.

De Gammaspectrometer meet de (van nature voorkomende) radioactieve straling in het steenskelet van het asfalt en geeft daarmee informatie over de *samenstelling* van het wegdek. Bijvoorbeeld over gebruik van verschillende soorten steenslag. Deze gegevens laten een geschiedenisboek zien van de weg: verschillende momenten van aanleg en reparatievakken worden zo zichtbaar.

Alle gegevens samen creëren een compleet beeld van de weg, zowel horizontaal als verticaal. Hierdoor kan de weg in homogene delen worden ingedeeld. Binnen een homogeen wegvak is de variatie in asfaltdikte, funderingsdikte en steenslagtype beperkt. Hierdoor kunnen boringen op een efficiënte manier worden geplaatst.

Beide meetsystemen zijn op een meetbus gemonteerd in combinatie met een GPS voor de plaatsbepaling. Zo kon op normale rijsnelheid worden gemeten met zo min mogelijk overlast voor het normale verkeer. Figuur 1 is een foto van de meetopstelling.

Figuur 1: Scanner 1 is de sensor voor natuurlijke achtergrondstraling, scanner 2 is de grondradar voor het meten van onder andere de constructieopbouw.

3 Data interpretatie

Dit hoofdstuk beschrijft de manier waarop we ingemeten data op kantoor verwerken tot bruikbare informatie.

3.1 Dikte elementenverharding

Grondradar onderzoek aan de weg geeft veel informatie over variatie in opbouw van de verhardingsconstructie. Het resultaat van de metingen zijn zwart-wit plaatjes met laagovergangen, en verschillen in structuur van asfalt of fundering. Welke laag precies onderkant asfalt/elementenverharding is en welke laag de ligging van de fundering laat zien, wordt geïnterpreteerd en in de profielen getekend. Deze interpretatie gebeurt op basis van ervaring met eerdere onderzoeken, kennis over de specifieke weg (bijvoorbeeld kennis van een beheerder over de aanleghistorie) of met behulp van boringen.

Bij de analyse van de verschillende typen verharding maken we ook gebruik van de camerabeelden die we opnemen tijdens de meting. Met deze beelden van de bovenkant van ons meetsysteem en de onderliggende verharding, kunnen we terugzien op welke soort verharding de radarbeelden zijn opgenomen.

3.2 Straatlaagdikte

Onder de elementenverharding is meestal een straatlaag aanwezig. Om de straatlaag in de radarbeelden aan te kunnen geven moet deze enige dikte hebben. Bij een te dunne straatlaag is niets te zien doordat de reflectie van de onderkant van de verharding samenkomt met de reflectie van de onderkant van de straatlaag. Ook moet het gebruikte zand in dichtheid voldoende afwijken van het onderliggende materiaal om een reflectie in de grondradar te veroorzaken. Wanneer het zand van de straatlaag (bijna) dezelfde dichtheid heeft als zand daaronder is er geen dichtheidsverschil waar de grondradar op kan reflecteren. Op basis van de radarbeelden en ondergrondmodellen verwachten we dat de straatlaag en verharding op natuurlijke zandgrond zijn aangebracht.

3.3 Steenslagwaarde

De data van de gammaspectrometer wordt geanalyseerd naar een steenslagwaarde. Deze geeft een goede indicatie van de verschillen in steenslagtype die in de weg aanwezig zijn. Deze kaart noemen we ook wel de geschiedeniskaart van de weg. Omdat het verschillende aanlegvakken (door de tijd heen) weergeeft.

Toelichting steenslagwaarde
Waar de SSW op deze kaart voor een langer weggedeelte een geheel andere kleur heeft, betekent dit dat dit weggedeelte zeer waarschijnlijk ook een geheel andere opbouw heeft.

Wat kun je ermee
De steenslagwaarde van de weg geeft u een handvat om de weg beter te begrijpen. Met de kaart kan andere informatie zoals asfaltdikte, draagkracht, mengselsamenstellingen van de weg in een breder kader worden geplaatst. Gecombineerd met andere informatiebronnen (boren, visuele inspectie of VGD metingen) kan de weg veel beter begrepen worden.

Onze geschiedeniskaart van de weg hebben wij in verschillende projecten toegepast en gebruikt om inzicht te geven in de variatie in opbouw van de weg. In deze projecten hebben wij hierdoor bijvoorbeeld inzicht gegeven in:

- De ligging van aanlegvakken
- De indeling van wegvakonderdelen
- De aanwezigheid van (niet zichtbare) reparaties
- De aanwezigheid van slakken en assen
- De begrenzing van schades of specifieke constructies

De geschiedeniskaart geeft direct inzicht in welke wegen homogeen opgebouwd zijn en welke wegen een “ratjetoe” zijn. Een mooie toepassing is bijvoorbeeld om de weg in te delen in homogene wegvakken die dienen als basis voor het onderzoek volgens de CROW 210.

4 Resultaten

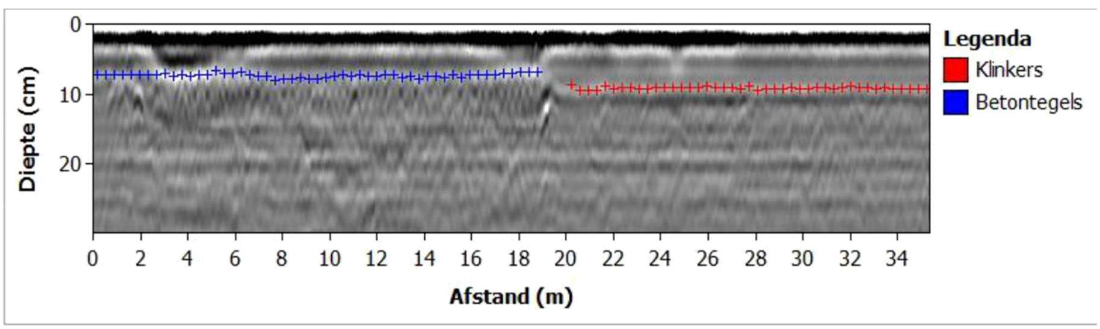
In dit hoofdstuk beschrijven we de resultaten van het onderzoek dat is uitgevoerd zoals beschreven in hoofdstuk 3.

4.1 Project specifieke uitgangspunten

In dit project is het van belang om verschillende typen elementenverharding van elkaar te onderscheiden. Onderscheid kan door de Wegenscanners worden gemaakt op basis van radarbeeld, camerabeeld en steenslagwaarde. Door de gegevens te combineren ontstaat uiteindelijk een compleet beeld van de variatie in elementenverharding.

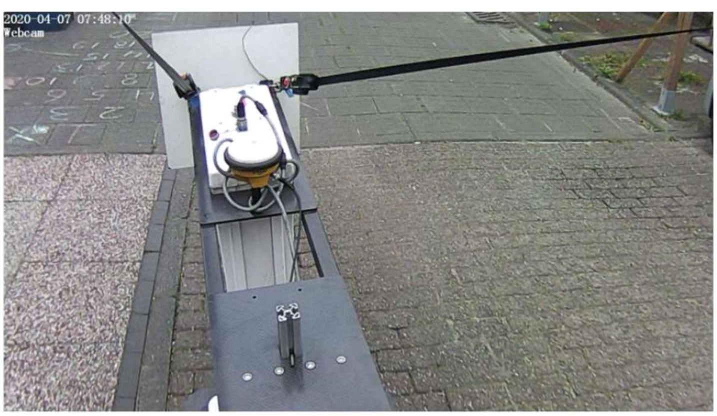
4.2 Dikte elementenverharding

Op basis van de radarbeelden zijn globaal twee typen verharding onderscheiden: klinkers en betontegels. De ligging van deze twee typen verharding is geplot op kaart 1. De dikte van de verharding is geplot op kaart 2. Een voorbeeld uit de radarbeelden waarin de verschillen tussen klinkers en betontegels te zien is, staat in Figuur 2.



Figuur 2: Voorbeeld verhardingsdikte in radarbeeld

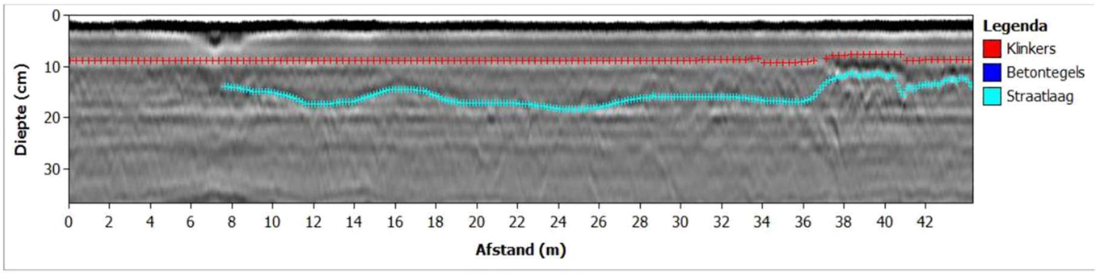
Wanneer de radarbeelden minder duidelijk zijn, kunnen we ook de overgangen tussen de klinkers en betontegels terugzien onze camerabeelden, zoals te zien in Figuur 3.



Figuur 3: Overgang verhardingstypen in camerabeelden

4.3 Straatlaagdikte

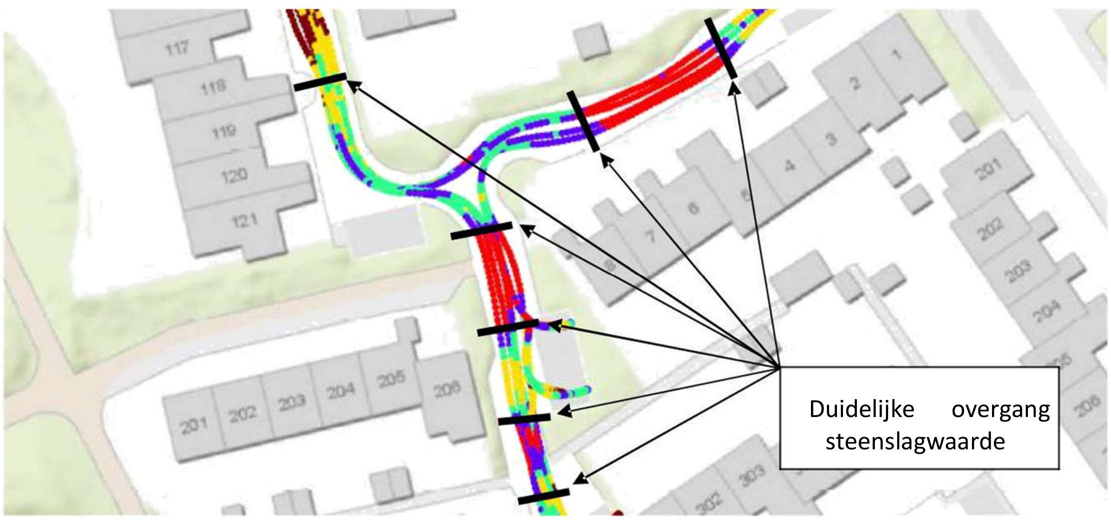
Zoals beschreven in hoofdstuk 3.2 kunnen we in sommige gevallen ook de straatlaag onder de verharding aangeven. Figuur 4 laat een voorbeeld zien van een straatlaag in de radarbeelden. De dikte van de straatlaag is berekend en geplot op kaart 3 in de bijlage bij dit rapport.



