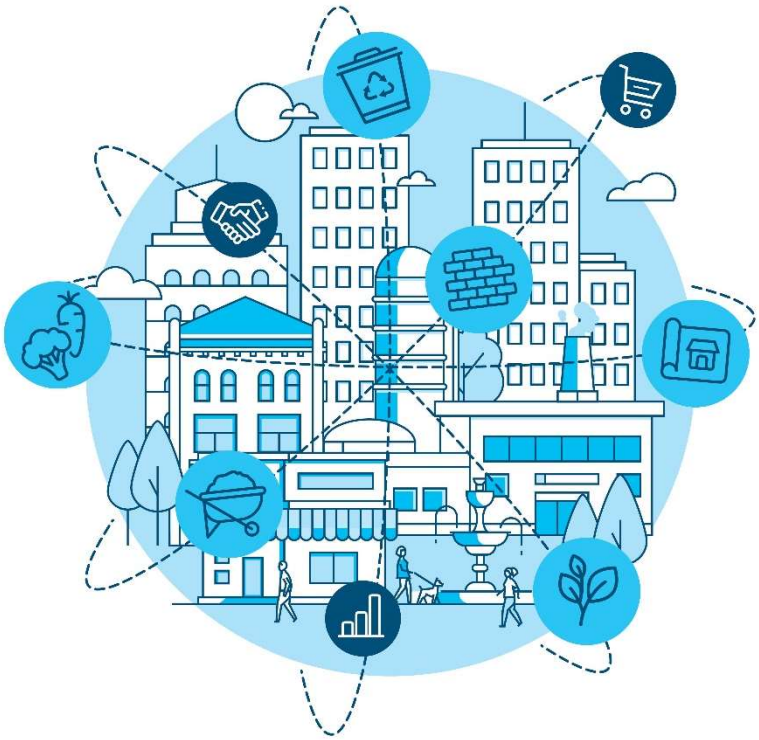
THE ROAD TO A DIGITAL TWIN

3D visualisation tool for circular road design

Saxion UAS & Municipality of Apeldoorn



Version	Final
WP	Work Package 2 Tasks 2.2, 2.7 & 2.9
Deliverable	None
Date	03-02-2022
Dissemination level	Public
Deliverable lead	A.G. (Bram) Entrop (Saxion UAS) A. (Adriaan) Hellemans (Municipality of Apeldoorn)
Authors	H.J (Jordi) van den Boog (student of Saxion UAS) J.M. (Joost) van Duijn (student of Saxion UAS) L.I. (Latisha) Talapessij (student of Saxion UAS) N.G.A. (Nick) Huusken (student of Saxion UAS) W.H. (Wouter) Jansen (student of Saxion UAS)
Reviewers	1st Examinator: C.E.M. (Corné) Jagers (Saxion UAS) 2nd Examinator: (Maerhaba) Yishake (Saxion UAS)
Abstract	The educational research project described in this report aims to develop a digital 3D model of one street in the municipality Apeldoorn. The model provides an overview of the amount and quality of building materials in this street.
Keywords	Circularity, Road Design, GIS, Construction and demolition waste, Quality of materials, residence participation
License	

Preface

In front of you lays our report on how we developed a 3D visualization tool to come to circular road designs. The research project underlying this report was commissioned by the research group Sustainable Development of Saxion UAS and by the municipality of Apeldoorn at the service of H2020 CityLoops. This report was written as a deliverable for the Smart Solutions Semester from September 2021 to January 2022 of the Saxion UAS.

The main research question was derived in cooperation with Bram Entrop of the research group Sustainable Development. During the research process, we received a lot of help from Sander Lubberhuizen, Adriaan Hellemans and Marloes Reekers of the municipality of Apeldoorn. At Saxion, our educational supervisor Corné Jagers was there for us.

We are grateful and thank them for their assistance enabling us to come to this report and the accompanying 3D model.

Jordi van den Boog
Joost van Duijn
Latisha Talapessij
Nick Huusken
Wouter Jansen

Summary

The objective of this assignment is to create a tool that visualizes the residual lifespan of the elemental pavements in Griffiersveld and at the same time to promote residents' participation. To achieve this, the project group started by gaining more insights in road renovation projects and drawing up a definition of circular road renovation. In road renovation projects it is all about reusing and finding new purposes for materials, that are being used in the existing road. It is important to have up-to-date information on how much materials and what the quality is of used materials in a road. This information can be stored in a document comparable to how a passport relates to a person; a material passport. The materials used in circular projects need to be tracible and need to be monitored.

Earlier a 3D tool was developed in Revit software under the supervision of the Saxion research group Sustainable Development. This one was capable visualizing data of houses in the municipality of Apeldoorn. The aim of this project was to add Apeldoorn's road network to this already developed tool.

However, adding the road network to the Revit model was not possible; it seems that Revit was not up to the job, when it comes to visualizing the reusability of materials for so many objects in a particular area. Revit is a BIM (Building Information Model)-Program and is primarily equipped to facilitate building designs. A GIS-based program, called QGIS, qualified as more appropriate. It is namely specialized in visualizing data on a large scale. An additional benefit is that a GIS-based program easily connects to the GBI-data already available at the municipality.

The dataset and maps that were being used in the Revit tool, can easier be accessed by a GIS-tool than a Revit tool. This is because GIS is a more suitable program and especially designed to visualise data like this. QGIS is usually based on 2D-data, but the program has a 3D feature.

In order to involve the residents in the process, the municipality of Apeldoorn would like to have its residents participate in the field of circularity. To answer the question of how the municipality can promote residents' participation, the participation ladder was examined and various projects were developed in which residents can participate. Where many municipalities are at the bottom of the ladder, informing residents, many want to move up the ladder stimulating and facilitating residents to participate in decision-making. In this particular case the renovation of the residential road Griffiersveld in a built-up area is being considered and its residents will have to be motivated in multiple different ways to become actively involved in the circular transition at hand.

The following projects were suggested to come to active residential participation: swapping tiles, botanical exchange and an interactive project planning of the road renewal project.

The tile swapping project motivates and activates residents to remove their tiles from their garden, stimulate storm water infiltration and to create a more natural environment. The tiles are replaced by vegetation.

The botanical exchange project encourages residents to exchange their own plants or shrubs with those of other residents or even with those of the municipality in the public space. The aim of this is to get residents to participate in the reuse of greenery.

The interactive planning runs simultaneously with the planning of the work at Griffiersveld. When the renovation work takes places, residents can have larger bushes or a large amount of pavement carried by the machines that are at site. The aim of this is to get residents to participate in the reuse of pavers, tiles and greenery. The concrete tile swapping project starts at the beginning of 2022. As soon as the tiles are out, there is room for more vegetation, which makes the green swap project useful. The interactive planning comes into play for larger plants or trees. Here, there needs to be close cooperation between the residents and the municipality, but they all work together improving their own residential area circularly.

Inhoud

1 Introduction

This project is commissioned by research group Sustainable Development of Saxion University of Applied Sciences in cooperation with the Municipality of Apeldoorn in favor of H2020 CityLoops.

The research group Sustainable Development is connected to the School of Business, Building & Technology of Saxion UAS. From this research group Associate professor Bram Entrop is involved in this project. The research group, called lectoraat Duurzame Leefomgeving in Dutch, focuses on applying innovative ideas as a base for usable and practical solutions to improve the living environment, while lowering our environmental impact.

The municipality of Apeldoorn is located in the province of Gelderland in the Netherlands. Sander Lubberhuizen, Adriaan Hellemans and Marloes Reekers are involved in this project on behalf of the Municipality of Apeldoorn. The city of Apeldoorn is a part of the CityLoops organization. CityLoops is a partnership program of seven cities within the European Union. Within this partnership, the cities are carrying out a series of pilot projects to main waste streams in Europe: construction and demolition waste and bio-waste. The purpose of this project is to form circular cities in which no materials are lost, to stimulate the transition to a circular economy (CityLoops, 2022).

This assignment is a continuation of two previously conducted student research projects. The projects "Circular redesign of Griffiersveld Apeldoorn" and "Facultative educational exploration circular material usage Griffiersveld Apeldoorn" will be continued during the execution of this project. The most important results of both projects are briefly described below:

Circular redesign of Griffiersveld Apeldoorn (2020-2021)

This project was carried out by students of the Saxion University of Applied Sciences at the request of the municipality of Apeldoorn and the Sustainable Living Environment lectorate. It was conducted in the first semester of 2020-2021. Within this project, research was conducted into the possibilities for carrying out the Griffiersveld street redesign in the most circular way possible. The result of this research is to test the materials released from the street for their reusability and then to sell them via a marketplace for reuse in other projects.

Facultative educational exploration circular material usage Griffiersveld Apeldoorn (2019-2020)

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 reusing materials.

Reading guide

The research design will be discussed in Section 2. The underlying problem, the corresponding research question and sub-questions, and the DMAIC research model will all be discussed in that section. A brief description of the street where the investigation is taking place is also provided. Three key concepts, theories, and models connected to this topic will be discussed in Section 3. The case, the inspection protocol, and the way the municipality of Apeldoorn processes and stores information will all be discussed in greater depth in Section 4. The origins of the 3D tool will be discussed in Section 5. The topic of resident participation is discussed in Section 6. Two theoretical models for resident engagement will be described and expanded upon in this section. Following that, three projects will be established with the goal of boosting local participation. The conclusion answers the research question, as well as the sub-questions. The recommendations can be found at the end of the report.

2 Research setup

In this section, the project will be explained in more detail. First, a general description of the assignment will be given, after which the location of the project will be explained. Then, the problem, scope, research question, sub questions and objective will be elaborated. This section will be concluded with an explanation of the research model chosen by us.

2.1 Problem statement

Road renovations are regularly carried out in the Netherlands. During these renovations, the used materials are often neglected, even though many of these materials can and should be reused. The problem is that the Netherlands does not use an efficient circular method for these road renovations. This leads to unnecessary transport costs, environmental pollution and time loss. This problem does not only occur in the municipality of Apeldoorn, but this is a worldwide issue. The government of the Netherlands aims to be 100% circular by 2050. Since the quality of roads in the Netherlands is high, road renovations occur very often, which leads to a large amount of waste.

To summarize, to increase the circularity in the Netherlands to reach the goal to be 100% circular by 2050 and to prevent our planet from being exhausted, we need to create a proper circular method for road renovation. To create a proper circular method for road renovation the project group, on behalf of the municipality of Apeldoorn, will carry out the assignment as stated below:

> *"How can information during different stages of a circular road renovation project be visualised in a digital 3D tool linked to existing information systems applied by the Municipality of Apeldoorn?"*

The objective is to create a tool that visualizes the residual lifespan of the elemental pavements in Griffiersveld and at the same time to promote residents' participation.

2.2 Research questions and methods

The project group will answer the following main research question over a period of six months:

"How can information during different stages of a circular road renovation project be visualized in a digital 3D tool linked to existing information systems applied by the Municipality of Apeldoorn?"

To answer the main research question, the project group come up with the following five research questions:

1) Which stages in a circular road renovation project can be distinguished?
In order to gain more insight into the circularity of road renovation projects, a definition of circular road renovation was first drawn up. Then a desk study was carried out to investigate

which criteria determine whether the maximum service life of a road has been exceeded. Next, the steps to be taken to start a circular road renovation project were determined.

2) What information needs to be visualised in a 3D-tool?
Before the 3D tool can be set up, it must first be investigated which data needs to be represented in it. When it has been determined which data is important for setting up the tool, the best way of retrieving this data is determined.

3) In which way can the data be visualised in a 3D-tool?
Once it was clear which data had to be represented in the 3D tool, an investigation was carried out into which software program could best do this. For this purpose, a desk study was carried out into the various tools which already exist, and which have the same purpose as the tool which has to be designed. When it is clear which tool will be used, it is investigated how the necessary data can be visualized in the software.

4) How can the system applied by the municipality of Apeldoorn be linked-to the tool?
Finally, the way in which the tool can be linked to the systems of the Municipality of Apeldoorn will be examined. For this purpose, the systems used by the municipality of Apeldoorn for the management of the road area are determined. Subsequently, the necessary data which can be visualized in the software used by the municipality of Apeldoorn will be examined.

5) How can the municipality of Apeldoorn come to participation with the residents?
Finally, it will be examined how the municipality of Apeldoorn can promote residents' participation. To this end, two theoretical models have been developed and applied, and three participation projects have been developed.

2.3 Research model and scope

Scope: The production of a 3D model of the street Griffiersveld and the promotion of resident engagement are at the heart of this study. The residences on the street, as well as the street itself, are rendered in 3D within the 3D model. After that, the street is divided into road sections and color-coded to determine how reusable the concrete paving stones and concrete tiles are.

Research model: For the development of the tool the student team uses the DMAIC research model. DMAIC is a data driven improvement cycle used for improving, optimizing, and stabilizing processes (Lean Six Sigma, 2022). This improvement cycle consists of five phases. This research model is chosen because it solves a problem step by step. This is the case of this project effective because not all problems and issues can be solved at once. Using this methodology, deeper and more specific problems are solved from the ground up. The biggest pitfall with this method is that you must consider how the tool will develop in the future. If this the future development is not taken into account, it is possible that the tool cannot be expanded in the desired direction. To prevent this, at the beginning of the project a brief sketch was made

of how the tool should look, taking into account the possibilities of the available programs. The five principles of the DMAIC model are (Lean Six Sigma, 2022):

1. *Define:* the purpose of this step is to define the business problem, goal, potential resources, project scope and a project timeline.
2. *Measure:* the performance of the current business process is measured. This measurement must be carried out objectively so that after implementation of the solution it can be determined whether there is actually an improvement
3. *Analyse:* the collected data is being analysed, via a root cause analysis, to identify the root cause.
4. *Improve:* the purpose of this step is to identify, test, and implement a solution. Note that it is important that the project team does no come up with complicated solutions while a simple solution is sufficient.
5. *Control:* the implemented solution is monitored, which involves checking whether the implemented solution is successful in the long term.

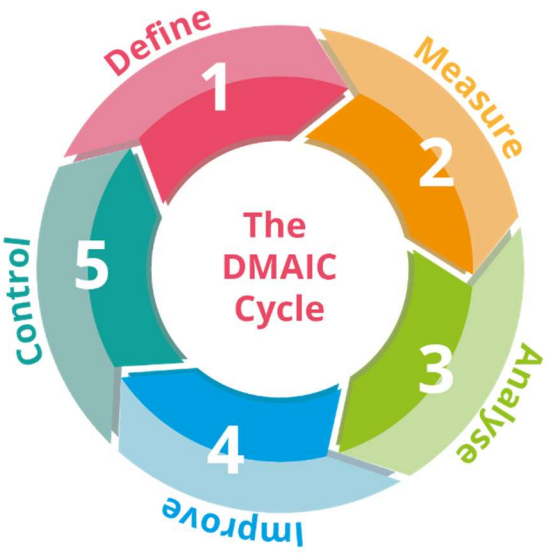


Figure 2.1: The DMAIC cycle (Lean Six Sigma, 2022)

First DMAIC-cycle

1. *Define.* The original tool is created in Revit. To expand the tool Revit has to include data on the scale of the whole municipality. These datasets must be combined in the
2. *Measure.* The data to be processed in the tool is not easily implanted in Revit. Many intermediate steps must be taken to visualise the available data set in Revit. This is because Revit is not intended for large-scale data visualisation. In addition, the programme is too heavy to run and render on an average computer. Changes in the datasets are difficult to implement and visualise.
3. *Analyse.* The data to be processed in the tool is not easily implanted in Revit. This is because Revit is not intended for large-scale data visualisation. Therefore, we looked for another programme that would be more suitable for processing the data sets. The conclusion was that it would be best to use a GIS-based programme to continue the tool.
4. *Improve.* The dataset used in the Revit-tool are transferred to a more suitable program called QGIS.
5. *Control.* Every existing dataset is successfully transferred except for the data of the roads. Every dataset is visualised in a 2D setting. This QGIS-tool can cover a much larger area than only Griffiersveld and Matenveld that are used in the Revit-tool. The dataset are automatically refreshed when changes are made by the owner of the dataset

Second DMAIC-cyclus

1. *Define.* The existing Revit tool must be expanded so that infrastructure can be included in the programme. This means that the next step towards setting up a digital twin of the Apeldoorn area is being taken. The dataset of the buildings in the Revit-tool currently exists out of: zip code, energy label, year of construction and use status. The dataset of the roads in the Revit-tool currently exists out of: substrate and the type of pavement. The data to be included in the Revit tool are the location of roads, the quality of roads and the road maintenance log
2. *Measure.* The data to be processed in the tool is not easily implanted in Revit. Many intermediate steps must be taken to visualise the available data set in Revit. This is because Revit is not intended for large-scale data visualisation. In addition, the programme is too heavy to run and render on an average computer. Changes in the datasets are difficult to implement and visualise.
3. *Analyse.* The data to be processed in the tool is not easily implanted in Revit. This is because Revit is not intended for large-scale data visualisation. Therefore, we looked for another programme that would be more suitable for processing the data sets. The conclusion was that it would be best to use a GIS-based programme to continue the tool.
4. *Improve.* The dataset used in the Revit-tool are transferred to a more suitable program called QGIS.
5. *Control.* Every existing dataset is successfully transferred except for the data of the roads. Every dataset is visualised in a 2D setting. This QGIS-tool can cover a much larger area than only Griffiersveld and Matenveld that are used in the Revit-tool. The dataset are automatically refreshed when changes are made by the owner of the dataset.

Third DMAIC-cyclus

1. *Define.* The data is currently in the tool only has a 2D representation. In order to come as close as possible to a digital twin, the tool should have a 3D view.
2. *Measure.* for an accurate and aesthetically better 3D model, a distinction is made between the 3D representation of roads and buildings.
   Buildings: in this version of the tool, everything is displayed in 2D. However, Delft University of Technology has developed a tool that makes a 3D representation of all buildings in the Netherlands. This 3D representation contains none of the data that the 2D representation does. The 2D dataset and the 3D dataset can be combined if there is at least one unique property per object which is overlaid in the 2D and 3D dataset
   Roads: the roads can be visualised less aesthetically than the buildings. For the roads, only a 2D dataset is available. This means that there must be found a way to transfer the 2D-shape into a 3D-shape
3. *Analyse.*
   Buildings: the first possibility is to manually give each building in the 2D and 3D dataset a unique ID number. However, this is a labour-intensive process and therefore only workable on a small scale. The second possibility to combine these datasets is to use the unique object property that is present in both the 2D and 3D dataset. This is the

geographical location, which is possible because the location of the buildings is bound to the Dutch coordinate system.
Roads: the roads can be converted to a 3D shape by giving a height to the 2D dataset in the appearance settings of the dataset.

4. *Improve.*
Buildings: the datasets are be based on geographical location. The Toolbox plugin in QGIS is used to combine the 2D and 3D dataset of the buildings base on coordinate systems. Every house is a own block that is linked to a location. This location is for each house unique. The data from each building in the 2D dataset is transferred to the 3D dataset based on the location.
Roads: to visualise the shape of the roads in 3D the 2D shape of the road is given a height of 0.1 m in the symbology settings.
5. *Control.* There has now been set-up a digital twin with all the available datasets of the municipality Apeldoorn. This can be visualised in 2D and 3D dimensional view. Every building and road has its own data that can be visualised by the user of the tool.

Fourth DMAIC-cyclus

1. *Define.* A function should be added to the tool to determine and take stock of the quality of the materials in a road and its component. This with the goal to find a suitable reuse for the materials can be found.
2. *Measure.* At the moment, there is no unambiguous method for determining the quality of the materials in a road so that it can be reused. And there is no standard for what quality the materials in a road should be in order to be reused.
3. *Analyse.* For the tool to work, a calculation tool must be drawn up based on surface area to determine the amount of materials in the road. To this must be linked a method that can assign the materials a new destination.
4. *Improve.* A traffic light system has been set up that breaks down the quality of the stones into three grades. Each of these grades is suitable for a particular new use. This traffic light system is linked to the various road components.
5. *Control.* A start has been made on a tool to assess the quality of different products, but how useful and valid this tool will be in practice will have to be tested.