Figuur 4: Voorbeeld straatlaag in radarbeelden

4.4 Steenslagwaarde

Op kaart 4 in de bijlage zijn de berekende steenslagwaardes (SSW) geplot. Figuur 5 is een uitsnede van deze kaarten waarop enkele voorbeelden van duidelijke overgangen in steenslagwaarde zijn aangewezen. In dit figuur zijn duidelijke verschillen in de steenslagwaarde aangewezen.



Figuur 5: Uitsnede steenslagwaardekaart met aangewezen duidelijke overgangen

5 Visualisatie

Dit hoofdstuk beschrijft hoe we de data voor jullie inzichtelijk hebben gemaakt.

5.1 Kaartmateriaal

Zoals beschreven in het vorige hoofdstuk zijn alle onderdelen van het onderzoek apart op kaarten in de bijlage van dit rapport geplot. Deze kaarten zijn gemaakt door de aangegeven lagen uit onze software te exporteren naar ArcGIS. Hierin berekenen we vervolgens alle laagdiktes en geven we daar een kleurenschaal aan. Voor de wegvakken berekenen we hier ook de gemiddelde diktes in het vak, wat we vervolgens er bij plotten in een label.

5.2 De Wegenscanners Applicatie

De verwerkte data is ook geëxporteerd naar de DWS app. Dit is een webpagina/applicatie die kan draaien op een smartphone, tablet of pc.

De data is eenvoudig in te zien en kan ook in het veld goed gebruikt worden wanneer er een internet en GPS verbinding is. Deze gegevens kunnen worden bekeken via:

app.dewegenscanners.nl
Projectnummer: 2020-W-505
Wachtwoord: daredo49

De inloggegevens voor deze app staan ook op het titelblad van dit rapport.

5.3 Shapefiles

Voor dit project hebben we de data klaargemaakt om op te leveren als shapefiles. Dit doen we door de data te koppelen aan het juiste coördinatensysteem en het de juiste projectie te geven, in dit geval het Rijksdriehoek stelsel (m). Ook verwijderen we alle overbodige datavelden. Bij de shapefiles waar we een kleurenschaal voor hebben aangemaakt slaan we een .lyr bestand op, waarmee deze kleurenschaal opnieuw door jullie kan worden ingelezen.

De volgende shapefiles zijn bij dit rapport bijgevoegd:

Naam	Bevat	Inclusief .lyr bestand
Betontegels.shp	Ligging betontegels	Nee
Klinkers.shp	Ligging klinkerverharding	Nee
Verhardingsdikte.shp	De diktes van de verschillende typen elementenverharding in cm	Ja
Straatlaag.shp	De dikte van de straatlaag in cm. In de shape staat ook de straatlaagdiepte en gekoppelde verhardingsdikte	Ja
Steenslagwaarde.shp	De steenslagwaarde zoals beschreven in paragraaf 4.4	Ja

Meetlijnen.shp	De door ons ingemeten lijnen. In combinatie met de asfaltdikte of funderingsdikte bestanden kan hiermee worden nagegaan waar geen asfalt of fundering aanwezig is.	Nee

6 Aanbevelingen

De gemeente Apeldoorn heeft de Wegenscanners gevraagd om de verhardingen van het Griffiersveld in kaart te brengen in het kader van Cityloops.

Door het onderzoek met de grondradar en gammaspectrometer is de variatie in asfalt en constructieopbouw gebiedsdekkend in beeld gebracht. De geleverde informatie:

- Geeft u inzicht in de opbouw en status van de aanwezige verharding, daardoor kunt u de opbouw en de status van de weg beter begrijpen;
- Kunt u gebruiken om het vervolgonderzoek beter en gerichter uit te voeren.

6.1 Validatie

Dit hoofdstuk beschrijft onze algemene aanpak t.a.v. validatie. Het omschrijft waarom validatie soms nodig is en gaat vervolgens specifiek voor dit project in op de benodigde validatie.

6.1.1 Validatie in het algemeen

In de metingen van de grondradar kunnen verschillende laagovergangen en anomalieën worden aangegeven. De meeste laagovergangen en anomalieën kunnen met onze ervaring en wegbouwkundig inzicht goed worden verklaard en worden geduid als bijvoorbeeld de onderkant asfalt of de onderkant van de fundering. Deze duiding baseren wij echter op onze algemene kennis en het kan voorkomen dat er locatie specifieke lagen of schades voorkomen die afwijken van het gangbare. Ook kan het voorkomen dat de opbouw van de weg complexer is dan verwacht en dat er meerdere lagen onder het asfalt voorkomen zodat het bijvoorbeeld niet duidelijk is welke laagovergang de onderkant van de fundering is.

Wanneer locatie specifieke lagen of schades voorkomen die erg veel lijken op het gangbare, kunnen wij dat ook na analyse niet altijd aangeven. Om onzekerheden hierover te voorkomen bevelen wij aan om de resultaten te bespreken met een persoon met kennis over de weg of het gebied.

Wanneer de opbouw van de weg complexer is dan verwacht en als het niet duidelijk is hoe de verschillende lagen moeten worden geduid, is dat bekend na de analyse. In dit geval doen wij aanbevelingen voor boringen.

6.1.2 Validatie in dit project

In dit project verwachten we niet dat validatie van onze data nodig is.

6.2 Gebruik data

Diverse data is ingewonnen. Hieronder wordt per data type aanwijzingen gegeven hoe er met de data omgegaan kan worden.

6.2.1 Constructieopbouw

De informatie van de constructieopbouw (dikte asfalt, dikte fundering) verschaft inzicht in de aanwezige verhardingsopbouw. Aan de hand van dit inzicht kan een keuze worden gemaakt om delen van de opbouw te laten zitten of volledig op te breken. Tevens kunnen de te nemen (herstel)maatregelen aan de hand van de verhardingsopbouw beter bepaald worden.

De data kan worden gebruikt in samenhang met valgewichtdeflectiemetingen (VGD). In paragraaf 1.1.1 wordt een toelichting gegeven.

6.2.2 Steenslagwaarde

Hiermee wordt inzicht verkregen in de aanleggeschiedenis. Voor een uitvoerige beschrijving wordt verwezen naar hoofdstuk 4.4.

6.3 Extra informatie

Uit de data zijn nog meer aspecten te halen die bij kunnen dragen aan efficiënt wegbeheer. Dat kan alsnog gedaan worden, zonder extra metingen uit te voeren. Onderstaand enkele suggesties welke informatie alsnog uit de data te genereren is.

6.3.1 Bepalen hoeveelheden

We kunnen uit de data informatie genereren over de vrij te komen hoeveelheden asfalt en funderingsmateriaal. Dit doen we door op een aantal locaties de gemiddelde wegbreedte te bepalen (aan de hand van een digitale ondergrond) en vanuit de lengte de oppervlakte te bepalen. Vanuit de constructiediktes uit de analyse worden de hoeveelheden berekend.

7 Verklarende woordenlijst

Asfaltdikte
De dikte van het totale aaneengesloten asfaltpakket in centimeters.

Funderingsdikte
De dikte van de totale fundering in centimeters. Dit is de dikte exclusief egalisatiezand.

Steenslagwaarde (SSW)
De steenslagwaarde toont variaties in steenslagsamenstelling van de wegverharding. De SSW geeft een gemiddelde waarde van de bovenste 30 cm van de constructie.

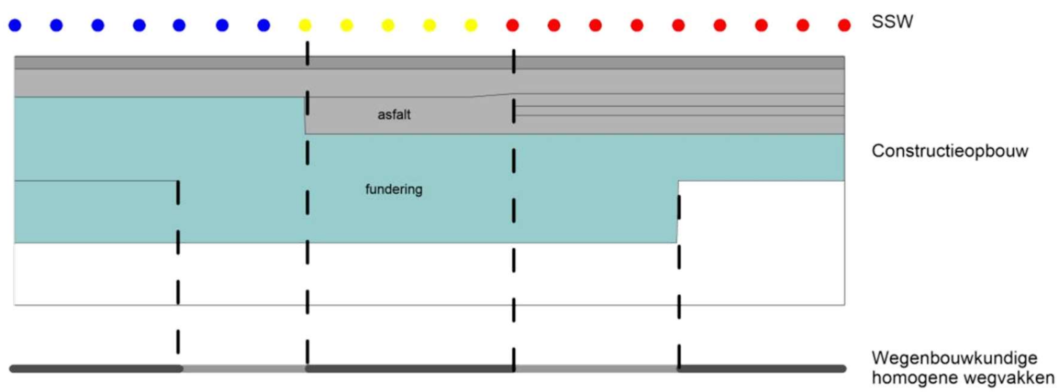
Deze waarde wordt gemeten met de gammaspectrometer. De waarde van de SSW is geijkt en kan tussen projecten worden vergeleken.

Gammaspectrometer
Sensor voor het meten van het type steenslag dat is gebruikt in de weg. De gammaspectrometer meet de natuurlijke achtergrondstraling die uit de weg komt. De metingen worden gerapporteerd in de steenslagwaarde (SSW). De gammaspectrometer is geijkt en de meetwaarden kunnen tussen projecten worden vergeleken.

Grondradar
Sensor voor het meten van de laagopbouw van de constructie.

Wegenbouwkundige homogene wegvakken
Wegenbouwkundige homogene wegvakken worden gemaakt op basis van constructieverschillen in het asfalt, de fundering en de samenstelling van de steenslag.

Constructieverschillen zijn bijvoorbeeld een andere laagopbouw van het asfalt of een andere laagopbouw van de fundering. Deze vakken worden per rijstrook gemaakt.

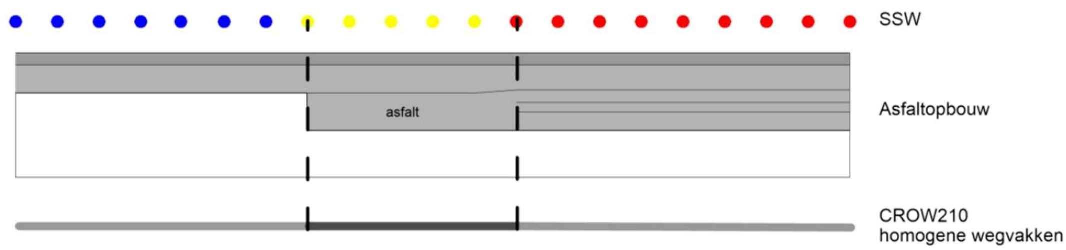


Figuur 6: Voorbeeld van een indeling in wegenbouwkundige homogene wegvakken.

Op projectniveau hebben de vakken een lengte van minimaal 20 m. Op netwerkniveau hebben de vakken een lengte van minimaal 50 m.

Homogene wegvakken volgens CROW 210

CROW 210 homogene wegvakken worden gemaakt op basis van constructieverschillen in het asfalt en in samenstelling van de steenslag. Deze vakken worden per rijstrook gemaakt. Het doel is een weergave van de milieukundige geschiedenis van de weg. Deze vakken kunnen worden gebruikt om een efficiënt boorplan te maken om de teerhoudendheid te bepalen.



Figuur 7: Voorbeeld van een indeling in homogene wegvakken voor CROW 210.

Op zowel projectniveau als netwerkniveau hebben de vakken een oppervlak van minimaal 500 m^2.

Verbrijzeling van het asfalt

Verbrijzeling van het asfalt is het uiteenvallen van de onderkant van het asfalt. Dit verbrijzelde asfalt vermengt zich met funderingsmateriaal.

Door deze vermenging is de overgang van het asfalt naar de fundering in de radarbeelden geen harde lijn. In deze gevallen wordt de onderkant van het zichtbaar nog goede asfalt vastgesteld als onderkant asfalt.

Scheurvorming

Scheurvorming wordt aangegeven wanneer in de radarbeelden afwijkende patronen te zien zijn die kunnen duiden op het voorkomen van scheuren in het asfalt. Het voorkomen van zones van scheurvorming wordt of per wegvak of op een aparte kaart aangegeven.

Onthechting

Onthechting is het van elkaar loslaten van twee op elkaar liggende asfaltlagen. In de radarbeelden zijn afwijkende patronen te zien die kunnen duiden op het voorkomen van onthechting in het asfalt. De aanwezigheid van zones met deze afwijkende patronen wordt of per wegvak of op een aparte kaart aangegeven.

Figure 7 Here you can be seen the different types of stone in the Griffiersveld. On the red line can be seen the concrete bricks, on the green line the concrete tiles.

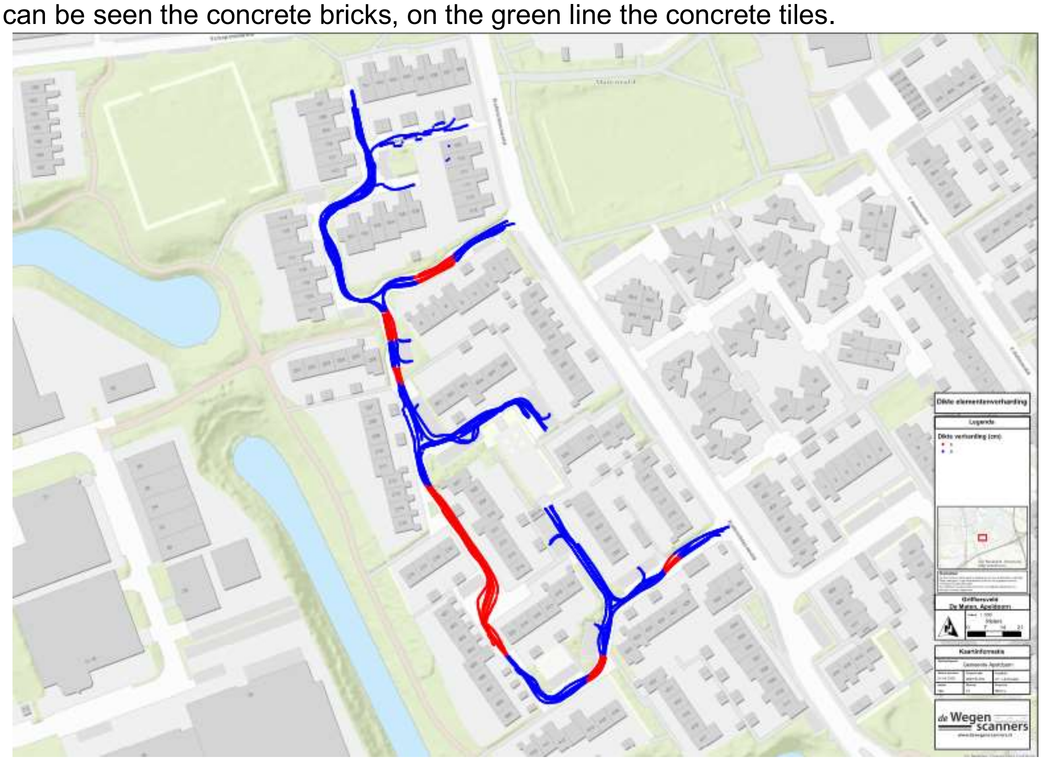


Figure 8. The scan clearly shows the difference between the concrete tiles and concrete bricks in the way. Here can be seen the different thicknesses blue (concrete clinkers 8cm), red (concrete tiles 6cm).

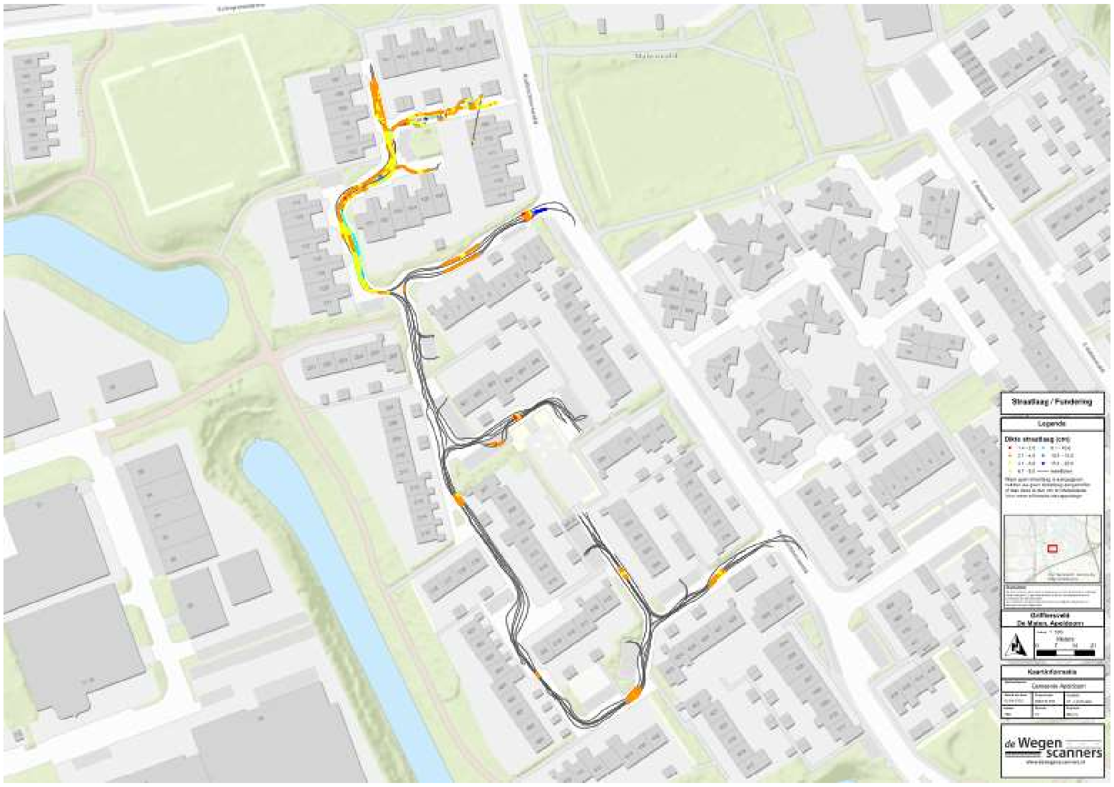


Figure 9. Here can be seen the thickness of the street layer, this is a very striking drawing because there are only a few small coloured spots in the lower part. However, it is good to see that in the upper part the foundation is a bit thicker. This upper part is built just a bit later than the lower part. Most likely a much thicker layer of yellow sand was used. This is why the scanning equipment is used. The small spots in the rest of the street are the thresholds and here and there some repairs of the road surface where a thicker layer of yellow sand was used during the repair.

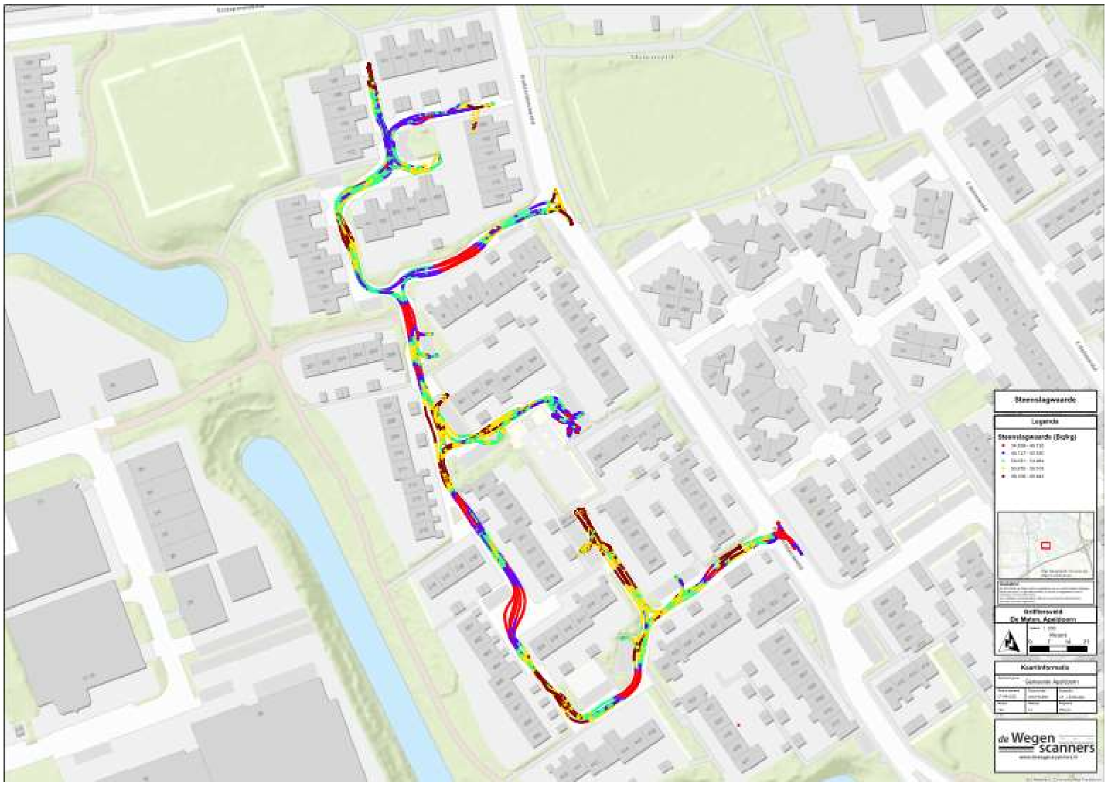


Figure 10. This figure shows the crushed stone value. The crushed rock value measures the level of radioactivity at the roadside. Where the crushed rock value on the map has a completely different colour for a longer road section, this means that this road section very probably also has a completely different structure. Again, the difference between the concrete tiles and stones is clearly visible. However, it is striking that the gravel value for the concrete tiles is the same (red). Then you would expect that the concrete bricks also have about 1 colour. However, this is not at all the case and the colours are mixed. The composition of the types of concrete bricks differs a lot. This is actually not reflected in practice. Explanations for this are that there are probably different types of bricks because several producers may have been called in. It is also probably true that in the 70's it was still a bit of a mess in terms of production of the concrete bricks. In short, all kinds of cement, sand and gravel were mixed in as long as it was as cheap as possible. Furthermore, it is very difficult to really get connections out of it.