2.4 Griffiersveld

This research will be conducted for the street Griffiersveld. Griffiersveld is a street in the De Maten district in Apeldoorn. De Maten is the largest neighbourhood in Apeldoorn Southeast and is a so-called cauliflower district. A neighbourhood that is characterized by residential areas that are accessible via main roads. There are 101 houses in Griffiersveld, and the average year of construction is 1977. There are only single-family homes and there is no through traffic in the street. The front gardens of the houses are large enough to accommodate a car, but there are also parking spaces. The street has greenery, a small playground and a square in the middle of the residential area. Figures 2.2 and 2.3 show where Griffiersveld is located in Apeldoorn.

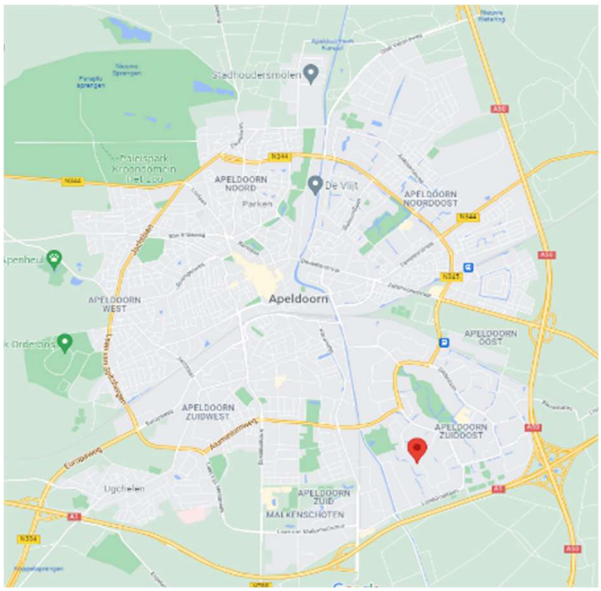


Figure 2.2 Apeldoorn (Google Maps, 2022)

Figure 2.3 Griffiersveld (Google Maps, 2022)

2.5 Demographics of Griffiersveld

To motivate residents to be actively involved in circularity, residents are to be informed appropriately. How the message and the message itself are disseminated must match the target groups. If successful, residents can relate to the errand and are more inclined to be actively involved in circularity. That is why this section will also discuss the demographics of Griffiersveld. Demography largely determines who our target groups are and how we should approach them.

Griffiersveld is located in the Zuidoost district. Since no data is available on the demographics of Griffiersveld, we use the data available from the Zuidoost district to make an estimate of the demographics of Griffiersveld. This district has a total of 25,720 inhabitants, of which 49.3% are men and 50.7% are women. The ages are distributed as follows:

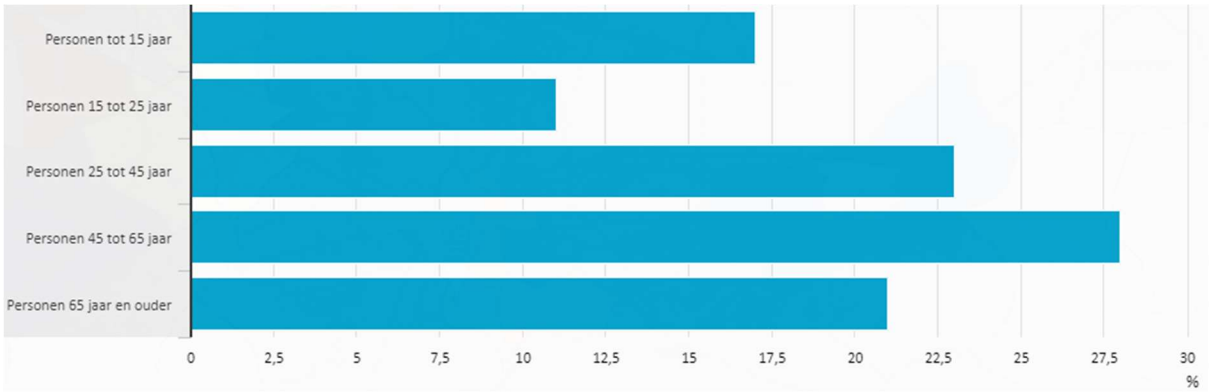


Figure 2.4 Age distribution Zuidoost in 2020 (CBS, 2022).

Of the 25720 inhabitants, about 6690 inhabitants have a migration background.

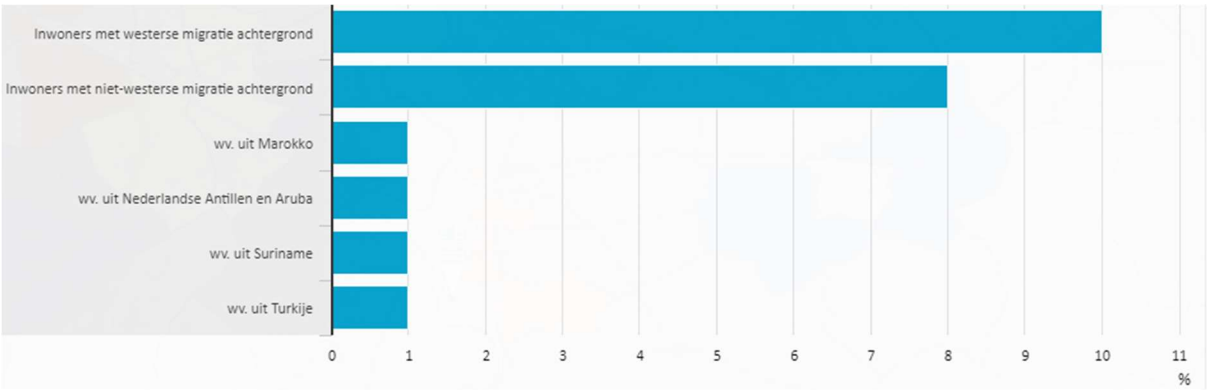


Figure 2.5 Origins residents Zuidoost in 2020 (CBS, 2022).

The Zuidoost district has 11,225 households, of which 32% are single-person households, 31% are households without children, and 36% are households with children. The average household size is 2.3.

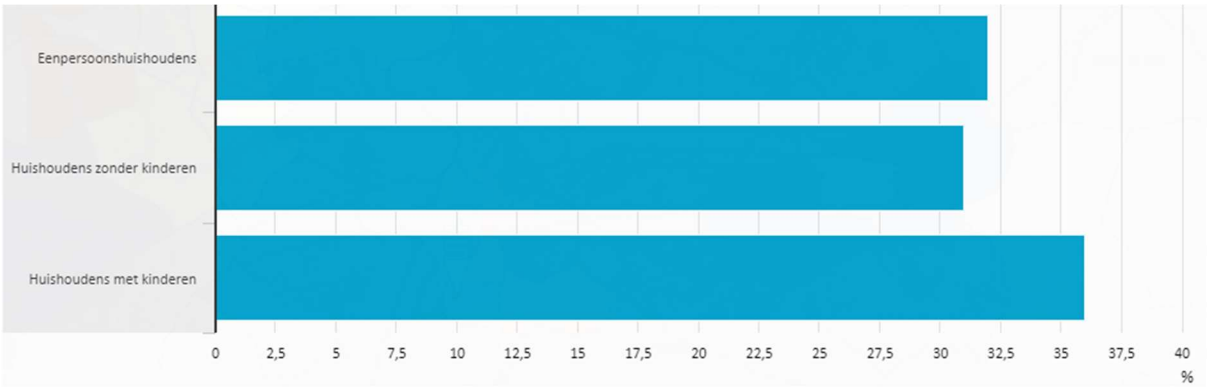


Figure 2.6 Households Zuidoost in 2020 (CBS, 2022).

560 inhabitants receive a general social assistance benefit. 1,310 receive a disability benefit, 330 receive unemployment benefit and 4,870 receive a supplementary pension.

2.6 Design of Griffiersveld

A road can be split in different components, for this project the different road components will be divided by the different materials used in the road. The management system of GBI is using road section to divide the information the municipality. For this project the components will be split based on the materials used. This means that there are in the case of Griffiersveld three different road components, namely:

- Concrete pavers: the main material of pavement in Griffiersveld are concrete pavers, in total there is an area of 3180 m^2 of concrete pavers. These materials are esthetical worn-out but technical the pavers are fine.
- Concrete tile 300 x 300 mm: the second most used material in Griffiersveld are standard concrete tiles. In total there is an area of 995 m^2 of concrete tiles.

Figure 2.7 Future design Griffiersveld (Gemeente Apeldoorn, 2022a)

- Concrete band: in total there is a length of 620 m^1 of concrete band. The second most used material in Griffiersveld are standard concrete tiles; Foundation: in total there is an area of 4.523,7 m^3 of sand foundation. The second most used material in Griffiersveld are standard concrete tiles.

The concrete tiles and concrete pavers will be exchanged for new concrete pavers. At the parking spot the best stones in Griffiersveld will be reused. In total an area of 240 m^2 will be replaced by a green area.

3 Theoretical framework

This section focuses on the theoretical framework. Important concepts and theories relevant to the research are discussed here. Topics that are considered important within are: the circular economy, circular road construction, the lifespan of roads and a definition of residual lifespan will be given. This section also looks at circular solutions for construction and demolition waste.

3.1 The circular economy

A circular economy is an economic system of closed loops in which raw materials, components and products lose their value as little as possible, renewable energy sources are used and systems thinking is at the core. It is important to understand this principle to understand the basics of the cycles in the construction and demolition waste sector. The Dutch government distinguishes three types of economies, the linear economy, the reuse economy, and the circular economy, see Figure 3.1 (Government of the Netherlands, 2021).

The linear economy is as an economy wherein raw materials are used to make a product and is thrown away after its use. In an economy based on recycling, materials are reused. The waste, as mentioned in the linear economy, will be used to make another product. Keep in mind that the new product is of a lesser quality, which is known as downcycling. The circular based economy relies on making products and materials more efficiently and reusing them in order to prevent waste. If, for any reason, new raw materials are needed, they must be obtained sustainably to prevent damage to the environment (Government of the Netherlands, 2021).

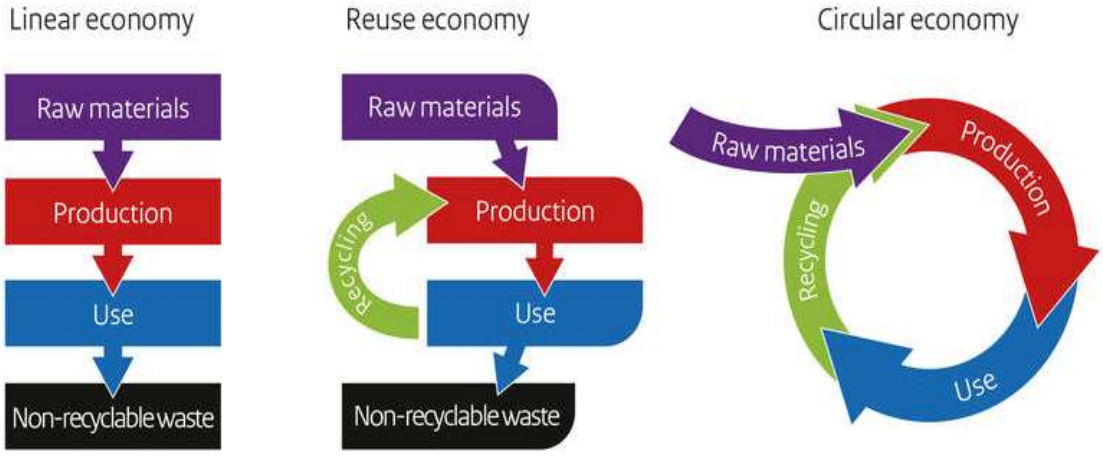


Figure 3.1 The different economies (Government of the Netherlands, 2021).

In the near future it is not feasible to not use recycled materials, as raw materials are becoming increasingly scarce. Therefore, it is of great importance that the design and production of products are aimed at closing the loop as depicted in both Figure 3.1 and Figure 3.2. To do so manufacturers must develop a new revenue model, design a product aimed at closing the loop, collaborate with members of the supply chain, upcycle and recycle all materials, and use

renewable energy. If all the materials and products can and are produced and recycled in such way there is no waste, we speak of a circular economy.

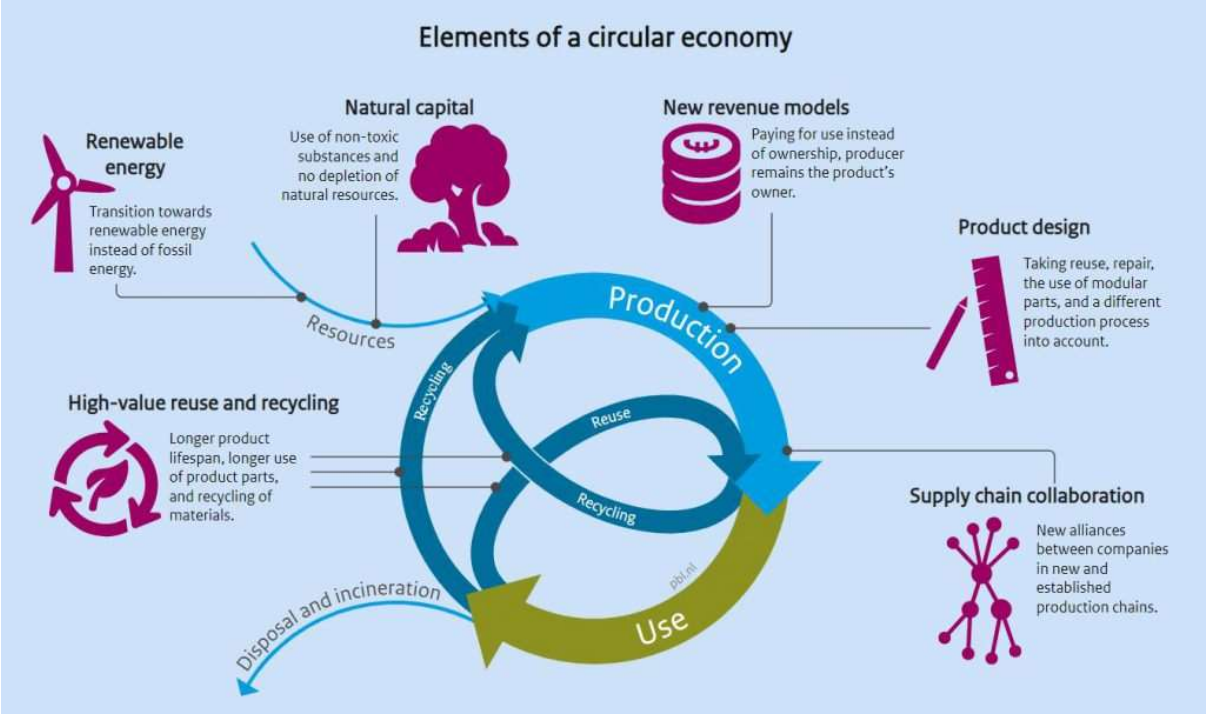


Figure 3.2 Elements of a circular economy (Het Groene Brein , 2020).

3.2 Circularity in road projects

This section of the theoretical framework is about building materials, construction and demolition waste streams. This is important to understand the context of this project. This information is necessary to determine the quality and new purpose of the materials in Griffiersveld.

3.2.1 Construction and demolition waste streams

The flow chart, as depicted in Figure 3.3, shows each of the materials' distinct material cycles. The explanation on this flowchart can be found in (Ten Brink et al., 2021) Last semester, a group of students began working on this project. Ruiz, Ramón, and Domingo (2019) wrote an essay that the students based their explanation on. As a result, it was agreed to mention them in the text.

Only phases 3 and 5 ('End of Life' and 'Material recovery and production') will be discussed in greater depth in this report, as they are the most important in this study. The flowchart in this context starts at step 3, 'End of Lifetime.' The initial step in this process is to look into the possibility of reusing materials or products. This allows the distinction between demolition and (selective) dismantling to be made (Ruiz, Ramón, & Domingo, 2019).

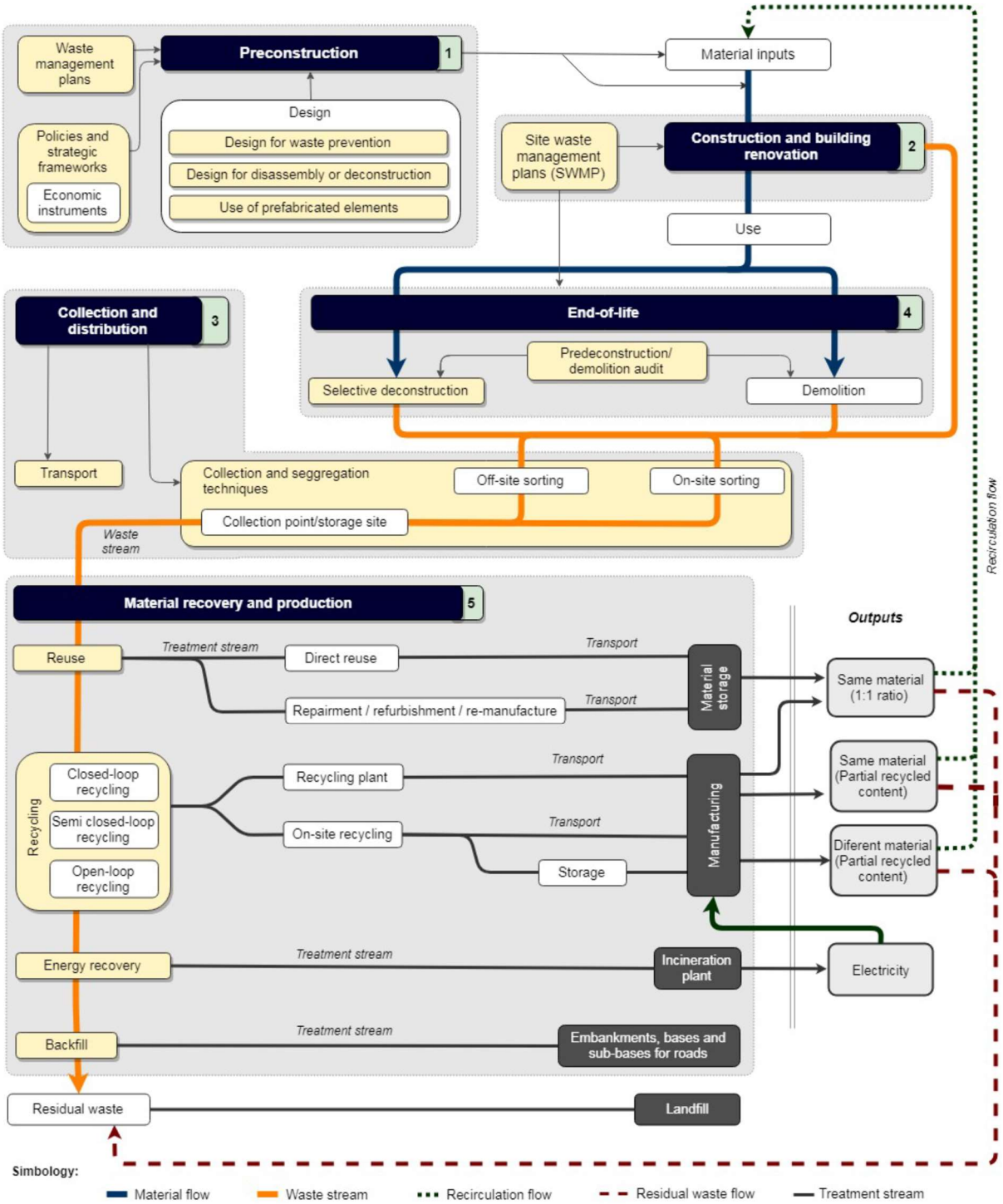


Figure 3.3 Flow chart concerning the circular use of materials (Ruiz, Ramón, & Domingo, 2019).

Activity 3 in Griffiersveld circular redesign is step 5 'Material recovery and production.' The materials are categorized into the following streams, with the most desirable streams appearing first and the least attractive appearing last: reuse, recycling, energy recovery, land replenishment, and residual waste.