Appendix VIII: Designing a depot

1. Introduction

Mixed wastes in Apeldoorn is today brought to a company called Attero. Attero is a recycling company that recycles mixed materials. Attero has no locations in Apeldoorn, so this means that CDW that is generated now is being transported out of Apeldoorn to a different treatment facility. Therefor a way of treating CDW in Apeldoorn should be considered (Attero,2020).

Apeldoorn wants to have control of the materials within the municipality. By having their own material depot, they can better control where the materials are being sold and re-used. In short, Apeldoorn wants to become a supplier of materials and do not wish to be sellers. They want to help show material users what materials are present in the depot by having a digital material bank. The idea is then that the users of materials buys these materials from Apeldoorn. Apeldoorn also gets the ability to know what materials they have to use in civil projects, etc. By having a municipal owned material bank Apeldoorn can plan their future projects with respect to what materials they already have present at the depot.

When designing a material bank there are different steps that need to be considered. When a municipality in Romania wanted to design a material depot these steps below were vital to follow so that they could get a positive outcome. The design notes here will focus on the selection of the locations, and an area plan for the locations chosen.

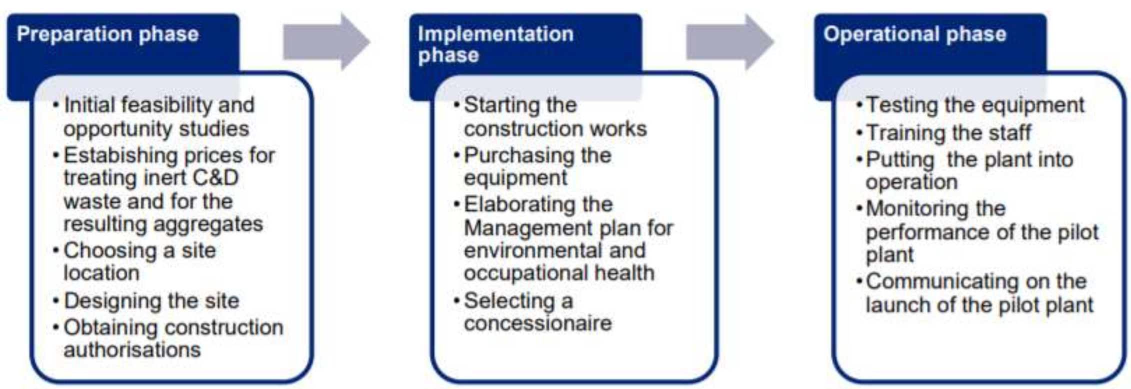


Figure 1: Three phases for making a successful depot (Deloitte, 2016).

2. Locations in Apeldoorn

Apeldoorn gave two different locations that they want to use for a circular depot.

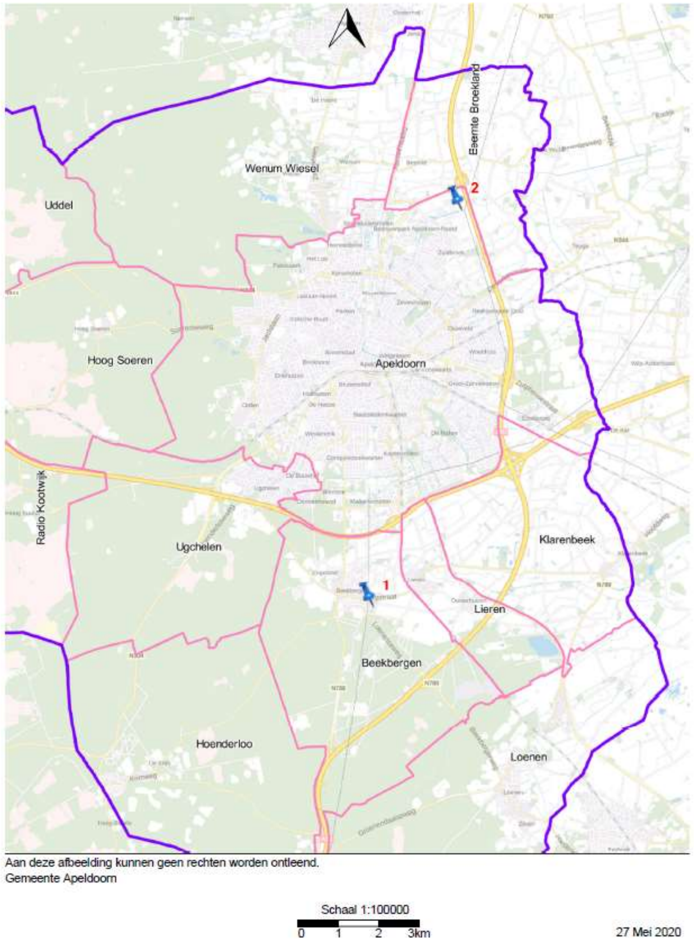


Figure 2. Map of possible areas for the depot as indicated by the municipality of Apeldoorn.

Location 1

Measured area: 3800 m^2.

Distance from construction site: 5.7 km (shortest distance)

Location 1 is situated in the area of Beekbergen. There is already a depot made on site and it is surrounded by trees, farmland and residential houses. The closest residential buildings are 24.85 m away. The area on the way to the depot is rural and not so wide. Some of the houses are situated very close to the depot, and for them the sound produced by the increased traffic might be too much for the residents. Measured using google maps to be about 4.4 m. A standard lorry is about 2,5meters wide. (Smithsbletchington, 2016) This may be a problem for heavy and wide lorries in the future, as it may clog up the road.


Figure 3: Depot present at location one.

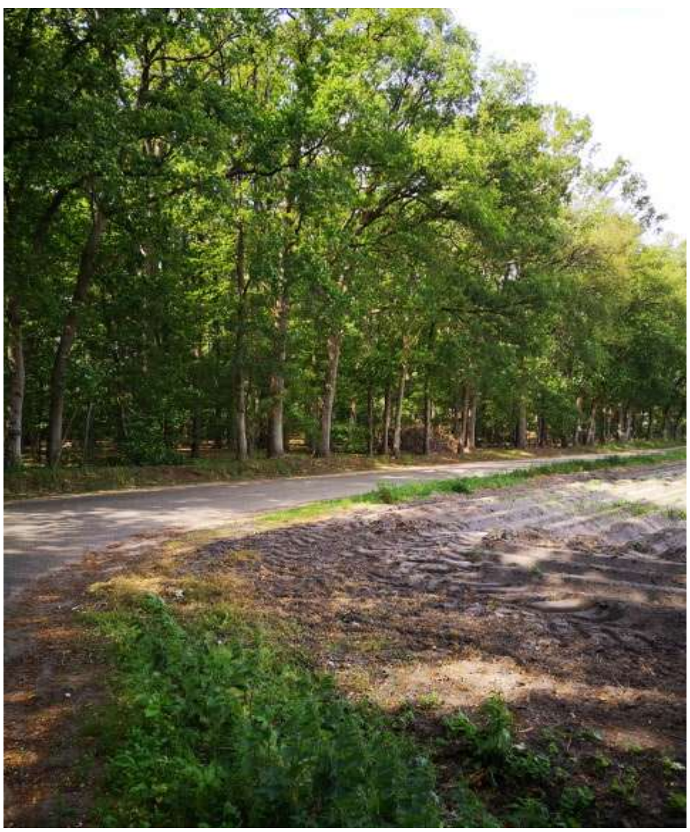


Figure 4. The forest around the location and the road

Figure 5. Overview of the Area provided by the municipality

The good thing about location one is that it is already a depot on the site. As well as the location is quite close to the construction site. However, there are some bad things about the location is that trucks would have to drive a lot through residential areas before they arrive at the depot with the materials. The size of the area, and the forest around does not give a lot of flexibility for the depot to expand if the municipality needs more space in the future.

Location 2

Measured area: 10204.146 m ^{2}

Distance from construction site: 7,6 km (shortest way possible)

The second location given to the project team from the municipality of Apeldoorn is situated in Laan van Zodiak. The area already has a soil bank and a depot for concrete and is next to a solar park. The closest residential area is about 68 m away. (measured from the end of the possible depot to the closest point of the residential area)

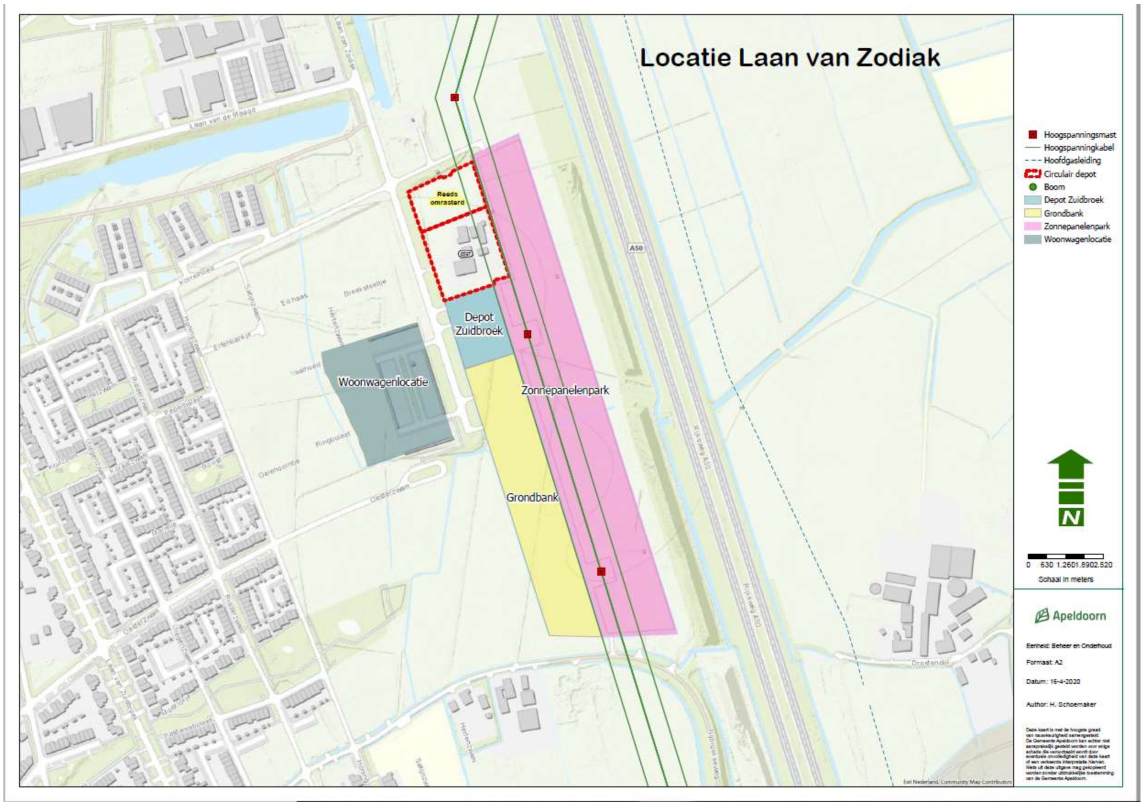


Figure 6. The area around site two. (Apeldoorn, 2020)

The area has good connections to the highway, as well as many other large roads in Apeldoorn. The road into the area is about 7,62meteres wide (measured using google maps). On the site there is some houses which will need to be torn down for the depot. Overall the area is fitting for a material bank.

Figure 7. Location number two. (Google Street View, 2017)

Next to site 2 the soil bank in Apeldoorn is situated. The area is approximately 18238 m^2.

Figure 8. Soil stored at the soil bank.

The soil bank is large and expandable, and the end of the location is to the end of the solar panels.

Figure 9. Taken from within the soil bank and shows the edge of the soil bank.

3. Transport emissions different sites

Site 1 is 5.7 km away from the construction site

Site 2 and the soil bank is 7.6 km away from the construction site

A calculator has been made to calculate the emissions of transporting the materials from the site to the depot. The local re-use is the storage facility for the materials that will be used as whole. And the end deposit is for the crushed materials. We already know the quantities present from the 3D Scan done. The re-use percentage is the amount of materials that will go to the storage facility for re-using. To give a clear picture four different scenarios are being calculated. The calculations were done using the emission calculator in **Appendix IX.** When (1) 0%, (2) 33%, (3) 66% and (4)100% is brought for reuse. A recycling company wants to crush all materials and will have a re-use factor of 0%. While the goal of circularity is that 100% goes to site 1.

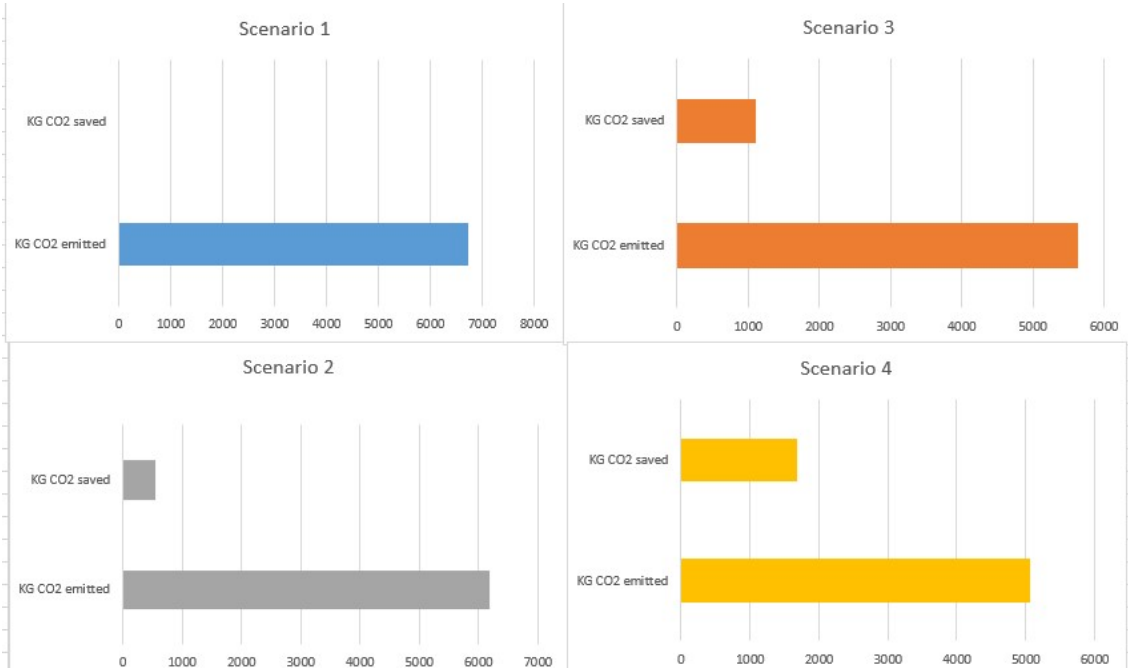


Figure 10. CO_2 emitted in the different scenarios.

In Scenario 1 no CO_2 is saved on transporting materials to location 1. The CO_2 saved is using scenario 1 as a reference. Scenario 2, 3 and 4, where 4 is the goal of circularity one also saves the most CO_2 by transporting the materials to a local re-using site. Here the re-use site is the material bank at location 1, and the end depot is the treatment facility at location 2.

4. Materials flows different locations

Both locations are suitable for a material bank. Location one already has a depot developed on site. With some indoor facilities available. The total area measured is 3800 m^2. While the storage area measured inside is about 800 m^2.

Location 1 is favourable for materials that is going to be re-used as whole, and only needs storage for max 1 year. As there is storage space already made indoors. Especially when we also consider that some of the materials that is present also hasn't all the qualities required to be re-used as whole and will hence be crushed.

The main concern with location 1 that would need to be addressed is that the roads to the depot is quite small and is not suitable for large vehicles. As well as many vehicles would need to drive though small roads in residential areas. The noise and extra traffic created would be disturbing for the area as there are some houses close to the site.

Location 2 is the favourable option for materials that will be crushed. The area already has the infrastructure needed to support the increased traffic a depot would create. Due to the large size it can expand in the future which makes it more versatile than site 1.

Figure 11. The flow of materials to the different sites.

The grading scale for the matrix under is divided into: Poor, Sufficient and good. (P, S, G) and P=1, S=3, G=5. To illustrate the main differences between the sites a grading scheme was made. The grades are given following the impressions gained while visiting both the sites.

	Site 1	Site 2
Infrastructure	P	G
Nearby area	S	S
Expandability	P	G
Infrastructure on site	G	P
Distance to area	G	S
Overall suitability	**15**	**17**

Table 1. A trade-off matrix between the different sites.

In the construction industry one deals with a lot of different materials, often mixed with each other. The properties and composition of the materials coming from the construction site dictates how complex a sorting and treatment system has to be. Accepting a mixed stream of materials requires a more specialized and sophisticated type of machinery, while having a homogeneous stream of materials coming in would require less complex type of machinery. (Galán, Viguri, Cifrian, Dosal, Anders, 2019)

A material bank for the municipality of Apeldoorn should only focus on the mixed Petrous flow as that is the most relevant for the construction industry. Mixed Metals and Mixed Urban Wastes should be sent to a recycling group with a treatment facility for these types of materials. These would be too complex for the material bank to be able to recycle for further re-use.

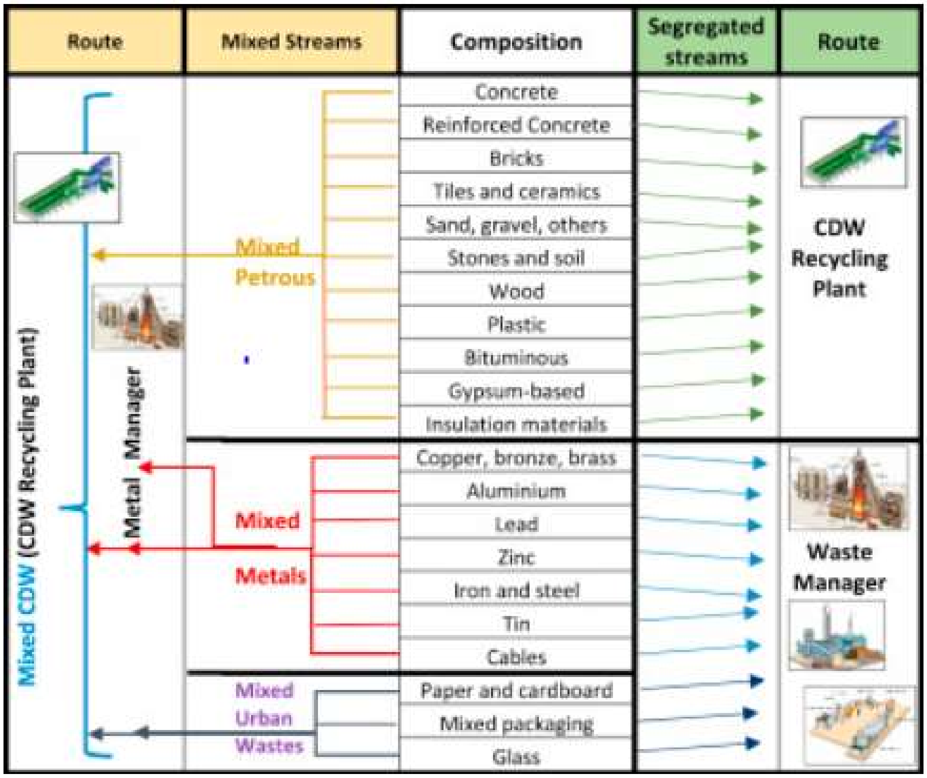


Table 2. Multiple flows of different types of CDW before re-use (Galán et al, 2019).

One of the problems of taking CDW to a recycling plant usually leads to that the client will have to pay for the materials to be treated, and then buy the recycled materials back. In the case of Apeldoorn, we want to avoid this. This means that Apeldoorn will have to have machinery that can crush materials so the municipality can keep the materials as long as possible.

Apeldoorn wants to focus on inert waste. Inert waste is classified as waste that isn't degradable and isn't chemically degrading over time. (EC, 2009). The material bank should therefore only deal with inert waste. Waste that isn't classified as inert by the European commission should be sent to recycling companies.

This means that the material bank for Apeldoorn should be able to receive 8 different kinds of materials from various construction projects. This would allow the municipality to handle materials coming from both private contractors and from the municipal projects. Example if a private contractor in Apeldoorn demolishes a building it can then bring the CDW to the material bank where another contractor for example might need that type of material. By doing this the material bank becomes a hub and Apeldoorn can be a supplier of needed materials within its border.

There are other materials that could occasionally come in. These are for example light posts, trees and sewage and other metal pipes. The material bank should only accept these materials if they can be re-used as whole. If these materials can't be re-used, they should be sent to a recycling company as shown in Table 2.

Category	Name product	Material	Quantity	Entity
Concrete	Tiles	Concrete	850	m2
	Stones	Concrete	3690	m2
	Bands	Concrete	-	m1
Baked products	-	-	-	-
Asphalt	Asphalt road	Asphalt	128	m2
Soil	Yellow sand	Soil	5448	m3
	Black Sand	Soil	???	m3
Road furnitere	Street well small	Metal	46	units
	Street well big	Metal	16	units
	Traffic signs	Metal		units
Plastics	Reflector posts	Plastic	13	units
	Posts	Plastic	14	units
Green products	Big tree's > 6m	Wood	11	units
	Tree's <6 >2m	Wood	10	units
	Small tree's <2m	Wood	8	units
	Bushes < 1,5m	-	-	m2
	Grass	-	-	m2
Other products	Lampposts	-	35	units
	Wastebaskets	Iron	4	units
	Benches		3	units
	Parking spaces	Concrete	81	units
	Electricity house		3	units
	Fire hydrant		3	
	Play equipment		3	places

Table 3. Materials in the test area.