In the 'reuse' treatment flow, materials are reused or repaired/renovated one on one. This yields the same materials with as few adjustments as possible, and therefore few emissions. The only thing needed is a storage area.

In the second stream, the materials are taken to a recycling plant or are recycled locally. This results in the same material, either the same material that is partly recycled or a different material that is partially recycled.

The third treatment stream in step 5 is 'Energy Recovery'. Energy is being recovered in this stream by generating electricity from combustion plants. The recovered energy is used to facilitate the 'recycling' operations, hugely reducing the environmental impact of the production of recycled materials.

In the fourth stream 'Terrain replenishment', the material is (in many cases) downgraded. Hence, materials in this stream lose their value. The materials are utilized for roadside filling as well as road foundations.

'Residual waste' is the fifth and final treatment stream in step 5. The least desirable flow, as new materials, must be extracted. This treatment flow should be prevented to make civil engineering entirely circular. The material that enters this stream is being disposed of at the landfill.

3.2.2 Production of concrete tiles and pavers

To fully understand the material cycles in road renovation and building projects this section will describe how the materials within the scope are produced.

Concrete paving stones and concrete tiles are both made of concrete and the production process is similar. In the first step of the production process, the concrete mix is mixed. The composition of the concrete mix differs per manufacturer and type of brick. In addition, the manufacturer can add ingredients to change the properties and colour of the concrete. Concrete mainly consists of four materials, namely: cement, aggregates (sand, gravel or crushed old concrete) and water.

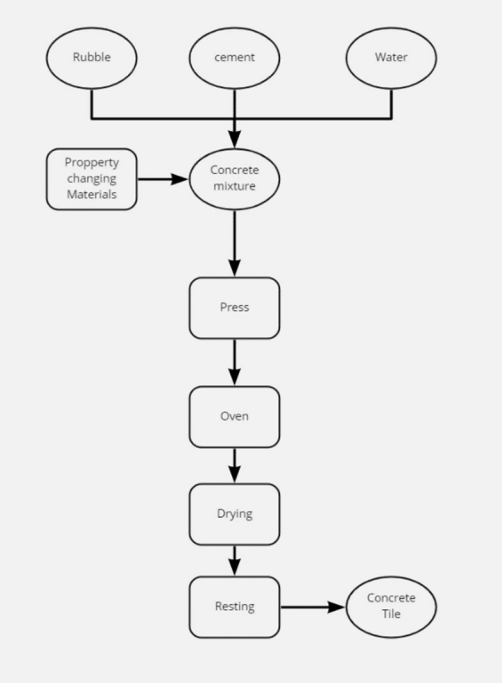


Figure 3.4: Production process concrete tiles

The concrete mixture is then poured into a mould and compressed under high pressure. After the concrete has been compressed, the concrete mixture is heated in the oven. When the concrete comes out of the oven it is laid to rest in a room with high humidity to harden. After a few days the concrete must rest some more days to harden further. After the production it takes up to 28 days for the concrete is fully hardened out

(Bouwbestel, 2022). In Figure 3.4 the production process is illustrated with the help of a process flow diagram.

3.3 Lifespan of a road

This section answers the sub question which stages are there during a circular road renovation project. In this section the five different stages of a road lifespan will be described.

3.3.1 Evaluation of the existing road

The first step is to evaluate the existing road. The average life span of a road in the Netherlands is 40 to 60 years. At the end of this life span, the quality and experience of the road is rapidly declining. Determining when a road reaches the end of its service life is not only based on the expected service life of this road. The quality of the road, its safety and the experience of the road user are also considered factored when determining the residual lifespan of a road. Whenever one of these factors no longer meets the requirements as set up by the Dutch government and the CROW. Then it is decided that the road needs to be replaced. Whenever a road is going to be replaced the pavement is going to be broken up and a new road will be designed. The design of a new road will be conducted as stated in Section 3.3.2.

3.3.2 Design of the new road

A new road connection will be built somewhere if the necessity for it has been identified and the funds are available. The next step is to work out the global alignment of this road into a definitive trajectory plan. Some design requirements and design guidelines apply to this trajectory plan. When a road is designed, it must comply the guidelines of the CROW.

Economic requirements	The economic requirements of the road design are construction costs, maintenance costs and operating costs. *Construction costs:* the construction of a road should be as cheap as possible. This can be achieved by not incorporating any costly engineering structures in the design and by moving as little soil as possible in the intended trajectory plan. *Maintenance:* the maintenance of a road should be as low as possible. This means that areas with weak soils should be avoided, as more subsidence will occur there. *Operating costs:* the trajectory of a road should be determined in such a way that it forms the shortest possible connection between point A and point B. This is to keep vehicle running costs as low as possible. In order to keep driving costs even lower, gradients (lost slope) and hairpin bends should be avoided as much as possible.
Planological requirements	A new road should attract traffic to an area to relieve other roads. The more traffic that uses a new road, the greater its economic benefit. The trajectory of a road should therefore be determined in such a way that it is not located too close to a road with the same function, is located in the vicinity of many traffic-generating areas and is well connected to important existing roads.

Environmental requirements	The damage to the environment has to be minimal. Nature and silent areas should be avoided. Agricultural plots get cut through as little as possible. The road must fit into the parcel structure of the surroundings. If waterworks are disturbed, the water balance must be restored.
Aesthetic requirements	The course of the road should provide a peaceful and attractive sight in the surroundings. Both for the road user and for passers-by who observe the road from the side.
Traffic requirements	The road is safe and ensures a smooth traffic flow.

Table 3.1 Design requirement road design (Kuipers, 2017).

In addition to the design requirements (see Table 1), design guidelines for road design have also been drawn up by Kuipers (2017). The aim of the design guidelines is to create a recognizable road image for the road user. This ensures safe road behavior. Because road users are familiar with different road situations, they know what traffic behavior is expected of them. This increases traffic safety. This idea has been translated into design guidelines for three road categories (Kuipers, 2017): traffic- passing-through roads, access roads, and local roads. Table 3.2 shows the distinguishing features for each road category.

Roads traffic passing through	2x2 lanes (preferred) or 2x1 lane. Uneven intersections, such as a junction. Separate carriageway for cyclists, mopeds and other slow-moving traffic. Maximum speed of 100 km/h.
Access roads	2x2 lanes or 2x1 lane (preferred). Level junctions, such as a roundabout. Separate carriageway for cyclists, mopeds and other slow-moving traffic. Maximum speed of 80 km/h
Local roads	One carriageway without axis markings. Equalized intersections. Cyclists, moped riders and slow-moving traffic on the carriageway. Maximum speed of 60 km/h.

Table 3.2 Design guidelines road design (Kuipers, 2017).

3.3.3 Construction of the new road

The requirements and guidelines that a road must meet are globally described in the previous section Because this report is focused on the circularity of road design of the Griffiersveld street, this report targets mainly the likes of concrete paving stones. Concrete paving stones

consist of sub-concrete and have a top layer. Concrete paving stones are used in the Netherlands in various sizes, for example:

- Clinker size: 210 mm x105 mm, where approximately 44 pieces fit into 1 m^2;
- Waalformaat: 200 mm x 50 mm, where approximately 100 pieces fit into 1 m^2;
- Dikformaat: 210 mm x 70 mm, where approximately 68 pieces fit into 1 m^2.

In the case of this project, concrete paving stone will always refer to the clinker format. Before placing these pavers in a street, groundwork has to be carried out. This involves an earthwork contractor excavating the current earth track and laying a new earth track for the foundations of the road surfacing. Equipment and personnel are used to lay the concrete paving stones in the street. A road paving crew is always deployed, they will mainly use vibratory plates and wheeled loading shovels.

After the pavers are placed, the paving is finished off with a layer of sand. This sand layer ensures that the cohesion between the stones is strengthened. Concrete paving stones have a distance of 1 to 2 mm between them, leaving a small space between the tiles. The sand fills up this space, so that the tiles remain as stable as possible.

3.3.4 Maintaining of the new road

Activities that fall under maintenance of a road include repairs to the road surface, life extending measures, major maintenance and minor maintenance of the road. Major maintenance includes measures such as replacing the entire road surface or just part of it. The underlying structure or foundations may also be replaced. Minor maintenance concerns more small-scale interventions to keep the road safe. This includes measures such as replacing broken tiles, repairing unevenness in the road surface or removing weeds between the bricks.

3.3.5 End of life

At the end of the service life of concrete paving stones, are thrown into the shredder and ground into rubble. This debris will serve as soil improvement for foundations of e.g. roads and buildings or will be processed into new concrete. The end of life of concrete paving stones will be answered later in this report. Concrete paving stones are usually used in other places within the municipality or sold to private individuals or companies.

In this phase, the circularity of road design is further examined. On the basis of the research conducted earlier by CivilOost, the 'reuse' treatment flow is used. This means that in road renovation projects, the materials removed from the street are reused. The other option is to replace these materials by materials that are partially recycled. In the second "reuse" treatment flow, the materials are brought to a recycling plant. This allows the same material to be reused for other road projects in the future.

In short, the definition of circular road design used in this project is that the materials that are released are reused directly in the construction as much as possible. When the materials are

too damaged, they are transported to a recycling plant to be used in the construction of new building materials.

3.4 Residual lifespan

3.4.1 Technical residual lifespan

The technical residual life of a road is determined based on the guidelines of the Centrum voor Regelgeving en Onderzoek in de Grond-, Water- en Wegenbouw en de Verkeerstechniek (CROW – in English: Center for Regulation and Research in Ground, Road and Waterway Constructions and Traffic Engineering). In the Netherlands, CROW draws up the guidelines for infrastructure for the following three aspects (CROW, 2011): design, maintenance and tendering.

The technical residual lifespan is not expressed in years but rather a scale based on the quality of the different road components. Each of these components have their own scale and measuring criteria. for the definition of the criteria. The CROW draws up guidelines and these are therefore not binding. Only in very exceptional cases will it be decided to deviate from the guidelines.

Design

During design, the following points have a huge influence for the technical residual life (CROW, 2011):

- *Design lifespan:* a road or a road component is designed for a certain life span, whereby the minimum life span of the road is expressed in years. It is possible that during the design life span, various parts of the road will be replaced or undergo major maintenance. When or if this happens can be determined in the management and maintenance plan, but it can also be the result of findings by road inspection. At the end of the design life span, the condition of the road and the life expectancy of the various road parts are examined.
- *Management & maintenance plan:* during the design phase, consideration is always given to a management & maintenance plan. This plan states when and how often (major) maintenance will be carried out on the road. During its lifetime, a road usually costs about the same in terms of maintenance as it does in terms of construction costs. Changes in the Management & maintenance plan can shorten or extend the design lifespan
- *Climate adaptation.* When designing a road, several design principles are determined. These criteria can change during the lifespan of the road. These changing criteria have a direct influence on the management & maintenance of the road. This is because this will speed up the wear on the road. The two factors that have the most the most influence on the life span of the road, are:
  - Climate change can have a major impact on the quality of the road. climate change is understood to mean major changes in temperature and precipitation. When a road

or underlying infrastructure can no longer withstand extreme weather conditions, consequences in a direct impact on the management & maintenance of a road.

- Intensity: The use of a road is expressed in terms of intensity. The factors that play a role in this are the weight and frequency of vehicles using the road. If the intensity of a road exceeds its design, this has an influence on the traffic flow.

Maintenance

As a road ages, the frequency and intensity of maintenance increases. The road administrator can consciously choose not to carry out or to postpone maintenance. Poor and overdue maintenance increases the total costs of maintenance during the road's life span and reduces the quality of the materials in the road. This therefore has consequences for the possible reuse of the materials (CROW 2017).

Tendering

During the tendering process, agreements are made about various points that can influence the technical life span of a road or road components (CROW, 2011):

- *Use of materials:* During a tender, the choice can be made that the contractor will use its (own) used materials or that new materials must be purchased. In addition, it is determined who becomes the owner of the materials obtained and what purpose they are given. The reuse of materials can influence the technical life span of the road.
- *Lifespan:* If the design and construction of a road is put out to tender, the owner of the road can make demands about the minimum life span of the road. If this is not achieved because of design or construction errors, the responsible party must compensate the owner.
- *Maintenance:* During the tendering procedure, requirements can be set for the maximum amount of maintenance to be carried out during the service life of a road. If this is not achieved because of design or implementation errors, the responsible party must compensate the owner.

Final definition

The technical residual lifespan cannot be expressed in years. This is because a road can be divided into various components and road sections. All these components and road sections each have their own preconditions. What these preconditions are and how they are measured, is determined by the CROW knowledge institute. The technical residual life of a road component can be extended by carrying out early and timely maintenance. The quality of a road component can be expressed by a scale. The technical residual lifespan is expired if the cost of maintaining the road is overtime larger than the cost of building a new road.

3.4.2 Community residual lifespan

The social residual life determined by the road administrator. The road authority mainly looks at a number of points that, in contrast to the technical residual life, have nothing to do with the quality of the road components.

Esthetical
The road administrator may choose to replace the materials in a road at an early stage because he no longer finds the road beautiful. The road administrator often does this when he wants to change or modernize the appearance of an area. The road authority often chooses to redesign the entire street.

Climate resilience
The definition of Climate resilience is a combination of different perceptions of climate change. In the Netherlands, the policy is to design an area climate adaptively as possible. This has impact on the design of public space. Especially on the paved area, the goal is more often to resurface paved area to green areas. Therefore, a road authority may choose to redesign heavily paved areas and make climate-adaptive design choices in the process.

The starting point is therefore to have as much unpaved surface as possible, and if this is not possible the road authority has to aim applying other solutions to allow all the rainwater to infiltrate on site and reduce heat stress. If this is not yet the case the road authority can choose to redesign the road to make the road climate resilience.

Safety
In the past, the design guidelines for roads were different than they are now; this can be a reason for the road administrator to replace the road. It can also happen that a road meets all the design guidelines but is still considered unsafe by the road users. This can be another reason for the road administrator to replace the road.

Financial
A road authority is often eligible for various subsidies in the areas of management & maintenance, climate adaptation and CO_2 reduction. Applying for these subsidies often requires meeting certain requirements that may influence the circularity within a road.

Final definition
The definition of the social life span is even be more difficult to express than the technical life span. This is because the social remaining life span is determined by the policy of the road administrator. A road or a road component is not necessarily of poor technical quality, if the social remaining life span is exceeded. In addition, it is not necessary to replace the road immediately. The social residual life of a road or road components is exceeded, if the road administrator determines so.

4 Case study: Griffiersveld

This project is using the street Griffiersveld as a case study for setting-up this tool. The first step is to investigate the street of Griffiersveld and what the project is all about. The next step is to look into how and where all the information about this street can be found an how this information is processed.

4.1 Introduction

In this section you can found analyses focusing on the case of Griffiersveld. The street Griffiersveld has been designated as a case study for setting up the tool which is the final goal of this research report. This was done, because Griffiersveld is the first street that is going to be addressed in a broader project.

Griffiersveld is located in the district de Maten in the municipality of Apeldoorn. The municipality created an area plan for the district. The goal of this area plan is to give the entire district "de Maten" in the municipality of Apeldoorn a uniform appearance. At present, the neighbourhood "de Maten" is very outdated and has a bit of a rundown impression. This is because the concrete paving stones that have been in place since 1977 have been worn away and only the chippings are visible. The original pink colour is almost nowhere to be seen. This area plan has the goal to have the same type, texture, and colour of pavement in the entire district and at the same time make the district more climate resistant.

The paving in Griffiersveld consists of two different types of pavements. There are 30 cm x 30 cm concrete tiles and concrete pavers. At the time of their construction, the concrete pavers were light purple. Over time, this colour has worn off due to erosion and traffic. As a result, only the grey crushed stone is visible. In the new design for Griffiersveld, all paving will be replaced by yellow concrete pavers. A small part of the paving will make way for greenery.

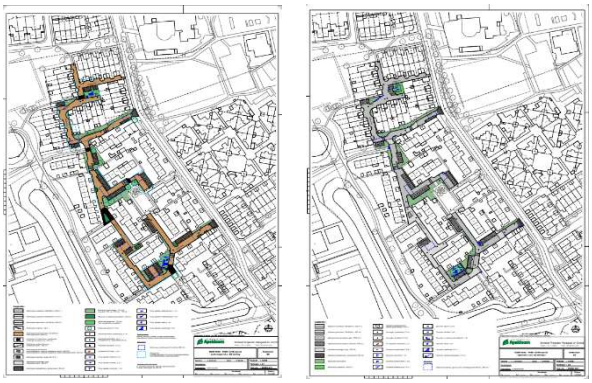


Figure 4.1: Current (left) and future (right) design

The sewage system of Griffiersveld is a combined system, this means that sewage water and rainwater are drained through the same system. In the new situation, 60% of the rainwater is disconnected from the sewer system and discharged into the surface water.

4.2 Inspection protocol

This section addresses the inspection protocol used by the Municipality of Apeldoorn. This section describes the steps that are taken during the inspections carried out on the municipality's road system. A visual inspection of the road surface is carried out every year.

This inspection takes place in accordance with the guidelines of CROW. CROW is a knowledge institute for infrastructure and public space in the Netherlands. The scope of this project is elementary pavements. During a visual inspection of elementary pavements, the following defects are taken into account (CROW, 2011):

- Quality of elements
- Transverse misalignment
- Unevenness
- Joint width
- Cant-op closure
- Holes
- Drainage
- Roadside
- Setting
- Longitudinal flatness.

The visual inspection is carried out by a hired company. This company carries out the inspection and passes on the results to the data manager of the Municipality of Apeldoorn. The results are then processed in the GBI system. This is discussed in more detail in the section Information processing. A street in municipality Apeldoorn is inspected once every two years. All the asphalt roads are inspected by radioactive scanners, the rest of the roads and road components are inspected at location by a road inspector.

4.3 Information processing

The Municipality of Apeldoorn performs the inspections in accordance with CROW guidelines. A visual inspection is carried out annually for each road section. The results of this visual inspection are processed in the GBI, as stated above. Based on the data in the GBI, a road maintenance schedule is then drawn up. This planning is based on the score values of the road section components. But before road maintenance is started, a measure test is also carried out. During this test, the road inspectors of the municipality carry out an additional inspection of the road sections that need to be replaced or maintained according to the visual inspection and the GBI. The actual road maintenance schedule is then drawn up based on this measure test

After the inspection is conducted by the standards of knowledge institute CROW the results are processed in the GBI-system of the municipality. In GBI there is a total of 53 fields that can be filled in by the inspector of by an road-administrator. The most of these fields are focused on asphalt pavements, this is the reason why in the case of Griffiersveld these fields are left blank.

For elemental pavement a total of three fields of interest to the quality can be regarded. This is not enough to determine the quality of the pavers. The subject of quality of the pavers will be expressed in another section. At this moment the fields that are used in the GBI environment to determine the quality of the concrete pavers an tiles are:

- Unevenness of the elements;
- Transverse unevenness of the elements;
- Look of the elements.

The Antea-group can expand the criteria on demand of the municipality or another user of the GBI software. This creates opportunities for the development of the tool.

5 The visualisation tool

This section describes how the 3D visualization-tool is set up and how it will be further analyzed. It starts with the systems definition of the tool. This means that is described with criteria the system must apply to. After the system is defined the existing information systems of the municipality of Apeldoorn are evaluated and looked into. If these two steps are clear, the development process of the tool is described.

The system definition is extracted from the main research question and is as follows:

"A digital 3D tool linked to existing information systems used by the municipality to visualize the data that is needed in the different stages a circular road renovation project."

This system will be defined in three different sections. In the first section the information systems currently used by municipality Apeldoorn are evaluated and looked into. The second section is describing the different stages within a circular road renovation. In the last section is will be described how to tool is set-up.

5.1 Existing information systems

5.1.1 Software: Revit

This section looks at which existing tools are available, their advantages and disadvantages, and how these tools will be used during the research and the set-up of the visualization tool. In the current model (see Figure 5.1), masses (seen as buildings/residences) and streets are used, in which the structure of the street and soil layers (Figure 5.2) are incorporated. The streets are also divided into road sections. These road sections are not in connection with the GBI system of municipality of Apeldoorn. To make this connection certain steps must be taken. The big con here is that this is not a direct connection, and the model cannot automatically be updated

Revit is a building-information model (BIM) that is used for the elaboration and design of buildings (Autodesk, 2022). A lot of information can be put into and taken out of the different "building blocks" in this software program. Revit is specialized for working out buildings, but when it comes to visualizing districts and cities, problems arise. Initially, the 3D software Revit was used. This program works well on a small scale, but when working on a large scale it is a heavy program to work with and therefore not suitable for the future purposes of CityLoops. Furthermore, it is difficult to apply a color system as mentioned in section 5.1.3. In Revit, it is difficult or even impossible to apply color codes to masses and road sections.

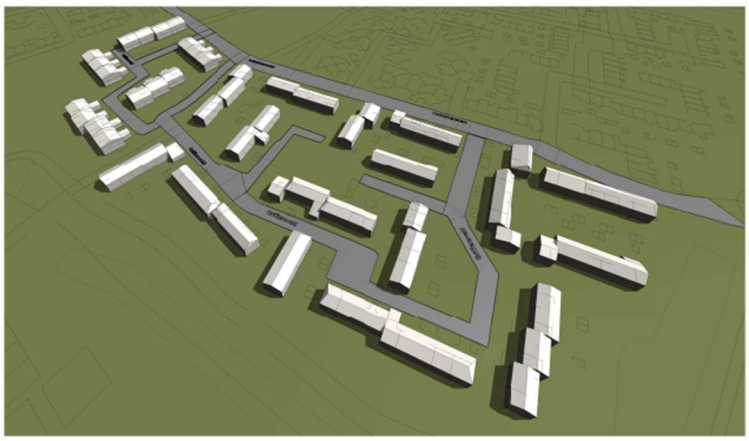


Figure 5.2: Visualisation of the current tool in Revit

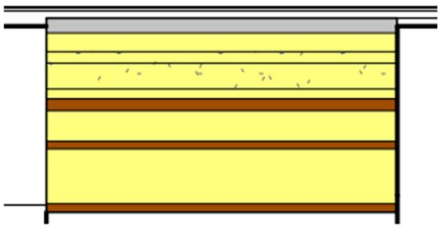


Figure 5.1: Street and ground layers Griffiersveld as shown in Revit

5.1.2 Software: GBI

The software that the municipality of Apeldoorn uses for their road management is GBI. GBI is a Dutch program that stands for 'gemeentelijk beheer informatiesysteem' what translates into Municipal Management Information System. This program is developed by a Dutch engineering firm called Anthea to help municipalities to create a system for asset management in public space. This program uses the principles of GIS (Geographical Information System) to create an online database of the road network in municipality Apeldoorn. In this database the Municipal employees have a detailed insight of the inspections and maintenance logs of the different road sections. It can therefore easily be exported to other programs, such as QGIS and Arcgis. In the GBI, all information that is collected from road inspections is processed as described in in Section 4.3. data processing GBI.

5.2 Information for stages in circular road renovation

In this section the different steps and the associated demanded information are described. This is done by combining the results from Section 4 and by making an inventory of information necessary to be included in the tool. To monitor and evaluate the existing road the following information is necessary:

The first step that can be monitored in the tool is the current condition of the road. In this stage is important to have a good idea of the quantity of the materials used in the different road components. Besides the quantity of materials, it is important to have the maintenance and inspection logs of the systems of the municipality.

- *Evaluation of the existing road* by means of an detailed view on the condition of the road. This can help the road manager decide when to undertake action and start renovating the road.

- *Quality of the materials used in the road.* If the quality of the materials is not meet the technical requirement the material must be replaced.
- *Pavement area of a certain quality.* If the quality of the materials is not meet the technical requirement the material must be replaced. It is important how much.
- *Volume and type of foundation.* If the quality of the materials is not meet the technical requirement the material must be replaced. It is important how much
- *GBI System.* The basic information of the road is stored in the GBI-system so it is important that the tool is connected to this system.

- *Design of the new road.* If a new road is designed the road it is important to have an detailed overview of the quantities and qualities of the used materials. This is import to determine a new purpose for the materials or reusing the materials in the new road.
  - *Quality of the materials used in the road.* It is important to have an overview of which materials can be used in the new road. Therefor the quality of the materials in the road is important. This way all the materials can be relocated to a new location or reused in the new road.
  - *Pavement area of a certain quality.* It is important to have an overview of how much materials can be used in the new road. Therefor the quality of the materials in the road is important. This way all the materials can be relocated to a new location or reused in the new road.
  - *Volume and type of the foundation.* It is important to have an overview of how much materials can be used in the new road. Therefor the quality of the materials in the road is important. This way all the materials can be relocated to a new location or reused in the new road.

- *Road maintenance.* If the new road has been constructed it is important to monitor the quality of the road. This way the road authority can determine when to plan necessary maintenance.
  - *Quality of the materials used in the road.* If the quality of the materials is not meet the technical requirement the material must be replaced.
  - *Pavement area of a certain quality.* If the quality of the materials is not meet the technical requirement the material must be replaced. It is important how much
  - *Volume and type of the foundation.* If the quality of the materials is not meet the technical requirement the material must be replaced. It is important how much
  - *GBI System.* The basic information of the road is stored in the GBI-system so it is important that the tool is connected to this system.

- *End of life.* At the end of this life cyclus, the cycle will repeat until the road will be demolished for good.

5.3 Digital 3D tool

5.3.1 Software: QGIS

For the first step to creating a new tool is deciding with program is going to be used. Because the information from GBI was not possible to implement in the Revit tool. Revit could not be used for municipal reasons; it was decided to set up a tool in a program that comes close to it. The program QGIS was chosen for this because all information from the GBI could easily be exported. In addition, the information in the existing Revit tool could easily be presented in QGIS via other channels. The following QGIS definitions are important to be familiar with (QGIS, 2022):

WFS-connection: A Web Feature Service-connection provides its users with GIS data in formats, that can be loaded directly in QGIS. It updates when the link itself is updated, and is reloaded into QGIS.

Shapefile: a file with polygons, lines or areas and is used to display certain 2D elements with information in them. CVS-file (Comma Separated Values) are files extracted from a software like QGIS to an Excel file. Those files can be used for using values or connect them to another layer in QGIS.

Geopackage: is an open, standard-based and self-describing format for transferring geospatial information. It contains OGC encoding standards for storing vector features, tile matrix, non-spatial attributes data and extensions.

Overlay: an overlay is a layer that can be used to connect another layer of which some features overlap with another. This creates a new layer with information and features from both layers.

BAG: a BAG is a layer which contains geodata of e.g buildings/properties or streets of cities. They contain columns with data such as the year of construction of a building, the area of the building, the energy label, etc. Every layer in QGIS has its own save file; make sure there is a logical pathway for the different layers, if it is necessary to do so.

5.3.2 The tool

The software used to develop this 3D tool is: QGIS. Section 5.3.1 explains why this is the best software for this tool. The tool is delimited to the district Griffiersveld, as explained in Section 2.3. and as is visualised in Figure 5.3.

Figure 5.3: Limited area: Griffiersveld

The tool is made from several layers. First, a layer with a background map of the entire Netherlands has been added. This map is linked to the pdok, an open geodata portal, through a link (PDOK, 2022). Via the pdok site you can add current information to QGIS by copying and pasting the link in the URL bar (as shown in Figure

5.5). If this link is updated, the map will be refreshed when the project is started again. URL site: https://www.pdok.nl/geo-services/-/article/basisregistratie-adressen-en-gebouwen-ba-1

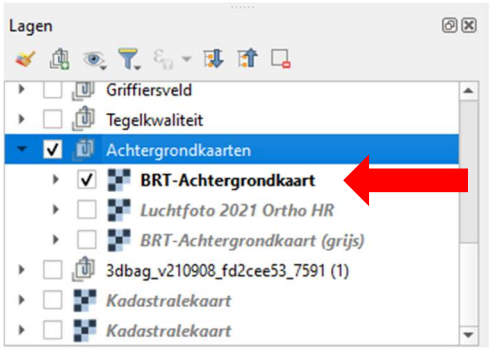


Figure 5.4: Layer with the background map

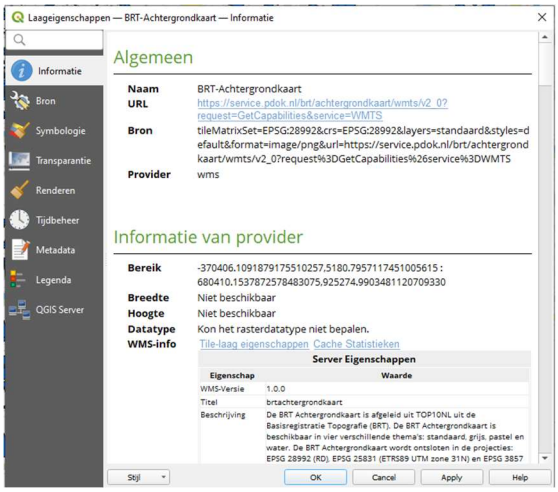


Figure 5.5: Layer properties menu

Then a layer of the district Griffiersveld is added as a 2D element (see Figure 5.7). This layer comes from the software GBI, from the municipality of Apeldoorn. This layer contains information of the houses in Griffiersveld. It contains columns with information about the year of construction of the house, the street name of the house, the energy label of the house, etc. This layer from GBI cannot be displayed in 3D, therefore four datasets (7591, 7592, 7593 & 7594) with 3D elements (see Figure 5.6) of the Griffiersveld district have been added. These come from 3D BAG (see Figure 5.8), which is created by the TU Delft. This is a 3D viewer of all the buildings in the Netherlands and is accessible via the following link: https://3dbag.nl/en/viewer (TU Delft, 2022). Because of this, the houses of Griffiersveld are visible in 3D.

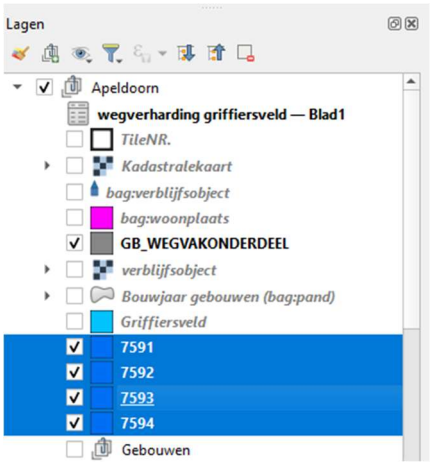


Figure 5.7: Layers containing the 3D elements (houses)

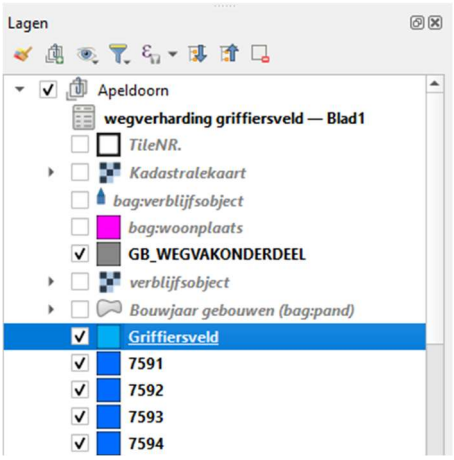


Figure 5.6: Layer containing the information (2D elements)

Figure 5.8: 3D BAG from TU Delft (TU Delft, 2022)

Next, the layer "Griffiersveld" is linked with the four layers containing the 3D elements of the houses (7591, 7592, 7593 & 7594). Here, the desired columns were selected which had to be adopted. However, this did not go perfectly, because there were double columns, one of which did not contain any information and the other one did. This problem has not yet been solved in the current tool. It is also awkward that two layers are required for a 3D element. This has to do with the fact that the geopackages from GBI are 2D instead of 3D. To improve this, this information from GBI must be linked to a file containing the 3D elements of the houses.

Now that the 3D elements (houses) contain information (see Figure 5.9), the first part of the tool is complete. Next, the road sections of Griffiersveld are added as a layer. This is also a geopackage from GBI and contains information about each road section. This information

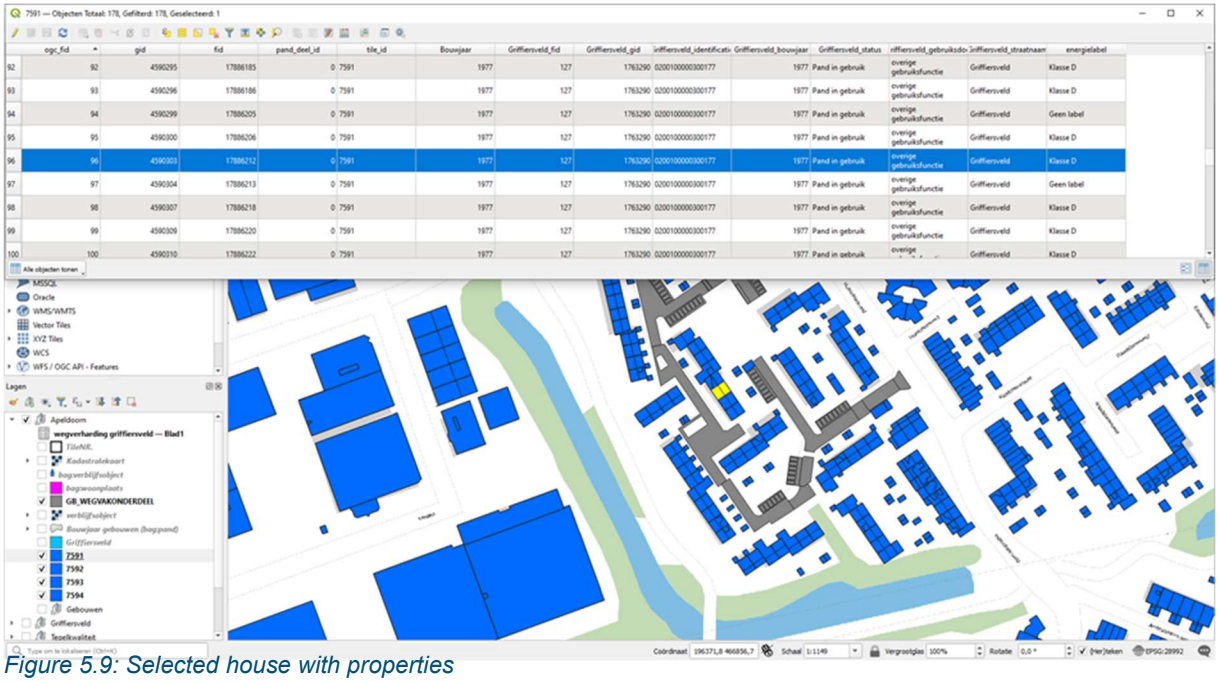


Figure 5.9: Selected house with properties

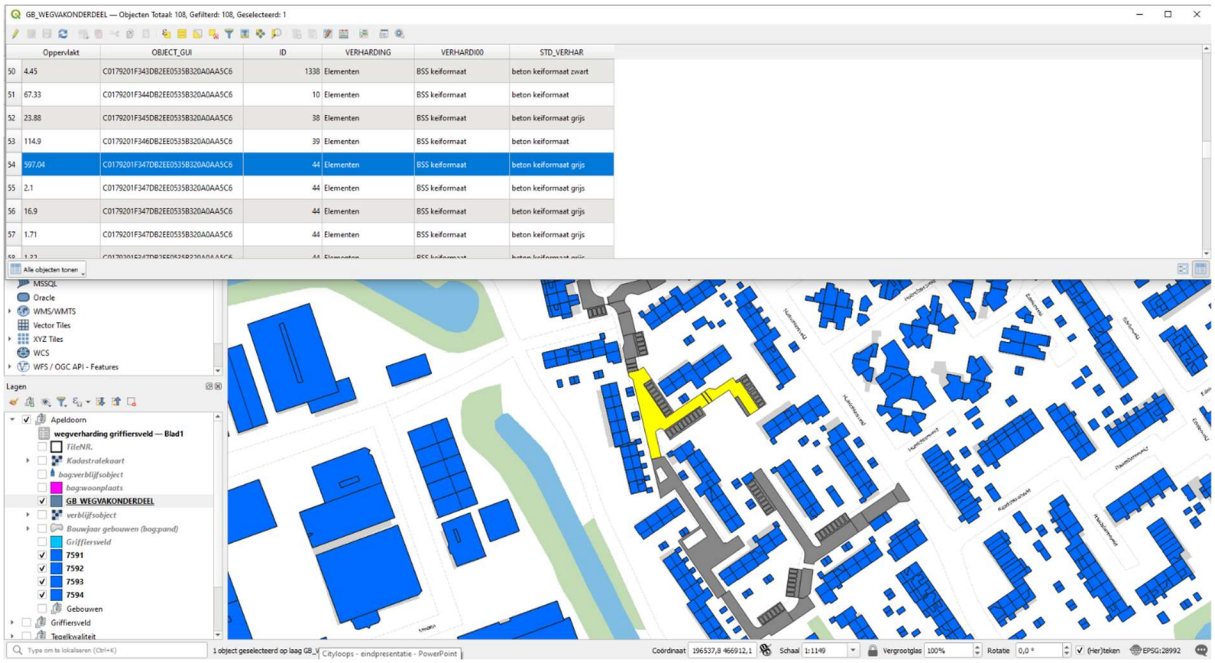


Figure 5.10: Information of the selected road section

includes the surface area of the road section, the street name, the type of surfacing and so on. As is seen in Figure 5.10. Unfortunately, the construction year of the street is not included, as this column was linked to GBI, but not to the shapefile we received, which was desirable.

In the end, the visualisation of Griffiersveld was successful and it looks like Figure 5.11 and Figure 5.12). To extract information from these 3D elements you need to select the right layer from the "layers" menu. When you have selected the correct layer, you can use the select button  to select a 3D element of the selected layer. Then click the property table button.  If all goes well, a screen with columns will appear. In this table, a row has been selected (blue) and information from the selected element can be read and used. This information can also be exported to Excel. More about this in Section 5.3.4.