Table 3 shows what types of material are present within the test area, with the main category stated as well as sub categories. One can make the assumption that the different materials present in de maten also is applicable to other streets in the Netherland and especially within the municipiality. It is good to take these different types of materials into consideration when dimensioning the material bank. All the trucks coming into the material bank should be weighed when they come in and then when they leave after they have dropped of their load. This is to note the quantities of materials stored in the different sites to the digital material bank.

Table 4 shows the different pure material streams that are coming in, and which might also need to go to location 2 for crushing.

Material	Can it be re-used as whole? (No crushing)	Can it be crushed?
Asphalt	No	Yes
Concrete (tiles)	Yes	Yes
Stone	Yes	Yes
Bricks	Yes	Yes
Wood	Yes	Yes
Soil	Yes	No
Trees	Yes	No
Sewage pipes, lampposts etc	Yes	No
Product of crushed materials (aggregates)	X	x
Total amount	X	x

5. Separation of materials

Having pure streams of materials makes it easier for the municipality to reuse materials as whole. A way of sorting the materials into different categories is needed. There are many different companies specializing in separation of inert waste like CDW. Having a good sorting process increases the recyclability's of the materials.

A way of separating materials is to use manual labour. This takes time, and limits how efficient the separation process might be. Manual labour also reduces the amount of pure materials that is extracted from the mix of materials that come is. This reduces the purity of materials, which then reduces the value of the output material.

A Finnish company called Zen Robotics have developed a robot arm that sorts mixed materials. By doing this Mixed waste is separated from each other to different pure fractions. The process starts with an excavator sorting out the mixed waste and separating the largest pieces. The materials are then sent into a screener which separates the solid waste from the fine waste like soil, sand etc. The waste is then spread on a belt in a monolayer, so the waste isn't overlapping. It is then screened by sensors and picked up by a robot arm. One robot arm can sort 4 fractions at the same time, and two robot arms increases this to 8. Materials are separated into different pure fractions. The advantage of this is that the materials coming in has a higher purity factor. The investment costs are high, however the efficiency and increasing purity makes it worth. This allows the municipality to spend less money on de selective demolition on site and can send a mixed flow of materials to the depot. The separate materials are then moved and stored in separated storage units (Deloitte, 2016).

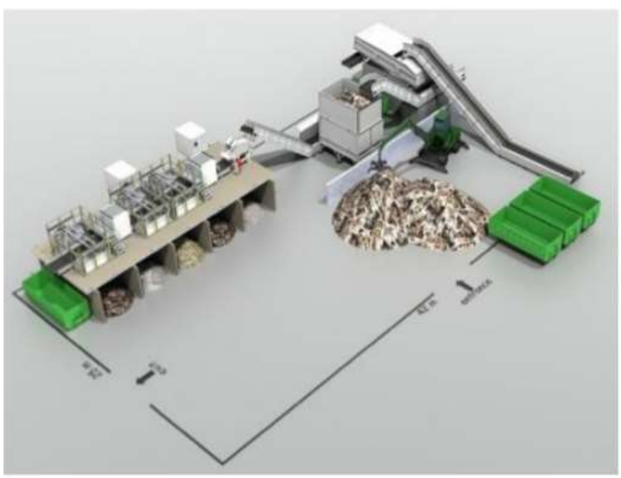


Figure 12. Zen Robotic sorting system

The space required for a robotic separation system is about 1000 m^2. The investment costs are around 600 to 800 k€ (Deloitte, 2016). The municipality should invest in such machinery due to the fact that it increased the value of the materials in the material bank. Having pure materials would also make it easier to match for different projects as one easily can categorize the different qualities of the materials. A sorter also weighs and categorizes the materials in the material bank. By doing this the municipality always have an accurate reading on how much materials are present. This increases the awareness of what is present and available. For example, it can count how many bricks, and their weight. It can then communicate this to the digital material bank. It is not necessary to get a machine like this in the beginning. In the future however it is important to keep in mind that a machine like that could be useful if the flows of materials increases and the labour required for the depot becomes large.

A robotic sorter can help to automate the facility for the future. The sorter can, by using AI technology sort the different materials coming into the storage facility and then send the materials that is predefined as re-usable as whole to a storage unit. It can also pick out materials that is not good enough for re-using and then mark it for crushing. This increases efficiency and purity of the materials in the facility and lets it operate 24/7.

Other different options are magnetic separators, air sorters and manual labour. However, these are not as accurate as a modern robotic sorter.

By having pure materials, one prevents downcycling as having sorted materials makes it easy to re-use. If the municipality does not wish to invest in such machinery, the roads within the municipality should be demolished with selective demolition to receive a flow of as pure as possible materials in.

For the testing phase it is recommended that the facility on location 1 accepts mono streams of materials, and then manually place them within the depot. For the future however Apeldoorn should consider investing in a more advanced machinery.

6. Treatment of materials

The idea of treating materials is to make the depot more flexible for supply and demand. By treating materials, the focus does no lay on polluted masses, but whole masses that either aren't good enough to be re-used as whole or for materials that is not needed in the near future. The municipality will know through GBI what projects they have in the future, and by that know what type of materials is needed. For example, if the municipality has a road renewing project in a year and need 300 tons of bricks they can store bricks from different projects in the depot until the new project needs the materials. If the depot then has 400 tons of bricks stored and needs aggregates, it can then crush the amount of excess bricks into aggregates and then also use that in a different project. By having this possibility, they reduce waste by reusing materials and reduced the need of virgin materials.

In Romania a treatment plant for CDW was constructed in 2015. Here materials were crushed into aggregates. The focus mostly laid on the re-use of concrete bricks and concrete tiles. The process in the depot is as follows: the materials are first weighed and then stored. An excavator brings the materials into a crusher which then crushes the materials into aggregates.

Figure 13. A concrete crusher at a depot in Romania. Here a dumper is being used to transport the bricks into the crusher. (Deloitte, 2016)

A soil bank in Finland is using the same principles as a material bank would serve in the municipality uses a crusher to crush concrete. Crushed materials will then be used as aggregates in municipal road projects (Myllymäki, 2020). Having a crusher available at the material bank is good as one can crush materials or re-use them as whole depending on the supply and demand. This gives more flexibility when you have materials that can't be re-used within the time frame the municipality sets.

A crusher does not necessarily have to be big. As the goal of the material bank is to facilitate so that materials can be re-used as whole a crusher should only be used on materials that either is not needed within a certain time period, or if the demand on aggregates is very high. There are many crushers on the market. As the goal of Apeldoorn is to keep the materials at their disposal as long as possible. For this purpose, a small mobile crusher is all that is needed. For example:

Figure 14. A mobile crusher. (ZB Group, 2020)

7. Area required

All the materials present in Apeldoorn could be stored outside. Location 1 will handle the whole materials. The depot already has sufficient space to store the whole materials. The indoor units have a total storage capacity of 800 m^2. To sort the different materials into the eight different defined materials it is recommended to start with manual labour during the taste phase. Materials that are then not suitable should then be sent to location two for crushing.

Figure 15. How materials are stored as whole

Calculations		
In the Griffiersveld area, the renovation includes replacing 3690m2 of concrete slabs, rebuilding 850m2 concrete tiles		
	TILES	BRICKS
Dimensions [mm]	300*300	105*210
A [m2]	850	3690
ρ [kg/m3]	2270	2270
A, one [m2]	0.09	0.02205
h, one [m]	0.065	0.08
V, one [m3]	0.00585	0.001764
Amount	9444.444444	167346.9388
V, all [m3]	55.25	295.2
m,one [kg]	13.2795	4.00428
m, all [tons]	125.4175	670.104
Area calculation		
1 Area (Lenght x width) [m2]	10	10
		100
Amount that fits one area	1111.111111	4535.147392
Amount of layers	10	15
Height of layers [m]	0.65	1.2
Amount in 1 layer	944.4444444	11156.46259
Area when piled [m2]	85	246
Area needed for these materials [m2]		331

	Area 1	Area 2
Area	3800	10204.14

Area planning			
Section	Size	Amount	
Roads:	200	2	
Unloading area	200	1	
Storage area, inside	100	0	
Storage area, outside	100	10	
Crusher?:	200	1	
Office:	25	2	
Other	100	1	m2
	Total area	1950	

Other space can consist of space for own machinery, social rooms etc
Inside: Doesn't have to be a warmed area, but with floor and roof in 10x10 areas
Outside: Crushed concrete and asphalt in 10x10 areas

Figure 16. Area calculations

To store all of the materials 331 m^2 is needed. For the materials present in Apeldoorn we need 85 m^2 of storage for the slabs. The brick needs 246 m^2 of storage. Therefore, it is decided that 10 m *10 m sections of materials are used to store the materials. To store all the bricks at one place a storage area of 25 m * 10 m is needed and should be used. The whole materials should be stacked to the best of the ability. It is therefore recommended to have a pure material stream in so that one can stack the whole materials based on qualities. The depot developed at site one has more than enough capacity to store all the materials from the test area. The area at site two is also dimensioned to handle the entire volume generated from the test area. Site one already has 800 m^2 of storage space developed and there has enough capacity to store all the materials coming from the test area if all the materials are deemed fit enough to be re-used as whole. Based on the materials coming in an outdoor facility is more than good enough. As there is already a facility with indoor storage, Apeldoorn should use those, as it gives some sort of protection to the materials from the environment.

Figure 17. A Depot in Apeldoorn.