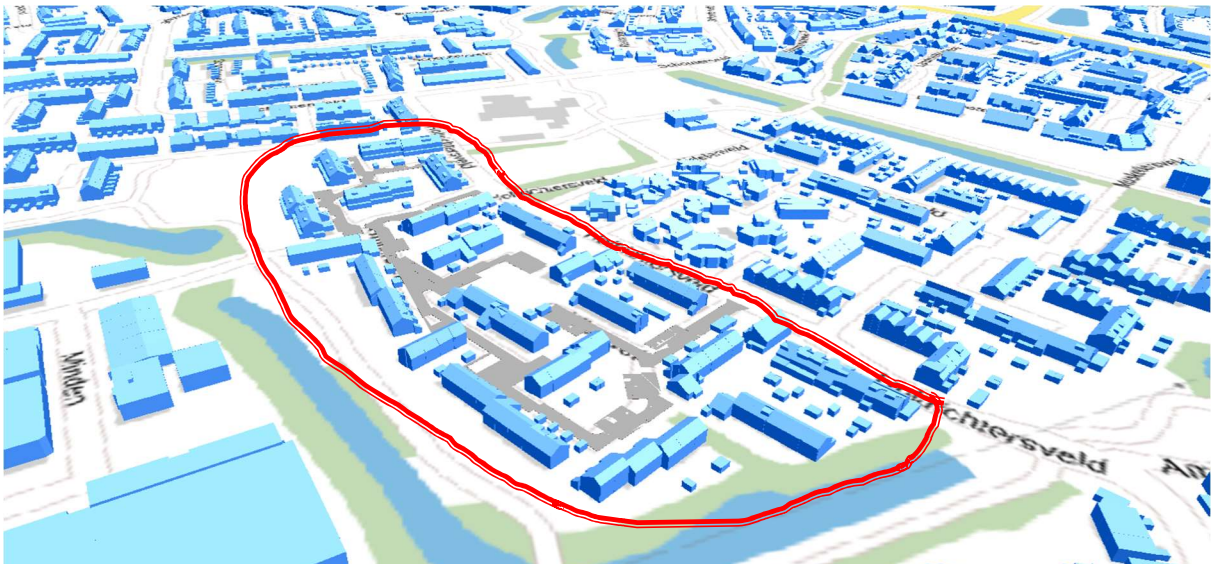


Figure 5.11: Griffiersveld in 3D

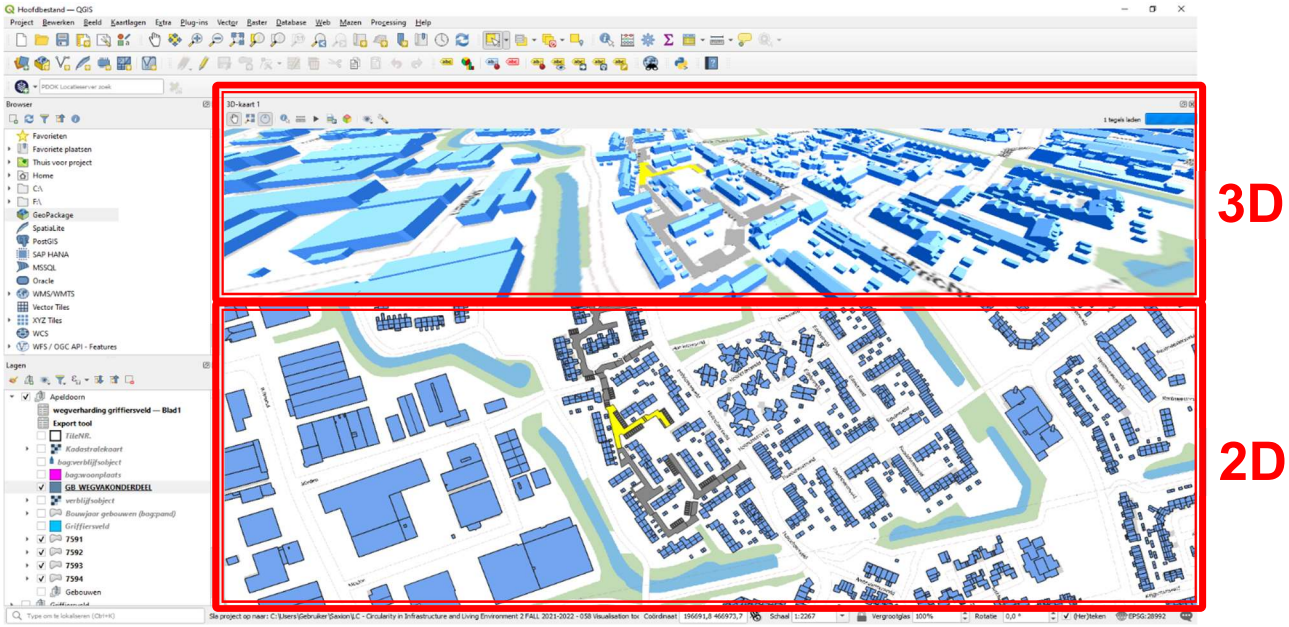


Figure 5.12: 2D and 3D view of Griffiersveld; in yellow the selected road section is shown.

5.3.3 Data sources

For the data sources the data from the previous tool is analysed in Section 5.1.1. and applied into the new QGIS-tool. Through this way the existing tool including is functions are transferred to the program of QGIS.

One of the initial reasons the tool was set-up in Revit to directly implement a material passport of a building into the tool. These building Passports can usually be exported to an excel sheet. If an identification number is included the material passport can easily be loaded in and linked to the 3D or 2D visualisation of the building.

The road section is exported out of GBI, these files are a one-on-one copy of the program. The big difference here is that the wanted filters must be implemented again in the QGIS-file. The TU Delft created a program to recreate the shapes of all building in the Netherlands. This dataset is used to make an 3D visualisation and make the tool more visual attractive to use.

To implement useful data into the 3D visualisation the information from the dataset BAG (Basic Registration of Addresses and Buildings) is used. The BAG dataset is linked in through a WFS connection, thereafter the data from the municipality Apeldoorn is extracted from the dataset.

The municipality wanted to add another dataset from the national energy atlas. In this dataset the houses in the Netherlands are given an energy-label. This data set was added by using the national energy map of the Netherlands. Unfortunately, these were added manually to each house in Griffiersveld. It's preferable to add this information in GBI directly.

5.3.4 Excel imports and exports

With the software QGIS, it is possible to export the values to Excel. This is also one of the reasons for choosing QGIS. When you click on "export" with the right mouse button and then on "save layer as". If everything goes right, you should see a screen with the information seen on Figure 5.13. Then you must select "comma separated values" (CVS) under "format". Then select the desired file name. Then select "separator: semicolon" under "layer options". This ensures that the columns also appear as columns in Excel. When you open the saved file with Excel you should see a file that looks like Figure 5.14.

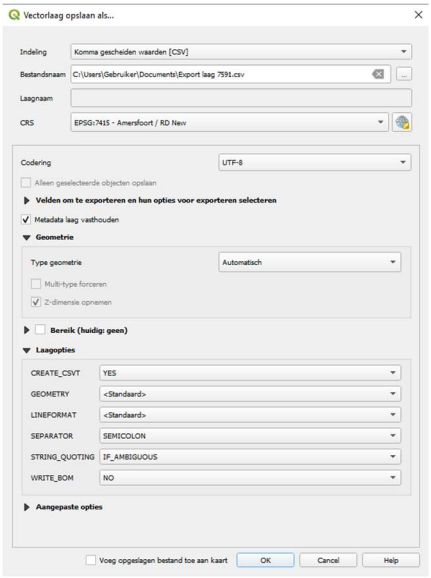


Figure 5.14: Save menu: export to Excel

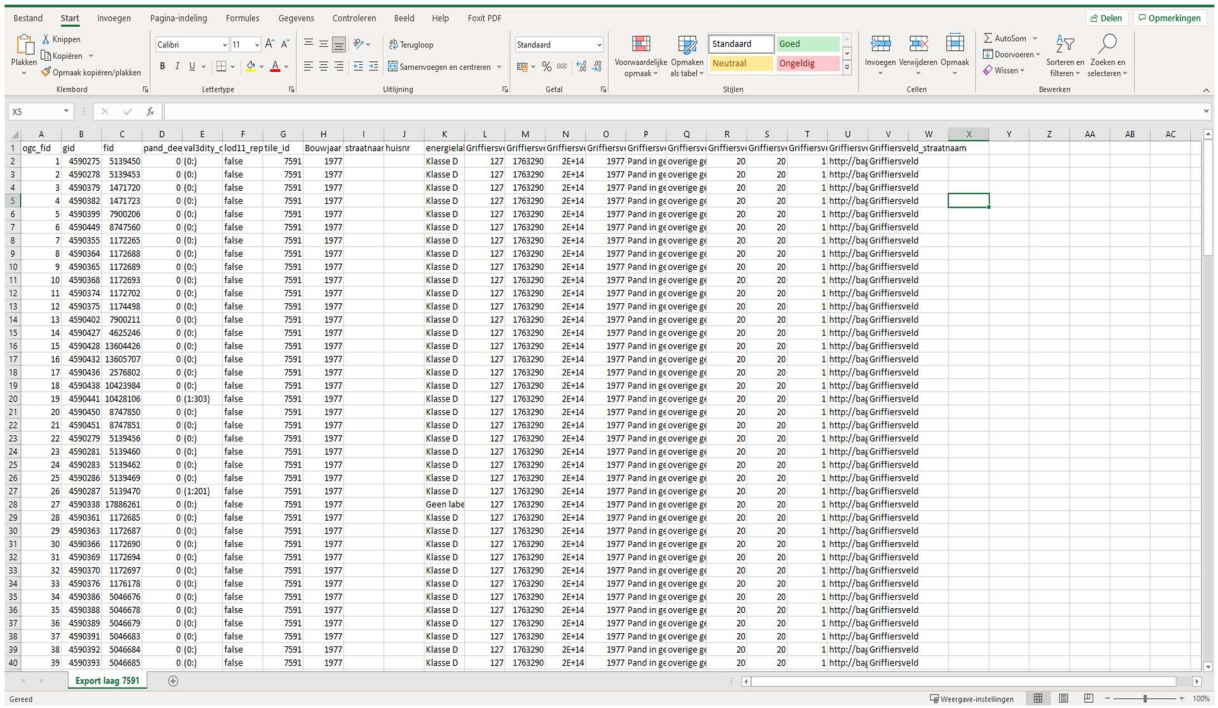


Figure 5.13: Properties table exported to Excel

To load the Excel file again, click on "map layers" in the menu bar. Then click "add layer" and select "add text separated layer" as shown in Figure 5.15. Then you will see a menu like Figure 5.16. Select the correct file and fill in the correct details as shown in the menu below. When the new import layer is loaded, you can link this layer again with the desired new information in the Excel file.

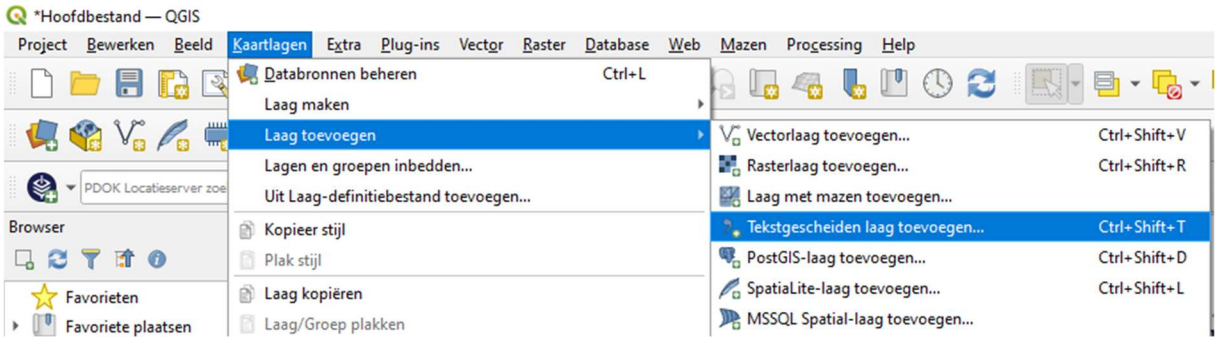


Figure 5.15: How to import an Excel layer

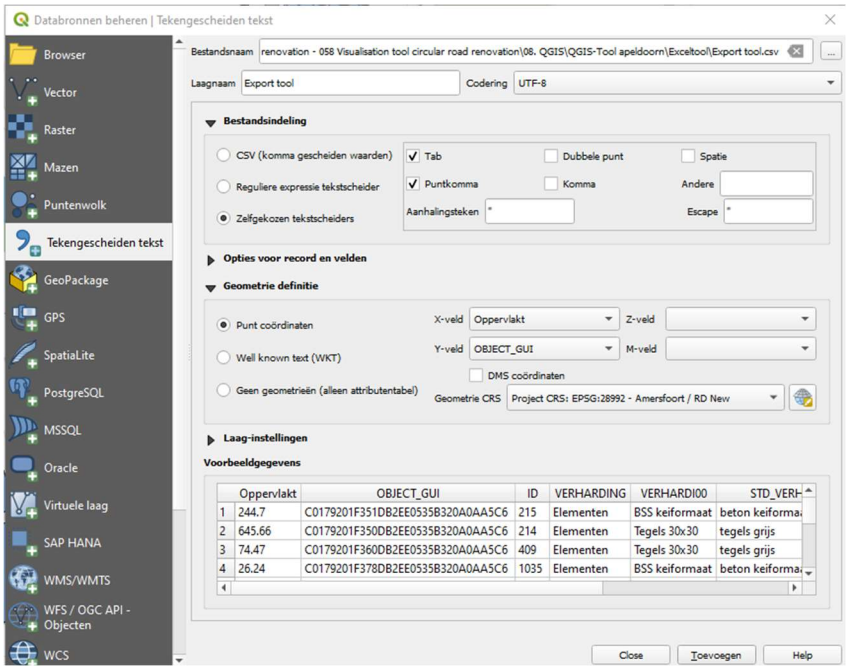


Figure 5.16: Text separated layer menu

5.3.5 Encountered difficulties

As already partly mentioned in Section 5.3.2, some difficulties emerged. First of all, problems emerged concerning the linking of some cells. The intention was to link the 2D elements with information to the 3D elements without information. This linking was successful, however, not all values were transferred correctly. This relates to the column "bouwjaar" (in English: “year of construction”. Next, this link was removed and recreated. Also, this time, no good result was achieved, and we couldn’t figure out how to get it to work. So, for this reason, it was decided to retain the wrong values in this case. But when the tool is expanded, this should be corrected before going further.

The plan was to implement a colouring system like seen in Figure 5.17 based of the year of construction of each individual building. This system currently does work, but all the buildings have the same year of construction (1977), which is incorrect. This leads to only one colour instead of a colour scale.

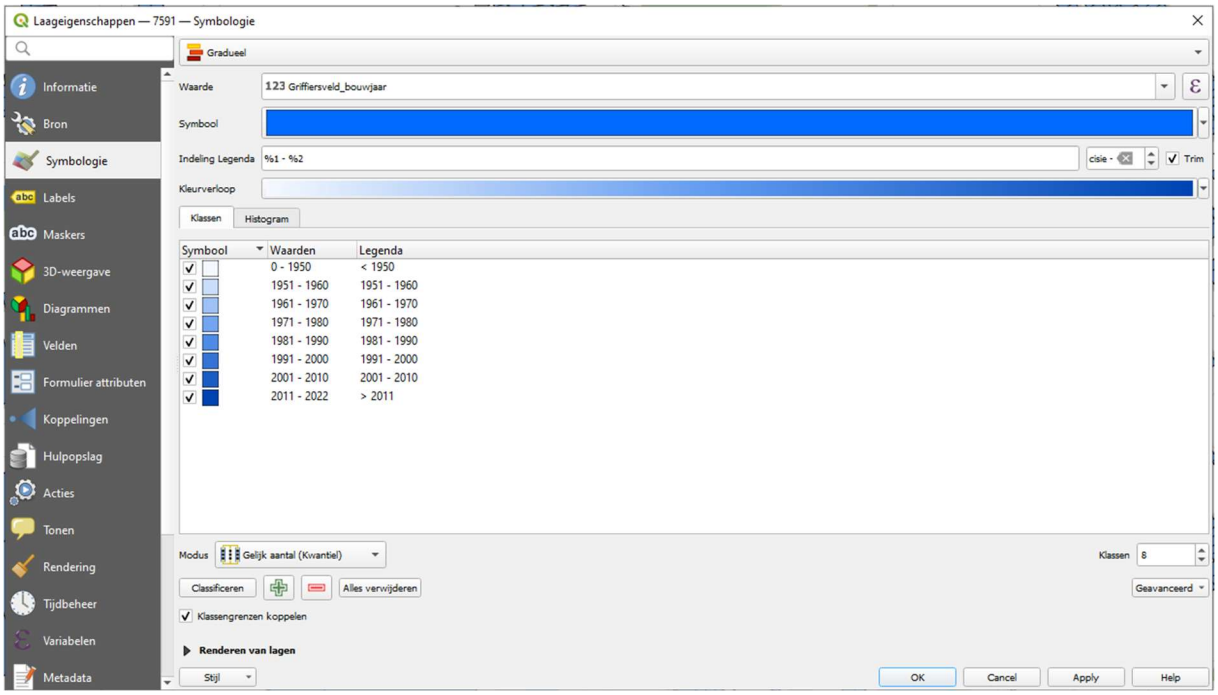


Figure 5.17: Intended colour scale of the buildings

We also had problems with the road sections. The geo-package of the road sections does not contain the desired information. This information should be added from GBI. After contacting the relevant person, it turned out that this information was present in GBI but was missing in the geo-package. It was then decided to leave it as it is.

5.3.6 Future of the tool

In order to improve and extend the tool, it is expected that it can be extended to entire cities instead of the current concept that only focuses on the district Griffiersveld. The intention is to add colour scales for buildings and roads that show the status of the desired value, as intended in Section 5.3.5. The colour scales give a simple overview in which the status of the required value can be seen at a glance.

3D (instead of 2D) geo-packages with information from GBI should also be added to simplify the connection with QGIS, so that it only requires one instead of two actions. Also, the linking of, for example, the construction years must be improved. This problem needs to be solved in order to use the tool properly. When the correct road information is added, then a colouring scale can be added for that road, like was done with the buildings.

5.3.7 End of Life

The quality of a road can be expressed in an esthetical and Technical terms. It is important do make a separation between quality of concrete pavers. This is important to monitor the quality of the concrete pavers and, when the paver is no longer wanted or being used, to find a new purpose for the paver.

Esthetical: the esthetical quality of concrete pavers is objectively determined. That a concrete element is no longer is esthetical appealing doesn't mean that the paver is creating damage to the road, road users or is creating dangerous situations. The esthetical values are determined by the road owner.

Technical: the technical quality of a concrete paver is easy to determine, if the concrete is broken the element is considered useless for using as a paver. If this happens the paver will be recycled for the raw materials of used as rubble foundation for a new infrastructure project.

Criteria	Description	Impact on quality	Description
Erosion of top layer	None existent	None (only aesthetic)	Top layer is clearly visible.
	Light Existent	Moderate (only aesthetic)	The crushed stone comes through top layer.
	Heavy existent	Heavy (only aesthetic)	The top layer is no longer visible. The entire top of the element consists of stone chippings.
Fracture	Not existent	None	The stone is not fractured.
	existent	Heavy	The element is fractured in two or more pieces.
Crumbling	Not Existent	None	The chippings in the element are not crumbling.
	Light Existent	Moderate	The rock chippings in the tooth are slightly chipping.
	Heavy Existent	Heavy	The rock chippings in the component are chipping heavily.

Table 5.1: Criteria table of individual stones

	1	2	3	4	5	6	7	8	9	10	11	12
1	Oppervlakt	OBJECT_GUI	ID	VERHARDING	VERHARDI00	STD_VERHAR	groen	oranje	rood	opp (m2)	opp (m2)	opp (m2)
2	244.7	C0179201F351DB2EE0535B320A0AA5C6	215	Elementen	BSS keiformaat	beton keiformaat	50%	20%	30%	122.35	48.94	73.41
3	645.66	C0179201F350DB2EE0535B320A0AA5C6	214	Elementen	Tegels 30x30	tegels grijs	80%	15%	5%	516.53	96.85	32.28
4	74.47	C0179201F360DB2EE0535B320A0AA5C6	409	Elementen	Tegels 30x30	tegels grijs	50%	20%	30%	37.24	14.89	22.34
5	26.24	C0179201F378DB2EE0535B320A0AA5C6	1035	Elementen	BSS keiformaat	beton keiformaat grijs	80%	15%	5%	20.99	3.94	1.31
6	597.04	C0179201F347DB2EE0535B320A0AA5C6	44	Elementen	BSS keiformaat	beton keiformaat grijs	50%	20%	30%	298.52	119.41	179.11
7	73.03	C0179201F376DB2EE0535B320A0AA5C6	1011	Elementen	BSS keiformaat	beton keiformaat	80%	15%	5%	58.42	10.95	3.65
8	43.1	C0179201F359DB2EE0535B320A0AA5C6	387	Elementen	BSS keiformaat	beton keiformaat	50%	20%	30%	21.55	8.62	12.93
9	0.97	C0179201F34DDB2EE0535B320A0AA5C6	208	Elementen	BSS overig	betonstraatstenen overig	80%	15%	5%	0.78	0.15	0.05
10	51.91	C0179201F35BDB2EE0535B320A0AA5C6	398	Elementen	BSS keiformaat	beton keiformaat grijs	50%	20%	30%	25.96	10.38	15.57
11	406.84	C0179201F35DDB2EE0535B320A0AA5C6	400	Elementen	Sierbestrating	sierbestrating	80%	15%	5%	325.47	61.03	20.34
12	67.33	C0179201F344DB2EE0535B320A0AA5C6	10	Elementen	BSS keiformaat	beton keiformaat	50%	20%	30%	33.67	13.47	20.2
13	51.95	C0179201F34EDB2EE0535B320A0AA5C6	210	Elementen	BSS keiformaat	beton keiformaat grijs	80%	15%	5%	41.56	7.79	2.6
14	6.78	C0179201F2EBDB2EE0535B320A0AA5C6	1158	Elementen	BSS Keiformaat	beton keiformaat zwart	50%	20%	30%	3.39	1.36	2.03
15	68.43	C0179201F365DB2EE0535B320A0AA5C6	554	Elementen	Tegels 30x30	tegels grijs	80%	15%	5%	54.74	10.26	3.42
16	47.04	C0179201F35EDB2EE0535B320A0AA5C6	401	Elementen	Tegels 30x30	tegels grijs	50%	20%	30%	23.52	9.41	14.11
17	38.5	C0179201F36BDB2EE0535B320A0AA5C6	858	Elementen	BSS overig	betonstraatstenen overig	80%	15%	5%	30.8	5.78	1.93
18	25.22	C0179201F354DB2EE0535B320A0AA5C6	311	Elementen	BSS keiformaat	beton keiformaat grijs	50%	20%	30%	12.61	5.04	7.57
19	39.74	C0179201F2DADB2EE0535B320A0AA5C6	1040	Elementen	BSS keiformaat	beton keiformaat grijs	80%	15%	5%	31.79	5.96	1.99
20	33.42	C0179201F35CDB2EE0535B320A0AA5C6	399	Elementen	BSS keiformaat	beton keiformaat	50%	20%	30%	16.71	6.68	10.03
21	114.9	C0179201F346DB2EE0535B320A0AA5C6	39	Elementen	BSS keiformaat	beton keiformaat	80%	15%	5%	91.92	17.24	5.75
22	0.22	C0179201F2FEDB2EE0535B320A0AA5C6	1193	Elementen	BSS Keiformaat	beton keiformaat zwart	50%	20%	30%	0.11	0.04	0.07

Figure 5.18: Exported Excel document from QGIS

The tool works on the basis of various road sections that are exported from the GBI of the Municipality of Apeldoorn. Each road segment has its own ID, which makes it possible to link the information from road segments. Because of opposition within the municipality of Apeldoorn, it is difficult to link this information to the systems of the municipality of Apeldoorn. However, we have put down on paper our insights on how this should be assessed.

Figure 5.18 shows part of an exported Excel file from QGIS. The columns "groen" (green), "oranje" (orange) and "rood" (red) have been added. These are linked to percentages that show how many square metres of stone have a certain quality. Green stands for aesthetic high-quality reuse (can be reused by the municipality itself). Orange stands for non-aesthetic high-quality reuse. This means that the bricks are of good quality for reuse, but not of the quality required by the local authority. Red indicates broken bricks or non-reusable bricks. These can only be reused by recycling.

Green: a green marking means that the tiles and concrete pavers are still of good quality from a technical and aesthetic point of view. This means that the materials could be reused in aesthetically high-quality places.

Orange: an orange marking means that the tiles and pavers still meet all technical requirements but are no longer aesthetically pleasing. This means that the materials can be used in less aesthetically pleasing places.

Red: a red marking means that the tiles and pavers no longer meet all technical and aesthetic requirements. This means that the materials are of the best use if they are recycled the right way.

6 Residents' participation

In this section a definition of resident participation will first be given, after which two theoretical models will be explained and applied. Following that, the OpenStad participation platform will be briefly explained, as well as why this platform will not be used after all. As a result, three projects have been developed in the remainder of this section to encourage citizens to participate in the circular economy.

6.1 Definition Resident Participation

Veen (2010) defines resident participation as “a process of continuous and broad involvement of residents through formal forms of participation in all phases of urban renewal, in which everyone can participate and where they are actively involved based on their knowledge of the neighbourhood. in the planning process, to positively influence the quality of the plan” (p. 19).

6.2 The Participation Ladder

The participation ladder of Edelenbos and Monnikhof (2001) consists of five steps, whereby the degree of participation increases and the number of participants decreases. The ladder distinguishes five forms of participation; inform, consult, advise, co-produce and participate in decision-making (see Figure 6.1). The already mentioned forms will be explained in this section.

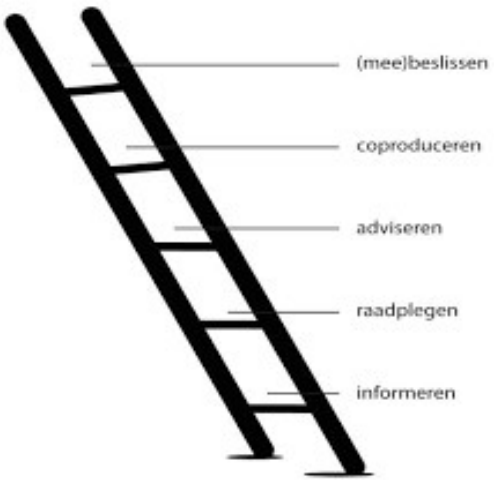


Figure 6.1 The Participation Ladder (Edelenbos & Monnikhof, 2001)

Informing is the first step on the participation ladder, in which municipalities only inform residents. The residents have no influence on the policy proposals. Consulting is the second step on the participation ladder. During consultation, residents can give their opinion on the policy proposals, but they have no influence on this. The third step of the participation ladder is advice, in which residents are given the opportunity to choose from a number of policy proposals drawn up in advance. Co-production is the fourth rung on the participation ladder. In the case of co-production, municipalities establish a framework that the residents themselves can define. The last step and also the highest form of participation is decision making. In decision-making, municipalities and residents jointly shape the policy proposals (Veen, 2010).

The municipality of Apeldoorn is currently on level one, as they only inform their residents and does not allow them to participate in the decision-making process. Apeldoorn wishes to move

to level five, where the municipality jointly makes decisions and formulate policy proposals. Apeldoorn wants to achieve this through Open Stad. Open Stad is, as will be discussed in more detail further in this section, an open-source platform for digital participation projects. Utilizing OpenStad Apeldoorn and students from Saxion want to promote residents' participation by informing residents. By inquiring residents about existing grants and circularity, we want to motivate residents to think about the impact they can have in reducing the CO_2 emissions by reusing materials and isolating their homes.

6.3 The CLEAR-model

In recent years, various studies have contributed to the knowledge of the enabling conditions for citizen participation. The CLEAR model, developed by Lowndes, Pratchett and Stoker (2006), combines results from previous studies and provides a clear overview of enabling conditions for citizen participation. The CLEAR model distinguishes five factors:

- **C**an do – can residents participate.
- **L**ike to – do residents want to participate.
- **E**nabled to – are residents enable to participate.
- **A**sked to – are residents asked to participate.
- **R**esponded to – can residents see that their input is listened to and is being used.

The first factor addresses the question of whether citizens have the necessary skills and facilities to participate. The second factor questions the extent to which citizens are willing to participate. The third question that is central to the CLEAR model is to what extent residents have access to the necessary organisations, facilities and networks. The fourth factor deals with the question of whether and how residents have been asked to contribute to the policy for the neighbourhood. If residents are listened to and residents see that their contribution has been reflected in the policy, then the fifth enabling condition is met (Lowndes , Pratchett, & Stoker, 2006).

6.4 Open Stad

Open Stad is an interactive website that aims to strengthen the collaboration between residents and municipalities. Through a dynamic website builder, the municipality can create a tool for each project in the municipality's corporate identity. Depending on the project, the municipality determines which widgets are necessary to maximize residents' participation (OpenStad 2022; VNG, 2022).

The platform is in use by various municipalities, including the municipality of The Hague. The municipality of The Hague decided to use this platform in 2019 and has now used it for 24 projects. For example, 4,098 residents of the Benoordenhout district voted online for their favourite residents' plans. That is a response of 33 per cent of the residential area, which is considerably higher when compared to previous projects where Open Stad was not utilized.

Figure 6.2 Open Stad as used by the municipality of The Hague.

Disclaimer

Unfortunately, halfway through the project, it was decided not to go ahead with Open City, as no 'go' was given to purchase the package. Miscommunication resulted in an essential signature missing. Resident participation is still an important topic within this project and an important condition for receiving a subsidy. That is why it has been decided to develop three participation projects regarding circularity. The main aim of these projects is to inform the residents of Griffiersveld about circularity and to be actively involved in circularity. The projects are explained is more detail in Sections 7.5 to 7.7. The 3D tool has little added value for residents, but the municipality of Apeldoorn can use the tool to show residents that the municipality is actively working on circularity.

6.5 Tiles Swapping

During 'NK-Tegelwippen', tiles are replaced with greenery to prevent flooding, provide cooling in hot weather, conserve water in droughts, and enhance living space for plants and animals. Furthermore, living in a green environment is beneficial to our mental health. The aim is also to create awareness among residents about circularity (Dus Wat Gaan Wij Doen, 2021).

6.5.1 Activities

The activities are divided into milestones and tasks as can be seen in Table 6.1. The municipality must first register in order to participate in the 'NK-Tegelwippen'. The municipality is then responsible for encouraging residents to engage in the 'NK-Tegelwippen'. The

municipality accomplishes this by informing residents through a communication strategy. This is covered in greater depth later in this section. During the period when residents can rock their tiles, the municipality will also have to make an effort to make materials available and provide a service for gathering tiles.

Milestones	Sub- milestones	Deadlines
Sign Up		February 10
Competition	Inform residents through various media.	Until October 31
Tiles swapping	Have residents register on the 'NK-Tegelwippen' website. Inform residents about matters such as subsidies, important data. Set up tile collection service Making equipment available	March 21 to October 31 Until October 31 February 10 to March 21 February 10 to October 31
Win		

Table 6.1 Milestones

6.5.2 Risks assessment

Every project carries hazards that can impair the project's planning and execution. These can be internal and external. A number of risks related to this project are discussed in Section 6.5.2.

Missing the application deadline
The municipality of Apeldoorn will be unable to participate in 'NK-Tegelwippen' if it does not register on time. Therefore, registration must be given a prominent place in the planning and project meetings.

Residents are informed too late and/or insufficiently
Residents who are not informed in a timely and adequate manner may be unable to participate in het NK-tegelwippen. They had no notion that 'NK-Tegelwippen' is taking place. Therefore, residents must be informed in time via a letter. Receiving a note in the letterbox is uncommon, that residents will likely read it. In addition, it is a good idea to organize an informative market to inform locals.

Residents do not register on the website of 'NK-Tegelwippen'
Photos of the tiles must be taken and uploaded to the 'NK-Tegelwippen' website. If not done, the tiles are excluded from the final score. As a result, the municipality's chances of winning 'NK-Tegelwippen' are reduced. Residents must therefore be informed in a timely and sufficient manner via the aforementioned note and informative market.

The tile collection service is not adequately set up
The tiles must be collected centrally and collected by an external party. The tiles that score green in our traffic light system can be taken to the depot where they can be stored for future use. Our traffic light system requires that yellow-scoring stones must be reconditioned by a

third party before they may be reused. Tiles that score red are best crushed and used as input for the production of new bricks or as foundations for roads.

Insufficient equipment
A shortage of materials and collection points makes it difficult for residents to participate in this project. It is therefore necessary for the municipality of Apeldoorn to make an inventory of how many residents are participating in this project. Based on this, the municipality knows how much material (shovels, rubble bins) is needed to make available to the residents.

Theft or damage of equipment
The municipality carries the risk of losing or damaging the equipment it lends out. This is bad because it adds to the costs. By paying a deposit, the municipality may mostly avoid this. This encourages tenants to handle their belongings with care and discourages them from stealing.

6.5.3 Project Phasing and Schedule

In the table below, all tasks are listed in the order in which they should be performed. The order is from top to bottom. The tasks can be carried out simultaneously, which will be clarified in the planning.

Activity	Deadline	Milestone	Sequence
Register the municipality on the website of the 'NK-Tegelwippen'.	10/02/2022	Sign Up	This must be completed in order to move on to the next milestone, the 'Execution'.
Making equipment available	21/03/2022	Tiles swapping	This must be completed before the residents start. No tiles can be knocked without equipment.
Set up tile collection service	21/03/2022		This must be completed before the 'NK-Tegelwippen' officially starts and residents can register on the 'NK-Tegelwippen' website.
Inform residents through various media.	21/03/2022		This must be completed before the NK tile-wiping officially starts.
Inform residents about matters such as subsidies, important data.	31/10/2022		This must be completed before the 'NK-Tegelwippen' officially starts. Residents can register on the 'NK-Tegelwippen' website.
Have residents register on the 'NK-Tegelwippen' website.	31/10/2022		

Table 6.2 Project phasing

The planning is largely based on the phasing of the project in Section 6.5.3 and was created using Excel. It concerns a Gantt-Chart, which is a widely used tool to visualize the project planning. Execution is expected to run from January 31 to October 31, 2022. The preparatory tasks must be completed before March 21, 2022, at the latest, as the 'NK-Tegelwippen' will then start.

It is worth mentioning that, in contrast to the project phasing, the planning has been expanded with a further subdivision of the tasks. An example of this is informing residents to which three sub-tasks have been added, namely appointing a person with ultimate responsibility, drawing up a plan of approach and implementing this plan of approach.

6.5.4 Budget

Tile collection service

Two options were considered during the project's development. The first choice involves Rodebak's services, whereas the second option concerns Veldhuis Klarenbeek's services. Rodebak charges € 150 per month to rent a 4 m^3 debris container, which includes delivery, collection, and garbage processing (regardless of weight) (Rodebak.nl, 2022). Veldhuis charges € 120 for a two-week rental of a 6 m^3 rubble container, including delivery, collection, and disposal of the material (regardless of weight). The cost of renewing is € 15 per week. When it comes to price, it's worth noting that these two solutions are identical. Veldhuis' dumpster, on the other hand, is larger.

Equipment costs

The cost of the equipment is determined by the number of people who want to compete in the 'NK-tegelwippen'. As a result, the municipality of Apeldoorn must first determine how many citizens want to participate. Residents will need a shovel and a wheelbarrow to participate in the 'NK-tegelwippen', according to the project group. If the municipality does not already own or rent these items, it can purchase or rent them. Praxis, a commercial chain of DIY-stores in the Netherlands, charges € 23.75 per week to rent a 100-liter wheelbarrow. € 50.- is required as a deposit. A shovel costs around € 19.- and can for example be purchased at a local DIY-store.

6.5.5 Conditions

A number of prerequisites must be completed in order for the project to succeed. Within the municipality, a project team with a project manager and project members must first be assembled. These individuals will be involved in the project's activities. After that, a clear strategy must be devised. Tasks and deadlines must be visible, and each activity must be linked to a project member so that it can be managed appropriately. Secondly, every project requires a budget. Because of external parties and available material for inhabitants, the budget is crucial for the project 'NK-Tegelwippen'. Finally, evaluations must be conducted on a regular basis. The project lasts eight months out of the year, and a lot can happen during that time.

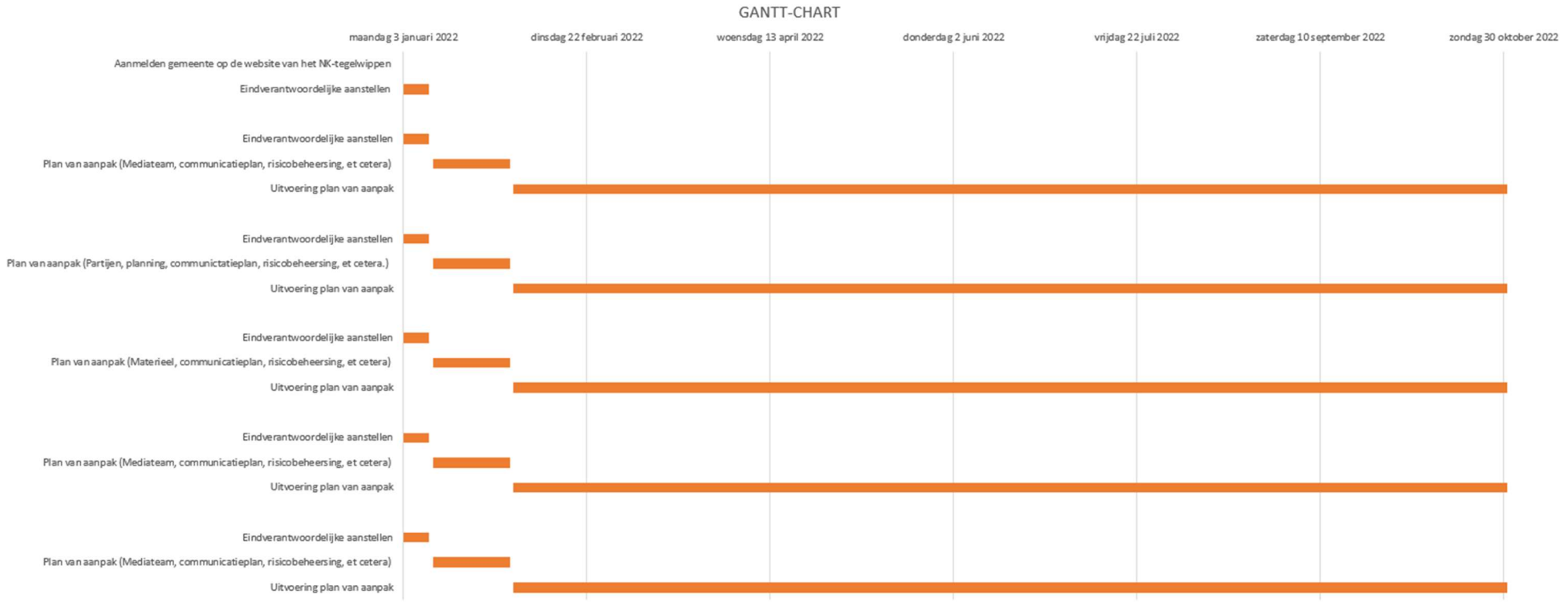


Figure 6.3 Planning NK-Tegelwippen

6.5.6 Methods to inform residents

To notify inhabitants about the ‘NK-Tegelwippen’, the internal aspect is examined first, such as how the municipality of Apeldoorn previously informed its residents, and then the external aspect is examined, such as how other municipalities do this. The development of a number of communication tools to inform residents about circularity and involvement follows.

Internal
Residents in Apeldoorn will receive information on ‘NK-Tegelwippen’ through the municipality's communication department. According to the involved civil servant, there was little promotion for the previous edition and no campaign for ‘NK-Tegelwippen’ 2021. The communication department is responsible for effectively communicating this information to the target group and motivating them to engage into tiles swapping. The communication department will use a variety of communication methods to accomplish this. Later in this part, we'll go over these methods in further detail. The communication to the residents will be used throughout the project to ensure that the residents are kept informed from beginning to end.

External
Digital communication with the municipality is becoming increasingly popular among Dutch citizens. As a result of digitization, municipalities have a plethora of options (Hachmang, 2019). In the Netherlands, there are clearly distinctions between different groups. Higher-educated people use web forms more frequently, whereas young people prefer live chats and social media.

Rucphen, the winner of ‘NK-Tegelwippen’ 2021, has launched a campaign to engage its inhabitants in 2021. Their initiative, 'Tile out, plant in it,' has resulted in positive collaboration between the municipality, residents, and the local gardener (Provincie Noord-Brabant, 2021). During ‘NK-Tegelwippen’, the municipality of Enschede has set up a free pickup service to remove the wiped tiles (Gemeente Enschede, 2021).

Means of communication
Letters, social media, meetings, and a social media campaign are all options for the municipality to communicate.

Letters
It's becoming increasingly rare to find a letter on the doormat these days. As a result, recipients are more likely to read a letter as soon as it arrives. Residents receive more information about ‘NK-Tegelwippen’ in this letter. Here you will find the following information: relevance, why, what, when, how, and a link to the website.

Social media
Social media allows you to reach a large number of people. It's critical to have good visibility if you want to reach out to your target audience. Social media allows you to reach a large number of people. Residents can be made aware of the municipality's message via social media posts on Instagram and Facebook, as well as a Facebook event. As shown in Figures 6.4 and 6.5,

the municipality can get a toolkit with templates for flyers, posters, and social media postings via the ‘NK-Tegelwippen’ website.

Figure 6.4 Poster (NK Tegelwippen, 2022).

Figure 6.5 Social-media post (NK Tegelwippen, 2022).