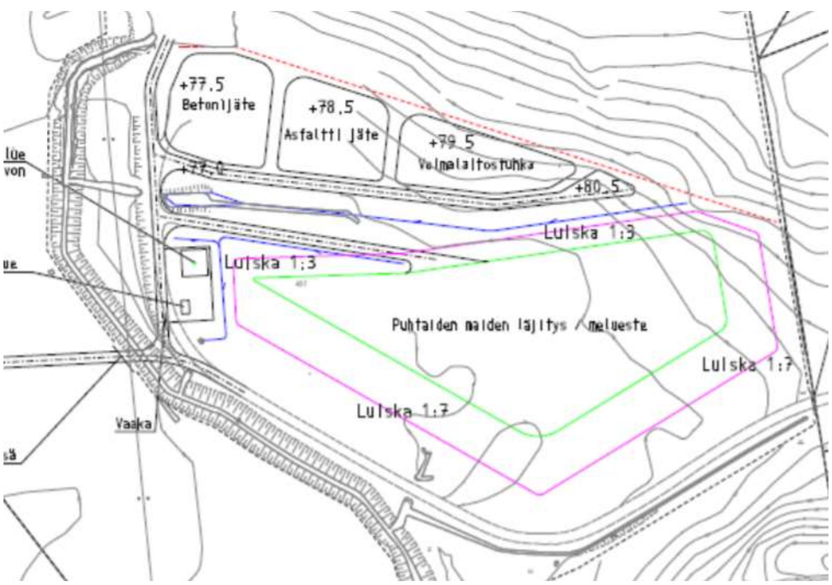


Figure 18. The area plan from a Finnish soil bank. (Susanna Myllymäki, 2020)

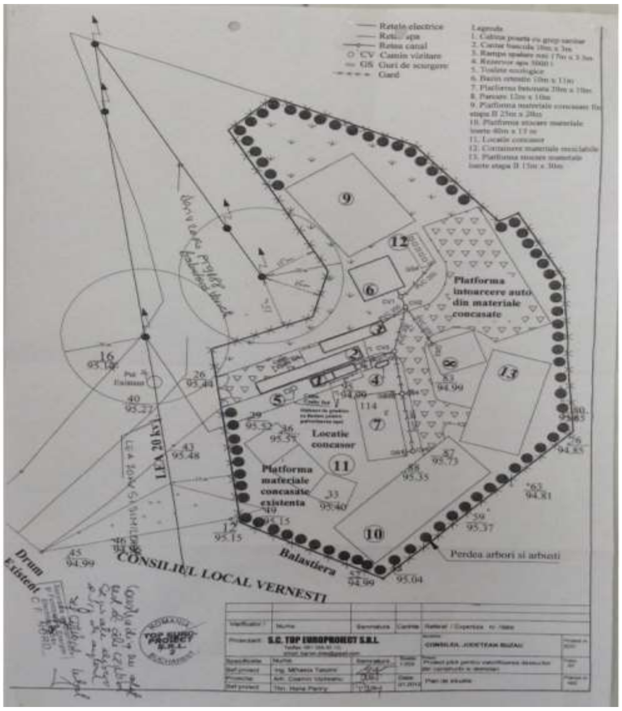


Figure 19. The area plan from a Romanian treatment plant. (Deloitte, 2016)

Figure 20. How soil is stored at the soil depot in Apeldoorn.

Soil will go to the soil bank that already is in Apeldoorn. It will be separated from the materials that will be crushed and will enter location two at a separate entrance. In total there is 5448m3 of soil present in the test area. Worst case scenario one will need to move all of the soil, however that is not very likely. Soil will be separated at site two based on its properties into three different piles. In Apeldoorn the soil present is mainly a sandy type of soil. All soil can be stored outside. We have that the volume is 5448m3 of soil. We assume that most of the soil can be re-used again and won't be touched. The soil that is moved will move to the soil bank and will be stored there according to its properties. Soil should be separated as it is being done in the Finnish material bank. Having a separate way of delivering soil is more efficient, as one can have two different flows within the material bank. The soil can be delivered to a site next to the depot, with its own entrance. The soil should be separated based on its characterization and its soil type. There are many types of soil, and one should take that into account for when storing the sand. For example, one pile of sandy soil, clay and loamy soil. (Boughton, 2020)

To summarize we need 331 m^2 of storage at location one to be able to facilitate all the materials that are coming from the construction site. Since there also is a depot there it is nothing that needs to be done to get it ready as a depot. It will need a weight to weigh the truckload with materials that comes in so one knows the quantity.

Location two should be dimensioned to have 331 m^2 of storage for aggregates, pre storage as well as space for a crusher. As well as space for offices, roads and a weight. Worst case Scenario all the materials will be crushed. Site two should be a complete outdoor facility, only including an office.

8. Design sketches material banks

For site 1 an AutoCAD file was provided of the already made depot. This has been converted into Revit and made into a 3D model for the municipality. Due to the lack of specific data like height and what materials the different buildings are made off some assumptions have been made. The total area that can be built on is 3858 m^2.

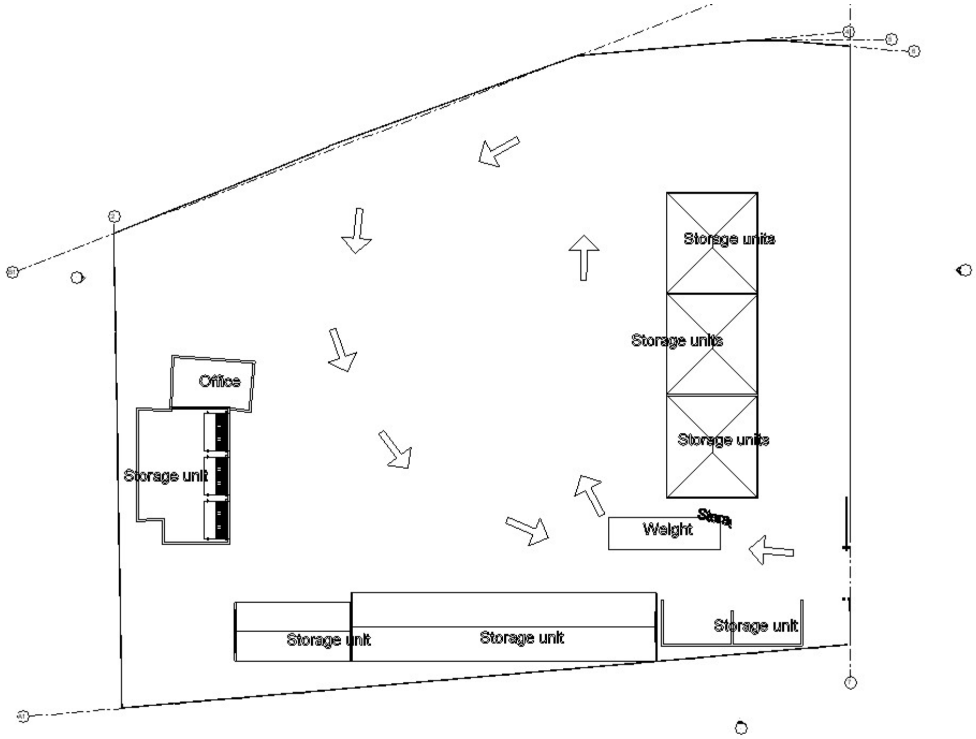


Figure 21. The area plan of site 1

The storage units on the right-hand site is each on 104 m^2, which in total gives us the storage capacity of 312 m^2. On the bottom right hand side there is an outdoor storage unit with the storage capacity of 69 m^2. The building next to it only has a roof, and the total storage capacity is 318 m^2. On the left-hand side there is a storage building and an office. The office is on 44 m^2 and the storage unit connected to is on 129 m^2. In total the storage capacity that is already available is about 828 m^2. The total area of the site is 2850 m^2.

Figure 22. 3D Model of how site one looks like.

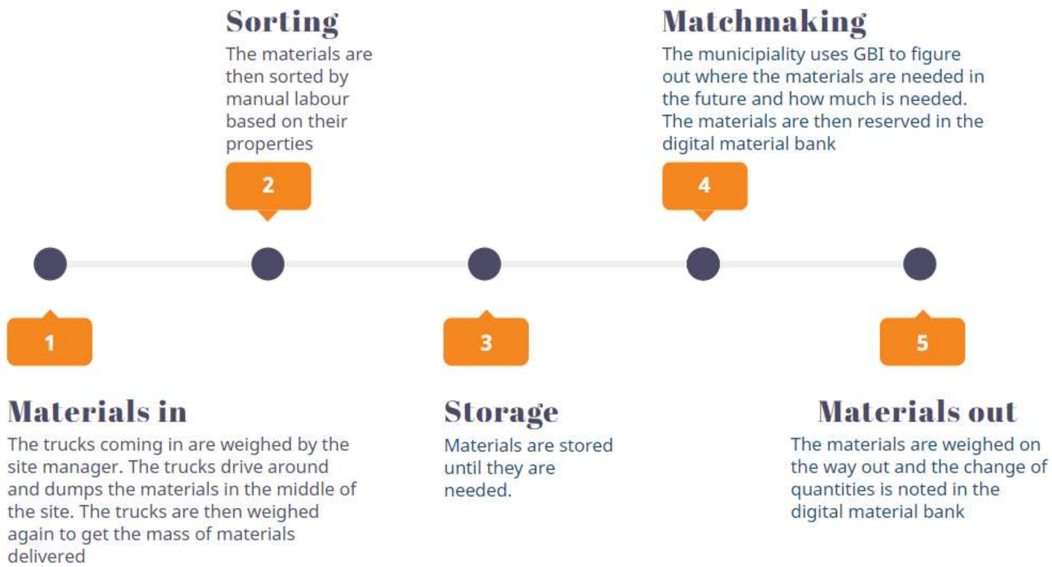


Figure 23. Flowchart at site 1

Site 2 didn't have a treatment facility on site already. The treatment site is dimensioned to be able to treat and pre-store up to 350 m² of inert waste for crushing. On the right side it is allocated so the municipality can increase the storage and treatment capacity in the future. The materials are stored on the left side of the square in the corner. Before an excavator is putting the materials into the mobile crusher. The crusher fills one area at the time with crushed aggregates. The total area of the facility is 5570 m², while the entire area is about 11.000 m². Within those 5570 m² the municipality still have 2800 m² to expand within the facility, as well as 5000 m² to the left of the facility.