Meetings

Although social media allows you to reach a huge audience, face-to-face contacts are essential. Residents will have more opportunities to interact with one another, promoting social cohesion in the community. In the Griffiersveld, a prominent location on the street provides an excellent opportunity to set up a resident information market. There will be stalls here where locals can learn about various issues such as how to make your home more sustainable, the ‘NK-tegelwippen’ and tree exchange, as well as participate in participatory work planning. This will be discussed in greater depth later in this section.

Social media campaign

As previously stated, the ‘NK-Tegelwippen’ 2021 winner has launched a campaign to encourage local inhabitants to engage in the project. Several towns had already launched the 'Tegel eruit, plantje erin' initiative to encourage residents to participate in sustainable activities. Operation Steenbraken is being carried out by the municipality of Apeldoorn. This is a non-profit organization that works with governments to make their communities greener. 'Tegel eruit, plantje erin' has already begun in the municipality, although it is still a small-scale project (Gemeente Apeldoorn, 2022b). The ‘NK-Tegelwippen’ is well-suited to a large-scale effort like this. Flyers and posters are available on the ‘NK-Tegelwippen’ website for the municipality to promote via social media or in local supermarkets so that this is visible to everyone.

6.6 Botanical Exchanges

The liveable, climate-robust city is currently a topical theme. Transplanting greenery can give the same tree or shrub more value. Think of trees that have been planted too closely together in the past. By removing them now and using them again elsewhere, the trees get the necessary above-ground growth space. In this way you can use transplanting as a method to

deal sustainably with greenery in the city in order to improve the quality of life (Doornenbal, 2021).

6.6.1 Activities

The activities are divided into milestones and tasks. The municipality must first develop project frameworks and compile a list of residents who are interested in participating. The project group knows the constraints that a project must meet by looking at the (technical) feasibility through project frameworks. This will be covered in greater depth later. Residents must be informed through a communication plan in order to engage in this initiative. This is covered in greater depth later in this section. It is conceivable to determine how much equipment must be made available to the residents based on the inventory already mentioned.

Milestones	Sub-milestones	Deadlines
Preliminary investigation	Drafting project frameworks	10 February
	Inventory of participants	February 10 to October 31
	Appointing responsible persons	February 10 to October 31
Execution	Inform residents	February 10 to October 31
	Making equipment available	February 10 to October 31
	Plan of approach	February 10 to October 31
	Implementation of action plan	February 10 to October 31

Table 6.3 Milestones

6.6.2 Risks assessment

(Technical) feasibility
Trees with a trunk diameter of five cm or less are simple to transplant and do not require heavy equipment. Transplanting trees even with a small trunk diameter is already quite challenging due to the risk of irreparable damage. A tree with a trunk diameter of 5 cm or more has a root ball that is at least 40 to 75 cm in diameter and weighs between 50 and 400 kg. The tree is tough to move due to its weight. To avoid damage to the root ball, the tree must be removed from the earth by a specialized team (De Boomdokter, 2021). Shrubs, on the other hand, are relatively simple to transplant due to their lighter weight and smaller size.

Residents are informed too late and/or insufficiently
Residents who are not informed in a timely and adequate manner may be unable to participate in this project. They had no notion that this project is taking place. Therefore, residents must be informed in time via a letter. Receiving a note in the letterbox is uncommon, that residents will likely read it. In addition, it is a good idea to organize an informative market to inform locals.

Insufficient equipment
A shortage of materials makes it difficult for residents to participate in this project. It is therefore necessary for the municipality of Apeldoorn to make an inventory of how many residents are participating in this project. Based on this, the municipality knows how much material (shovels/wheelbarrows) are needed to make available to the residents.

Theft or damage of equipment
The municipality carries the risk of losing or damaging the equipment it lends out. This is inconvenient because it adds to the costs. By paying a deposit, the municipality may mostly avoid this. This encourages tenants to handle their belongings with care and discourages them from stealing.

6.6.3 Project Phasing and Schedule

In the table below, all tasks are listed in the order in which they should be performed. The order is from top to bottom. The tasks can be carried out simultaneously, which will be clarified in the planning.

Activity	Deadline	Milestone	Sequence
Drafting project frameworks	10/02/2022	Preliminary investigation	This must be completed in order to move on to the next milestone, the 'Execution'.
Inventory of participants	21/03/2022		This must be completed in order to move on to the next milestone, the 'Execution'. It also provides insight into the necessary shovels and wheelbarrows.
Appointing responsible persons	21/03/2022		This must be completed in order to move on to the next milestone, the 'Execution'.
Inform residents through various media.	21/03/2022	Execution	Residents are informed before and during the project.
Making equipment available	21/03/2022		This must be completed before the residents start. No greenery can be exchanged without proper equipment.

Table 6.4 Project phasing

The planning is largely based on the phasing of the project in sub-section 6.6.3 and was created using Excel. It concerns a Gantt-Chart, which is a widely used tool to visualize the project planning. Execution is expected to run from January 31 to October 31, 2022. The preparatory tasks must be completed before March 21, 2022, so that this project runs simultaneously with the ‘NK-Tegelwippen’.

It is worth mentioning that, in contrast to the project phasing, the planning has been expanded with a further subdivision of the tasks. An example of this is informing residents to which three sub-tasks have been added, namely appointing a person with ultimate responsibility, drawing up a plan of approach and implementing this plan of approach.

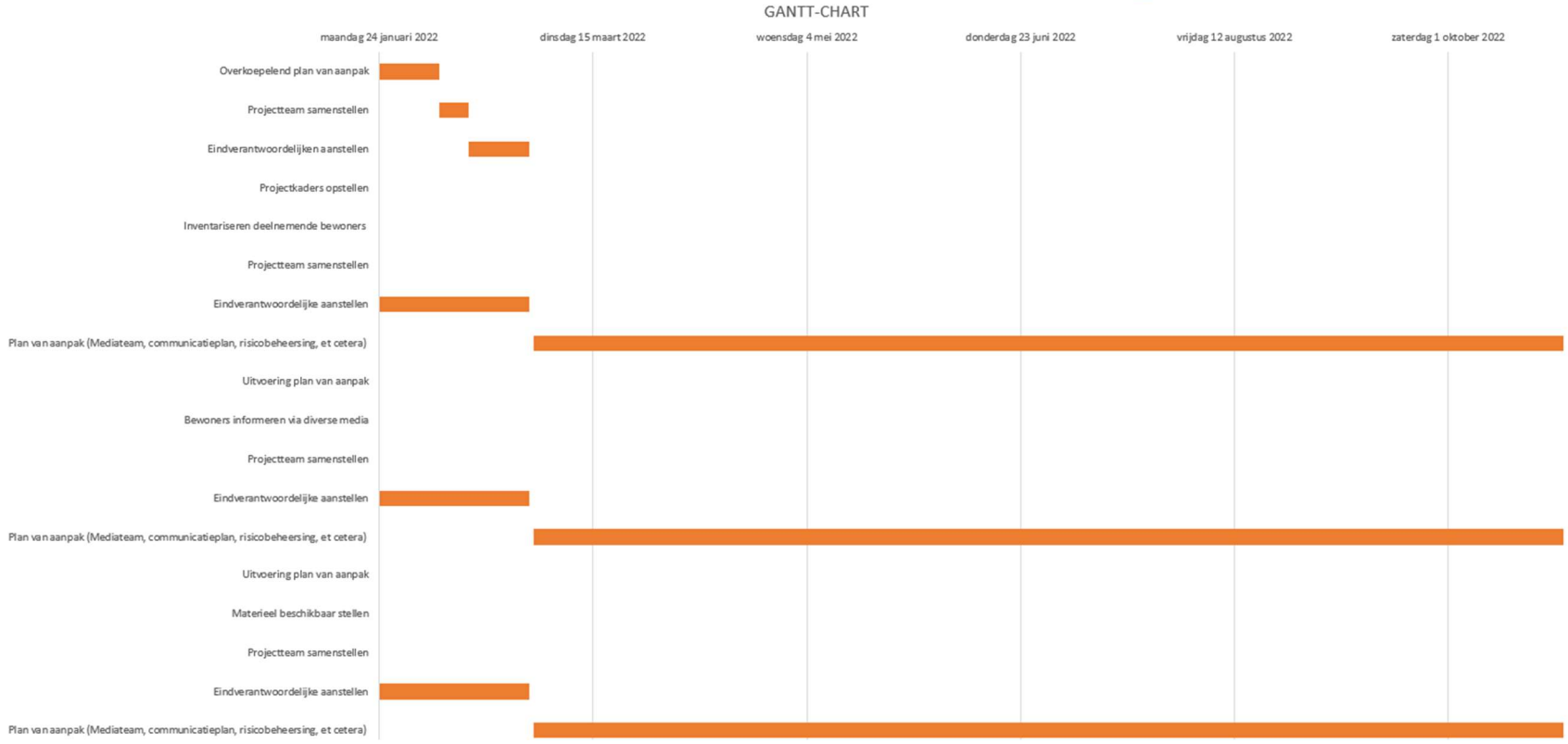


Figure 6.6 Planning Botanical Exchange

6.6.4 Budget

Equipment costs
The cost of the equipment is determined by the number of residents who wish to take part in the initiative. As a result, the municipality of Apeldoorn must first determine how many citizens want to participate. Residents will require a shovel and a wheelbarrow to complete this project properly, according to the project group. If the municipality does not already own or rent these items, it can purchase or rent them. Praxis charges €23.75 per week to rent a 100-liter wheelbarrow. EUR 50.- is required as a deposit. A shovel costs around €19,- per and may be purchased at a local DIY-store.

Expenses of bringing in a third party
The municipality of Apeldoorn's contact person, Marloes Reekers, has stated that engaging an outside company is not desired because it jeopardizes the project's economic feasibility.

6.6.5 Methods to inform residents

In order to inform residents about botanical exchange, the internal aspect is first looked at, how does the municipality inform its residents about greenery. Following that, a variety of communication tools are created to educate locals about circularity and their role in planting greenery in their gardens.

Internal
Residents who want to make their street or area greener can submit new initiatives to the municipality of Apeldoorn. You can do so by contacting the municipality directly and sharing your suggestions.

Means of communication
Letters, social media, meetings, and a social media campaign are all options for the municipality to communicate.

Letters
As mentioned before it is rare to find a letter on the doormat these days. As a result, recipients are more likely to read a letter as soon as it arrives. In this letter about botanical exchange the residents receive more information about the project. Here you will find the following information: relevance, why, what, when, how, and a link to the website of the municipality.

Social media
Social media allows the municipality to reach a big portion of its target audience. Residents may easily keep each other informed about what greenery they must exchange by creating a Facebook group. Anyone from the street can participate and swap or give away their shrub or plant with a post.

Meetings
If the municipality intends to reach out to everyone, physical meetings are now essential. In the instance of Griffiersveld, there is a fantastic opportunity to organize a physical meeting for the people of the street in the midst of the plaza. This meeting is an information exchange where the municipality presents its thoughts on a variety of topics, including the botanical exchange project, as well as information on circularity, sustainability, and other topics. This is an opportunity to speak directly to locals, with the municipality receiving direct feedback from residents' returns.

Social media campaign
The 'Tile out, plant in' campaign can also be used by the botanical exchange project. This is a good match for the 'NK-Tegelwippen' project. As previously said, the municipality of Apeldoorn has been working on this, but it is something that may be addressed on a broader scale. People enjoy watching what others are up to. Therefore, call on people to take a photo and share it on social media of their green garden.

6.7 Interactive Planning

By letting residents participate in an interactive planning we want to activate the residents to reuse materials. The interactive planning must attune the activities planned by the municipality to the residents' need to remove greenery, stones, et cetera, while at the same time enabling residents to mutually exchange greenery, stones, et cetera with each other. The schedule in Section 6.7.3 is a rough estimate of the activities in Griffiersveld. The project group was unable to obtain a definitive plan from the municipality of Apeldoorn.

6.7.1 Activities

A number of activities are required before and during the activities in Griffiersveld to make the interactive planning for both the municipality and the residents. The activities are divided into milestones and tasks as can be seen in Table 6.5.

The planning of the work in Griffiersveld is the most crucial aspect. Based on this the residents can sign up to have stones or plants from their own garden removed at one of the specified dates when the municipality will begin work in the street.

In order to realize this project, a project team and those with ultimate accountability will need to be appointed to guarantee that the project works successfully. Then it's crucial to keep residents thoroughly informed about the plans and what they may expect.

The residents must be able to register in advance using an Excel file, so that the municipality knows where to go to pick up any stones or greenery during the work in the street. These are then taken away by the municipality or placed elsewhere.

This planning can partly be used in combination with tile swapping and botanical exchange. However, this will not exactly coincide with the planning of tile swapping and botanical

exchange. The activities of Griffiersveld will start in the summer of 2022. From this moment on, residents can participate in the interactive planning as long as the activities in Griffiersveld are ongoing.

Milestones	Sub-milestones	Deadlines
Preliminary investigation	Appoint project team	January 24 to February 14
	Appointing responsible persons	February 15 to March 1
	Drafting project frameworks	March 2 to March 16
	Inform residents	March 17 to June 20
	Set up online forum	March 17 to June 20
	Inventory of participants	March 17 to June 20
Execution	Inform residents	June 21 to September 23
	Making equipment available	June 21 to September 23
	Plan of approach	June 21 to September 23
	Implementation of action plan	June 21 to September 23

Table 6.5 Milestones

6.7.2 Risks assessment

Residents are informed too late and/or insufficiently
Residents who are not given enough and timely notice may be unable to participate in this initiative. They were completely unaware that this project was taking place. As a result, people must be notified via letter in a timely manner. Since receiving a note in the letterbox is unusual, residents are more inclined to read it. Furthermore, organizing an informational market to inform residents is a great move.

The existing schedule becomes jumbled
The municipality must adhere to its own schedule to ensure that work is completed on time. In addition, the interactive work planning depends on the progress of the work, since the residents must indicate the time slot in which the parties involved remove the items from the front garden.

6.7.3 Project phasing and schedule

All tasks of the interactive planning are listed in the order in which they should be performed as seen in Table 6.6. The order is from top to bottom. The tasks can be carried out simultaneously, which will be clarified in the planning.

The planning is largely based on the phasing of the project in Section 6.7.3 and was created using Excel. It is a Gantt-Chart, which is a widely used tool to visualize the project planning. Execution is expected to run from January 24 to September 23, 2022. The preparatory tasks must be completed before June 20, 2022.

It is worth mentioning that, in contrast to the project phasing, the planning has been expanded with a further subdivision of the tasks. An example of this is informing residents to which three sub-tasks have been added, namely appointing a person with ultimate responsibility, drawing up a plan of approach and implementing this plan of approach.

Activity	Deadline	Milestone	Sequence
Appoint project team	14/02/2022	Preliminary investigation	This must be completed in order to move on to the next milestone, the 'Execution'. It also provides insight into the required ships and wheelbarrows.
Appointing responsible persons	01/03/2022		This must be completed in order to move on to the next milestone, the 'Execution'.
Set up online forum	20/06/2022	Execution	This must be completed in order to know how many participants join this project
Inform residents through various media.	23/10/2022		Residents are informed before and during the project.
Making equipment available	23/10/2022		This must be completed before the residents start. No greenery can be exchanged without proper equipment.

Table 6.6 Project Phasing

6.7.4 Budget

Because the municipality has already planned street work, the interactive planning project does not have to cost money. Second, the project team anticipates that a simple Excel file will suffice. Residents can indicate what they want out of their front garden in this Excel file. The file is organized as follows: addresses are on the left, time slots are on the right, and residents can indicate what they want from the front garden at the corresponding address in the middle. The file is available on the municipality of Apeldoorn's website. An Excel file does not have to be expensive, but it must be properly formatted.

6.7.5 Conditions

The municipality must agree with the parties involved what residents can offer to get out of their front yards. Furthermore, which addresses can provide something in relation to the time slot must be clearly indicated in the Excel file. The time slot is determined by the existing planning of the work. The street will most likely not be broken up in one go, but in segments to prevent nuisance. Each segment is assigned a time slot in which it must be completed during the planning process.

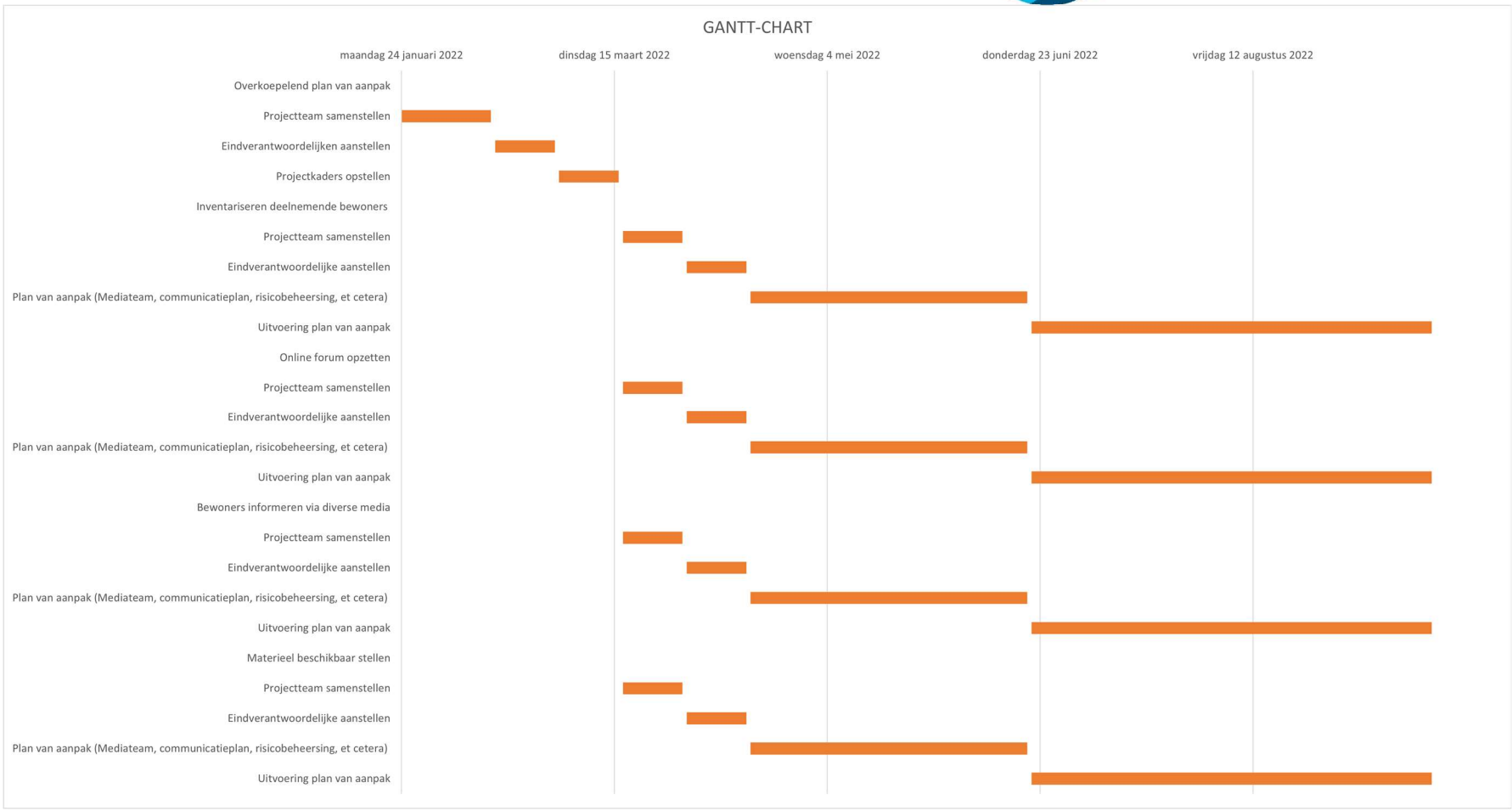


Figure 6.7 Planning Interactive Planning

6.7.6 Methods to inform residents

The interactive planning project is critical for effective communication with residents. This project is taking place at the same time as the work on Griffiersveld Street.

Communication methods
Letters, the municipality's website, and physical meetings are all options for communicating with residents about the interactive planning.