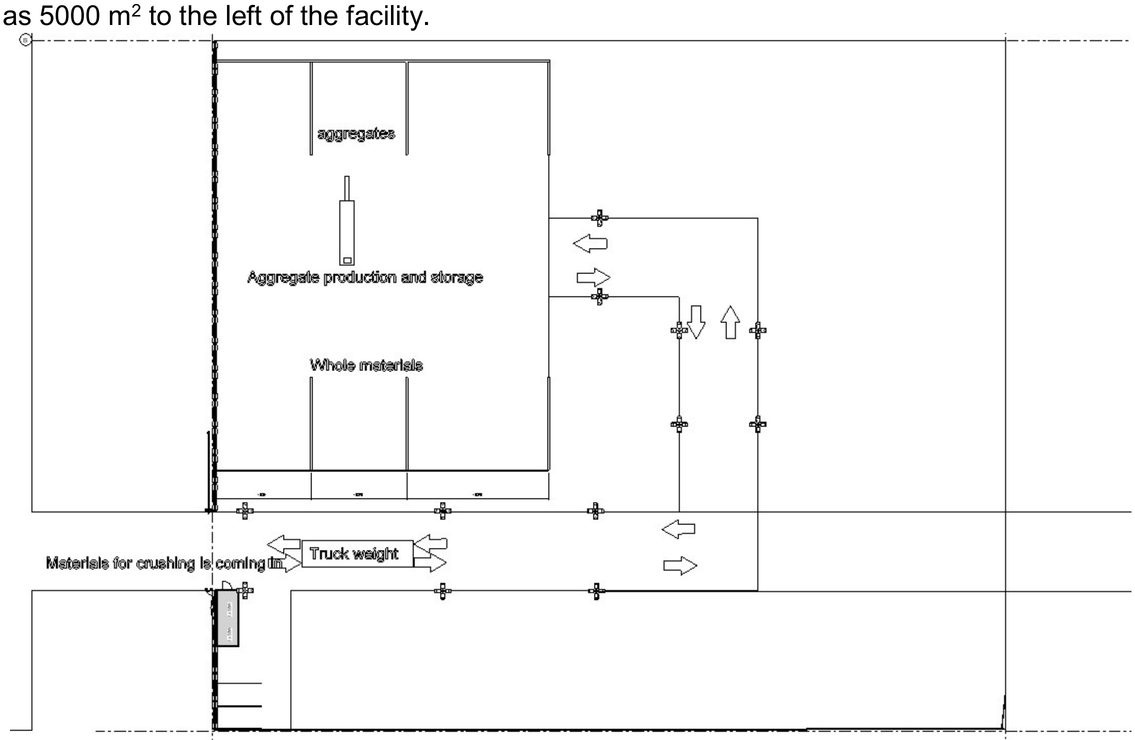


Figure 24. The area plan for the treatment facility

Figure 25. 3D model of the treatment facility

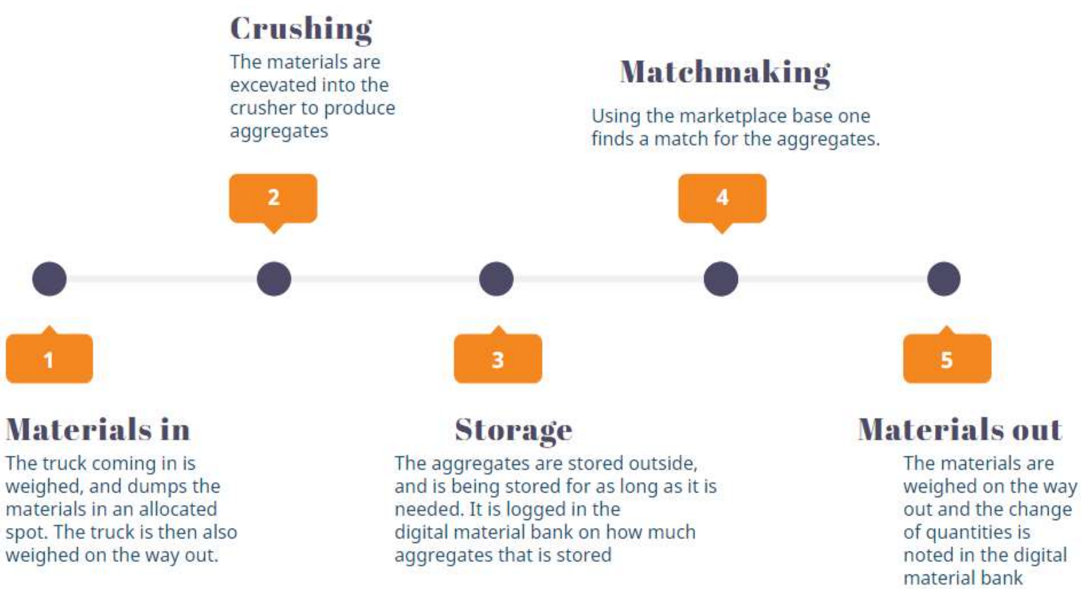


Figure 26. Flowchart of the treatment facility.

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Appendix IX: Calculator

To calculate emissions from mass transportation and CO_2 savings when transporting different quantities of materials, a tool has been developed. The tool is based on a tool made to calculate CO_2 emission from soil transportation sent to the project group by Klaus Kellerman. As the calculator made available doesn't include the materials present in the test area it has been expanded to include: bricks, concrete and Asphalt. The tool is being used to figure out the CO_2 emissions when transporting materials to different sites. Transportation of materials is quite environmentally damaging and should be reduced as much as possible.

The input data needed for the calculator is:

- Distance to the end deposit (km). In this case it will be Location 2, while the local re-use will be Site 2;
- The amount of materials (m^3);
- The distance to local reuse (km);
- Amount of materials being reused in percentage (A value ranging from 0 to 100);
- The amount of urban and highway driving (factor ranging from 0 to 1);

It is assumed that the materials that are being re-used is going to site 1, and the rest is being crushed at site 2.

	LCI	Input:
	Distance to end deposit, km	8,3
	Distance to local reuse	5,7
	m3 of soil	5448
	Reuse percentage soil	100
	m3 of bricks	295,2
	Distance to local reuse	5,7
	Reuse percantege bricks	100
	m3 of concrete	55,25
	Distance to local reuse	5,7
	Reuse percntage concrete	100
	m3 of asphalt	12,8
	Distance to local reuse	5,7
	Reuse percentage asphalt	100
	Use of excevator, hours	
	Use of dumper, hours	
	Use of wheel loader, hours	
	Transport of wheel loader+dumper (k	0
	Amount of Urban driving (%)	0,75
	Amount of highway driving (%)	0,25
Comments	Horsepower excevator	45
CO2-emissions soil transport per m3 kilometre	Soil transport, kg CO2/m3km	0,149210855
CO2-emissions Brick transport per m3 kilometre	Concrete Brick transport, kg CO2/m3k	0,203850013
CO2-emissions asphalt transport per m3 kilometre	Asphalt transport, kg CO2/m3km	0,202071395
CO2-emissions concrete transport per m3 kilometre	Concrete tiles transport, kg CO2/m3k	0,203636579
CO2-emmision from excevation	Excevation process kg CO2/hour	24,12
CO2-emmision from Dumper	Dumper emmission kg CO2/hour	39,32
CO2-emmision from wheel loader	Wheel loader emmision kg CO2/hour	24,44
Transport, lorry+wheel loader	Transport, KG CO2 / km	0,00
	Kg CO2 emitted per liter diesel	2,65
	KG CO2 emitted per liter gasoline	2,31
	KG CO2 emitted per kwh dutch energy	0,589

Figure 1: Input required for the calculator to work.

For the machine emission calculation an estimate on how long different types of machines are being used in (hours), as well as how long the transport distance of the wheel loader and dumper (unit In km) .

:

Output			
	CO2- Saving potential		
Soil transport	CO2-emmisions reusing r	100% on site reuse	0% on site reuse
Transport to end deposite, kg CO2	0	0	0
Transport to site for reuse, kg CO2	0	0	0
Soil sum	0	0	0
Brick transport			
Transport to end deposite, kg CO2	0	0	0
Transport to site for reuse, kg CO2	0	0	0
Brick sum	0	0	0
Concrete transport			
Transport to end deposite, kg CO2	0	0	0
Transport to site for reuse, kg CO2	0	0	0
Concrete sum	0	0	0
Asphalt transport			
Transport to end deposite, kg CO2	0	0	0
Transport to site for reuse, kg CO2	0	0	0
Asphalt sum	0	0	0
On sight machine use kg/ CO2			
Excevator	0	0	0
Lorry	0	0	0
Dumper	0	0	0
Wheel loader	0	0	0
Transport of wheel loader+dumper	0	0	0
Machine sum	0	0	0
KG CO2	0	0	0
KG CO2 saved	0	0	REFERENCE

Figure 2. outline of the output from the calculator.

It calculates based on three assumptions. 0% on site re-use (all materials are transported. 100% on site re-use (nothing is transported to the crushing site) and Lastly CO2-emissions reusing based on the re-use factors given in the input. For reference the scenario where 0% is going to local re-use is used.

Calculations of Emission factors for the Dutch situation

In the Netherlands we use a method called “The IPCC CO2 methodology”. This method has three different Tiers to it. The data gathered by the RIVM is coming from a Tier 2 approach. A more detailed explanation of the calculation method used in the Netherlands is further explained in the documents provided as references (1,2,3,5)

Numerical assumptions for transportation

We are assuming that we are using a truck that weighs the same as the Danish one, which carries 19tons of materials and weighs 32tons when full. We also assume that it drives 75% in an urban area and 25% on a highway. Due to the fact that the material bank will be present within the municipality itself. This may lead to more driving in urban areas. We assume that It returns to the construction site empty, however in the future it should also transport materials back to the construction site. Following TNO this gives the classification of Heavy-duty transportation with the expected CO2 emissions being (g/km):

CO_2 [g/km]	Jaar	2015	2020	2030
Road type	**Vehicle classe**			
urban congestion	Light-duty	350	313	275
	Busses	1013	998	989
	Medium duty [10-20 ton]	1138	1128	1097
	Heavy duty	2356	2441	2440
urban normal	Light-duty	232	212	189
	Busses	1013	998	989
	Medium duty [10-20 ton]	783	728	690
	Heavy duty	1542	1540	1527
urban free flow	Light-duty	223	201	179
	Busses	1013	998	989
	Medium duty [10-20 ton]	611	535	493
	Heavy duty	1149	1105	1086
Rural	Light-duty	142	137	127
	Busses	664	624	602
	Medium duty [10-20 ton]	520	507	504
	Heavy duty	994	1028	1038
Motorway average	Light-duty	183	168	156
	Busses	563	508	478
	Medium duty [10-20 ton]	451	431	420
	Heavy duty	768	787	792

Table 1: Emissions factors for transportation in the Netherlands made by RIVM in 2015. The numbers for 2020 will be used in these calculations. The transportation will be urban normal and motorway average. (RIVM, 2016)

The input needed in the calculator is the m^3 of materials and the distance. Therefore, the output we wish to achieve is kg co_2/ emitted per m^3 transported material per km driven. While it is preferred to have the unit in tons, m^3 is also approved but not as used as often.

As the lorry will be the same lorry to carry each material one won't get an accurate number as the mass it can carry of each material is the same (19 tons) the thing that will vary however is the amount of m^3 it can carry to achieve the same weight due to the different material densities. If the calculator was made to calculate for only one material CO^2/ton km would be a more accurate. Using kg CO_2/km*m^3 also reduces the risk of miscalculations when converting the material from m^3 -> tons. The goal is to later on a conversion factor will be made for each material, so the calculator both handles tons and m^3.

The densities present at the municipality of Apeldoorn

Material	Density (kg/m^3)
Concrete tiles	2265
Concrete Brick	2268
Soil	1520
Asphalt	2243

Table 2. Densities of materials present in Apeldoorn, calculated after being in touch with the municipality

Urban driving emission factors

Material	Emission factor
Concrete tiles	0.2309
Concrete Brick	0.2311
Soil	0.1705
Asphalt	0.2500

Table 3. Emission factors for urban driving

Highway driving emission factor

Material	Emission factor
Concrete tiles	0.1218
Concrete Brick	0.1220
Soil	0.0910
Asphalt	0.1316

Table 4. Emission factors for Highway driving

Total emission factor based on assumptions

Material	Emission factor
Concrete tiles	0.2036
Concrete Brick	0.2039
Soil	0.1406
Asphalt	0.2021

Table 5. Total emission factor

Additional references used in this appendix

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CityLoops is an EU-funded project focusing on construction and demolition waste (CDW), including soil, and organic waste (OW), where seven European cities are piloting solutions to be more circular.

Høje-Taastrup and Roskilde (Denmark), Mikkeli (Finland), Apeldoorn (the Netherlands), Bodø (Norway), Porto (Portugal) and Seville (Spain) are the seven cities implementing a series of demonstration actions on CDW and OW, and developing and testing over 30 new tools and processes.

Alongside these, a sector-wide circularity assessment and an urban circularity assessment are to be carried out in each of the cities. The former, to optimise the demonstration activities, whereas the latter to enable cities to effectively integrate circularity into planning and decision making. Another two key aspect of CityLoops are stakeholder engagement and circular procurement.

CityLoops runs from October 2019 until September 2023.

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