Letters
In the letter the residents will receive contains more information about the interactive planning. Here you will find the following information: relevance, why, what, when, how, and a link to the website of the municipality. This letter has to make clear when and where the activities in the street will take place. This way the residents know what time slot they can sign up for the interactive planning.

Meetings
If the municipality intends to reach out to everyone, physical meetings are now essential. The meeting for the residents of Griffiersveld takes place on the plaza in the street. This meeting is an information exchange where the municipality presents its thoughts on a variety of topics, including the botanical exchange project, as well as information on circularity, sustainability, and other topics. This is an opportunity to speak directly to locals, with the municipality receiving direct feedback from residents' returns. It is easier for people to ask their questions about the interactive planning and activities in Griffiersveld directly to the municipality.

7 Conclusion

Research question 1: Which stages in a circular road renovation project can be distinguished?

A circular road renovation projects consists of five stages: the evaluation of the existing road, the design of the new road, the construction of the new road, maintaining the road and the end of its life span. During the evaluation it is determined whether or not the road has to be replaced. When it has to be replaced a new road is designed, the design of the road has to meet various demands according to the CROW. After the designing phase the road is constructed. The construction consists of groundworks and laying the street pavement. The next stage is the maintaining of the road. The maintenance of a road consists of various types of services, like repairs, small scale interventions, etc. The final stage is the end of the lifespan of a road. During the end-of-life stage, it is determined what materials of the road are useable for recycling into new road projects. An road has end its end of life when the technical or community lifespan has been reached, which are:

- *Technical lifespan.* When the technical lifespan of a road is exceeded, it means that one or more road components are damaged. It is mandatory for the road owner to match all the technical standards. The technical standards of a road in the Netherlands are determined knowledge institute CROW. That the technical lifespan is exceeded doesn't mean that the materials of the road components that are being used in the road can't be reused in other projects.
- *Community lifespan.* When the community lifespan is exceeded, it means that the road is not living up to the standards of the road owner but is living up to the technical standards of the CROW. This means that it is not necessary to renovate the road, but it still done to live up to the standards set by the road owner

Research question 2: What information needs to be visualised in a 3D-tool?

The purpose of the tool is to visualise data that is coupled with the buildings and infrastructure in an 3D environment. This 3D environment has to include as much information about the buildings and infrastructure as possible. For this tool is looked into how concrete tiles and pavers.

The information about buildings that must be included in the tool, consists of:

- Year of construction;
- Status;
- Destination plan;
- Energy label.

The information about the roads that must be included in the tool, consists of:

- Quality of the materials in the road;
- Quantity of the materials in the road;
- Maintenance log of the road.

This data must be available during the different stages of a road renovation project. The different stages of an road renovation project are:

- *Evaluation of the quality of the existing road.* The first step is for the road owner to decide to renovate the project. This can be done based on inspection report or pressure from the community.
- *Survey of the quality and number of materials in the existing road.* After it is determined that the road must be renovated the next step is to determine the amount and quality of the different road components in the road sections.
- *Seek a new usage for the materials in the existing road.* If all the materials inventoried the next step is to determine which materials and road components can be re-used and for which materials need a new purpose. The new purpose is depended on the quality of the material.
- *Designing and constructing of the new road.* Now every material has a new purpose as much materials as possible are reused in the new design and the leftover materials have a new purpose
- *Maintaining the new road.* The last step is to maintain the road to ensure a longer technical lifespan.

Research question 3: In which way can the data be visualised in a 3D-tool?

The data of a road section or building can be linked in QGIS with a 2D element. The information can be linked from GBI to QGIS and is accessible via the properties panel as mentioned in Section 5.3.2. This 2D element is also a 3D element. This means that the data can be visualised in two ways: 2D and 3D. But the information will only be accessible via the properties panel. When needed, this information can be exported to an Excel file to use it for other purposes. For the 3D visualisation of the buildings a tool from the university of Delft is used.

Research question 4: How can the system applied by the municipality of Apeldoorn be linked-to the tool?

The system used by the municipality of Apeldoorn is GBI. The information within GBI can be linked to QGIS by adding the files as a layer. When added, they provide information via the properties panel. When the menu screen is visible, there are multiple columns of information visible, each containing information of a road section or building.

Research question 5: How can the municipality of Apeldoorn come to participation with the residents?

To encourage residents to participate, three participation projects have been developed. Residents should be informed about circularity and encouraged to commit to a more sustainable living environment through these projects. Tile swapping, botanical exchange and interactive planning are the three projects. The tile swapping project aims to replace stones with greenery, improve street life, and promote social cohesion. The botanical exchange project also aims to improve the street's quality of life. The primary goal of interactive planning is to encourage material reuse.

In this phase, the circularity of road design is further examined. On the basis of the research conducted earlier by CivilOost, the 'reuse' treatment flow is used. This means that in road renovation projects, the materials removed from the street are reused. The other option is to replace these materials by materials that are partially recycled. In the second "reuse" treatment flow, the materials are brought to a recycling plant. This allows the same material to be reused for other road projects in the future.

In short, the definition of circular road design used in this project is that the materials that are released are reused directly in the construction as much as possible. When the materials are too damaged, they are transported to a recycling plant to be used in the construction of new building materials.

8 Recommendations

What can we take away for other municipalities?

Other municipalities can also use the program QGIS as applied for the municipality of Apeldoorn. However, at the moment it is not clear to us which system the other municipalities are using. If this is GBI, then it can be applied in the same way. In a different system, it may be that the information that is loaded causes problems. This is therefore something that could be looked into further. The tool can be useful for municipalities if they want to keep track of the status of roads and neighbourhoods with a software such as QGIS.

Residents' participation

Research to promote resident participation has shown that municipalities have a great influence on its residents. In order to activate residents to participate in participation projects, the municipality must sufficiently inform its residents about issues such as circularity and inform them about the progress of these projects. It is therefore recommended to address the residents in a direct manner. In addition to letters and social media posts, a direct form of communication, such as an information market, is a good means of entering into dialogue with the residents. This way the residents and the municipality come together in one place. It is also recommended for other municipalities to use means of communication that are geared to their target group. The aim is to allow residents to work on a liveable green environment in their neighbourhood. This way residents work together with the neighbourhood and the municipality, on tile swapping and greenery exchange. This promotes social cohesion and knowledge in the field of circularity and sustainability among residents.

Step to a digital twin

The goal is to create a digital twin that contains all the necessary information about the infrastructure and buildings in a municipality. The information that is now included in the tool can be extended and thus used on a broader spectrum. The project group thinks that the following data can be put to useful functions within the tool:

- *Traffic data:* an useful extension for the tool is include traffic data in the tool. This way it will be possible to compare the data about the maintenance and road materials to the intensity of the usage of the road. This traffic data is this can help the municipality to determine better determine high priority roads.
- *Building passports:* most new buildings have a digital copy of all the materials that are used to build. This information can be stored in database of the municipality of the dutch government. If and this can be implemented is depended on the restrictions of the Dutch government.
- *Underground infrastructure:* all the information about underground infrastructure is stored by the Kadaster. The information can be obtained through a so called KLIC-mention. When an KLIC-mention is obtained the applicant get all the information about underground infrastructure of the area they specified. This means the location, type, diameter and owner of the pipes and cables in the area of the KLIC-mention. The data

is visualised in an 2D map coupled at geographic location. It is possible to load this map in the tool in the 2D environment.

- *Public infrastructure:* there is a lot of information about the location of public infrastructure. The information that can be found in this public dataset are: Location of street furniture, location of gullies, location of inspection pits, location of traffic lights. Location of store This information is stored as a cad drawing. This cad drawing can be loaded in the QGIS environment but is not interactive. In the future it is maybe possible to load this information and transfer it to an 3D environment
- *Civil infrastructure:* besides roads an municipality is the manager and owner of other kinds of civil infrastructure like bridges, stows, pumping stations etc. This infrastructure has its own maintenance log, monitoring systems etc. To include this in the tool it will create an complete image of the real-life environment.

Combining all the information described as above in the tool will create an tool with an overview of all the materials and infrastructure in the administration of a municipality.

References

Autodesk (2022). *Revit: BIM software for designers, builders, and doers.* Retrieved from: https://www.autodesk.eu/products/revit/

Bouwbestel (2022). *Hoe lang moet beton drogen?* Retrieved from: https://www.bouwbestel.nl/blog/

Brinke, R.J. ten, Hal, T.J.L. van, Jong, P.G.J. de, Lintelo, G.H.J. te, Podt, G.B., Revenberg, M., Ros, B. & Thijert, B.M. (2021). *Designing and realizing circular urban road renovation.* CityLoops. Saxion, Enschede.

Centraal Bureau voor de Statistiek (2022). Kerncijfers Wijken en Buurten. Retrieved from https://allecijfers.nl/wijk/zuidoost-apeldoorn/

CityLoops (2022). About CityLoops project. Retrieved from: https://cityloops.eu/

CROW (2011). *Handboek visuele inspectie 2011.* ISBN 978 9066285873

De Boomdokter (2021). *Hoe verplant je een boom? Stap voor stap uitgelegd.* Retrieved from: https://www.deboomdokter.be/blog/bomen-en-boomgaard/

Doornenbal , D. (2021). *Grote bomen verplanten, waarom?* Retrieved from: https://www.nationalebomenbank.nl/

Dus Wat Gaan Wij Doen (2021). *NK Tegelwippen.* Retrieved from: https://duswatgaanwijdoen.nl/projecten/nk-tegelwippen/

Edelenbos, J., Monnikhof, T. (2001). *Lokale interactieve beleidsvorming: een vergelijkend onderzoek naar de consequenties van interactieve beleidsvorming voor het functioneren van de lokale democratie*. Uitgeverij LEMMA, Utrecht.

Gemeente Apeldoorn (2022a). *Huidige situatie en voorlopig ontwerp Griffiersveld.*

Gemeente Apeldoorn (2022b). *Maak uw tuin groener.* Retrieved from: https://www.apeldoorn.nl/zorg-voor-meer-groen-in-uw-tuin

Gemeente Enschede (2021). *Gratis ophaalservice voor gewipte tegels.* Retrieved from: https://www.enschede.nl

Google Maps (2022). *Map data Apeldoorn – Griffiersveld.* Retrieved from: https://www.google.com/maps/

Government of the Netherlands (2021). *From a linear to a circular economy.* Retrieved from: https://www.government.nl/topics/circular-economy/from-a-linear-to-a-circular-economy

Hachmang, D. (2019). *Digitaal contact met gemeenten: dit vinden Nederlanders belangrijk.* Retrieved from: https://www.frankwatching.com/archive/2019/11/11/digitaal-contact-gemeenten-onderzoek/

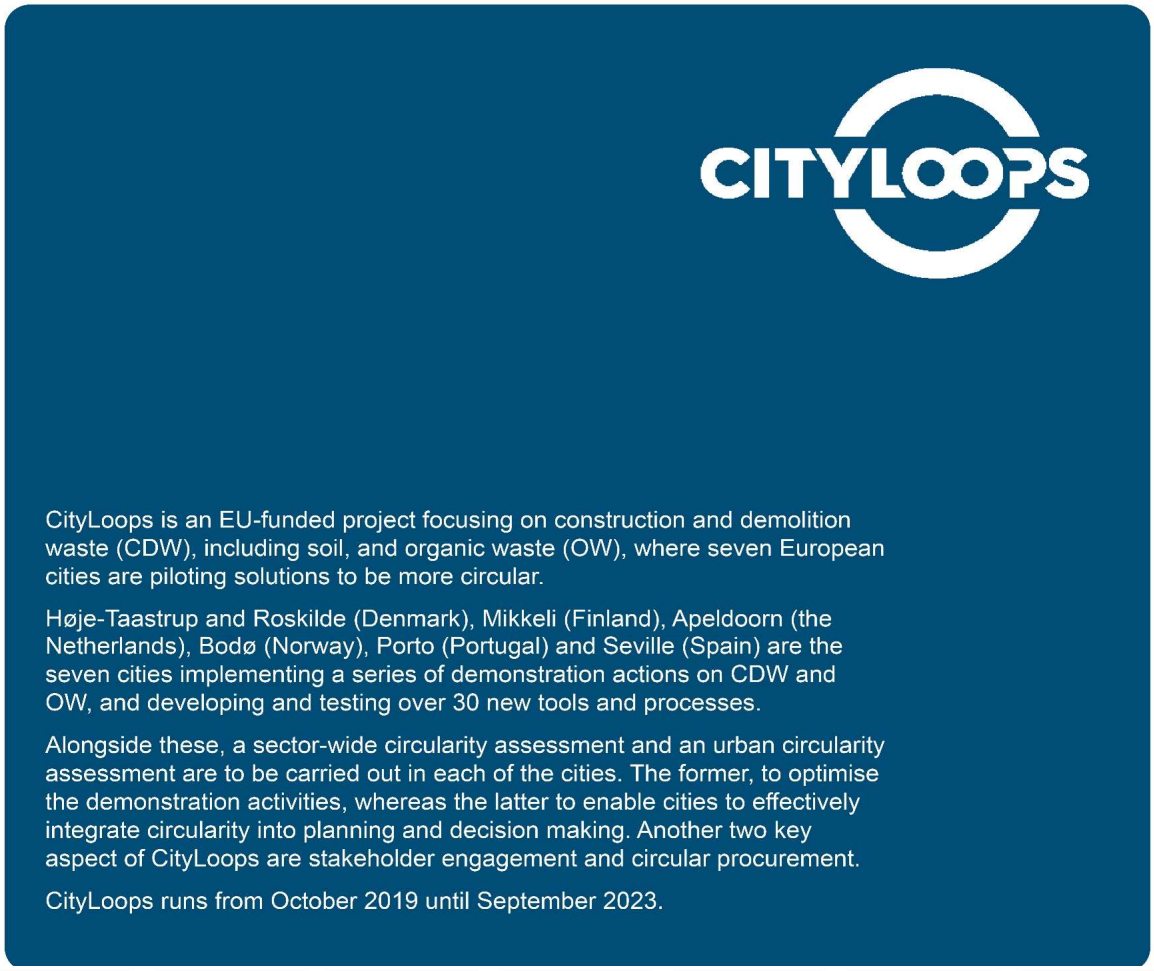
Het Groene Brein (2020). *What is the definition of a circular economy?* Retrieved from: https://kenniskaarten.hetgroenebrein.nl/en/knowledge-map-circular-economy/

Kuipers, L. (2017). *Wegontwerp.* ISBN 9789080205628, G.C.T Adviescentrum, Alkmaar.

Lean Six Sigma (2022). *The Lean Six Sigma Model; a Quick Look at the Lean Six Sigma Model.* Retrieved from: https://www.leansixsigmatraining.ie/the-lean-six-sigma-model/

Lowndes , V., Pratchett, L., & Stoker, G. (2006). Diagnosing and Remedying the Failings of Official Participation Schemes: The CLEAR Framework. *Social Policy and Society,* 5(2), 281-291.

Nationaal Kampioenschap Tegelwippen (2022). *NK Tegelwippen 2022; heel Holland wipt.* Retrieved from: https://nk-tegelwippen.nl/
OpenStad (2022). *Over Ons.* Retrieved from: https://openstad.org/over-ons
Publieke Dienstverlening Op de Kaart (PDOK) (2022). Over PDOK. Retrieved from: https://www.pdok.nl/over-pdok
Provincie Noord-Brabant (2021). *NK Tegelwippen: Rucphen als voorlopige groene koploper.* Retrieved from https://www.klimaatadaptatiebrabant.nl/
QGIS (2022). *QGIS; A Free and Open Source Geographic Information System.* Retrieved from: https://qgis.org/en/site/
Rodebak.nl. (2022). Puincontainer huren. Retrieved from: https://rodebak.nl/container/puincontainer/
Ruiz, L.A.L., Ramón, X.R., & Domingo, S.G. (2019). The circular economy in the construction and demolition waste sector – A review and an integrative model approach. *Journal of Cleaner Production 248*, 119238.
TUDelft (2022). 3D Bag. Retrieved from https://3dbag.nl/en/viewer
Veen, M.T.J. (2010). *Bewonersparticipatie de sleutel tot succes? Een onderzoek naar de invloed van bewoners op het succes en eindproduct van herstructureringsprojecten* (master thesis). Rijksuniversiteit Groningen, Groningen.
Vereniging Nederlandse Gemeenten (VNG) (2021). *Open Stad: van voor en door gemeenten.* Retrieved from: https://vng.nl/praktijkvoorbeelden/



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 821033.

Appendix I: Circular material use

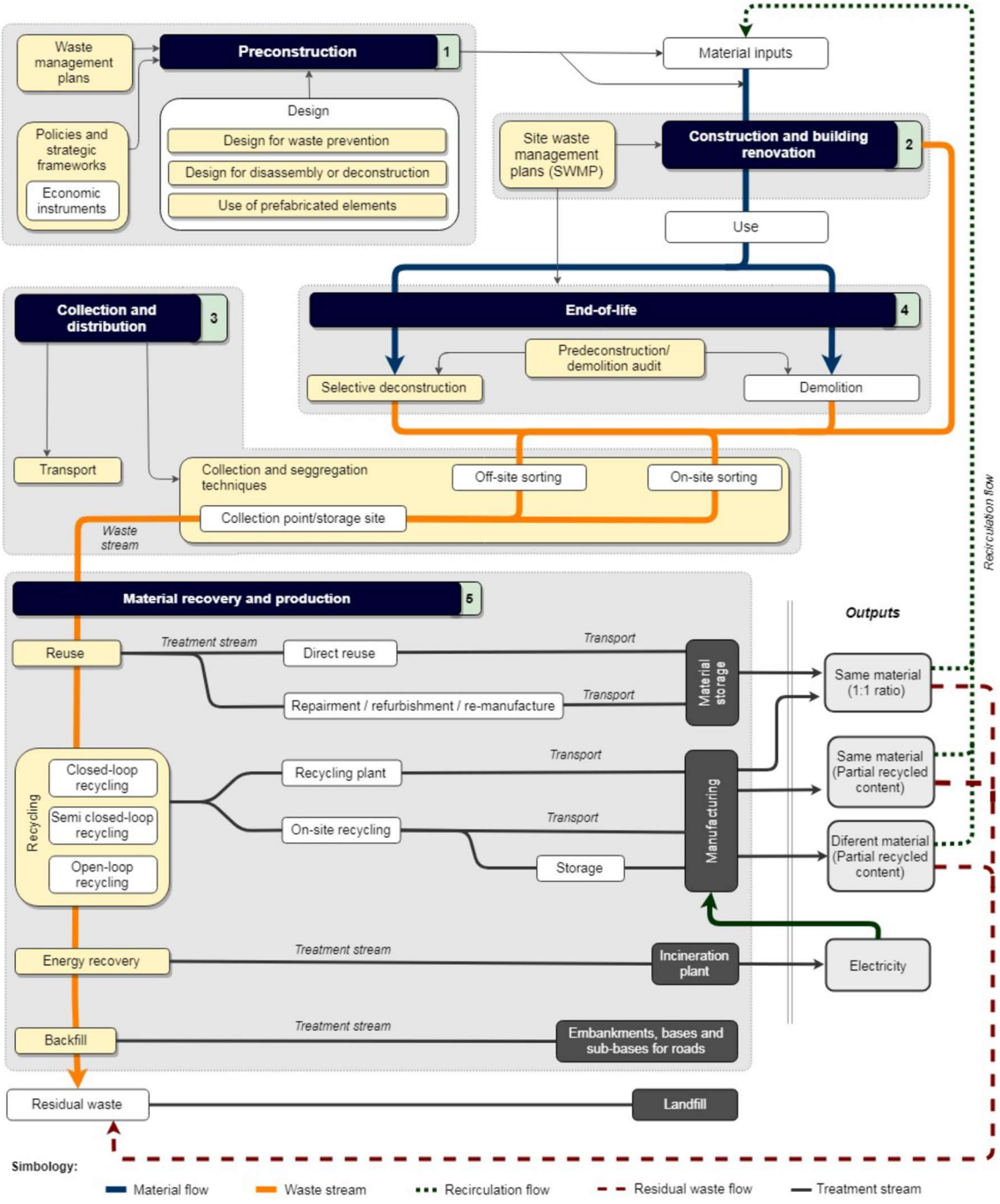
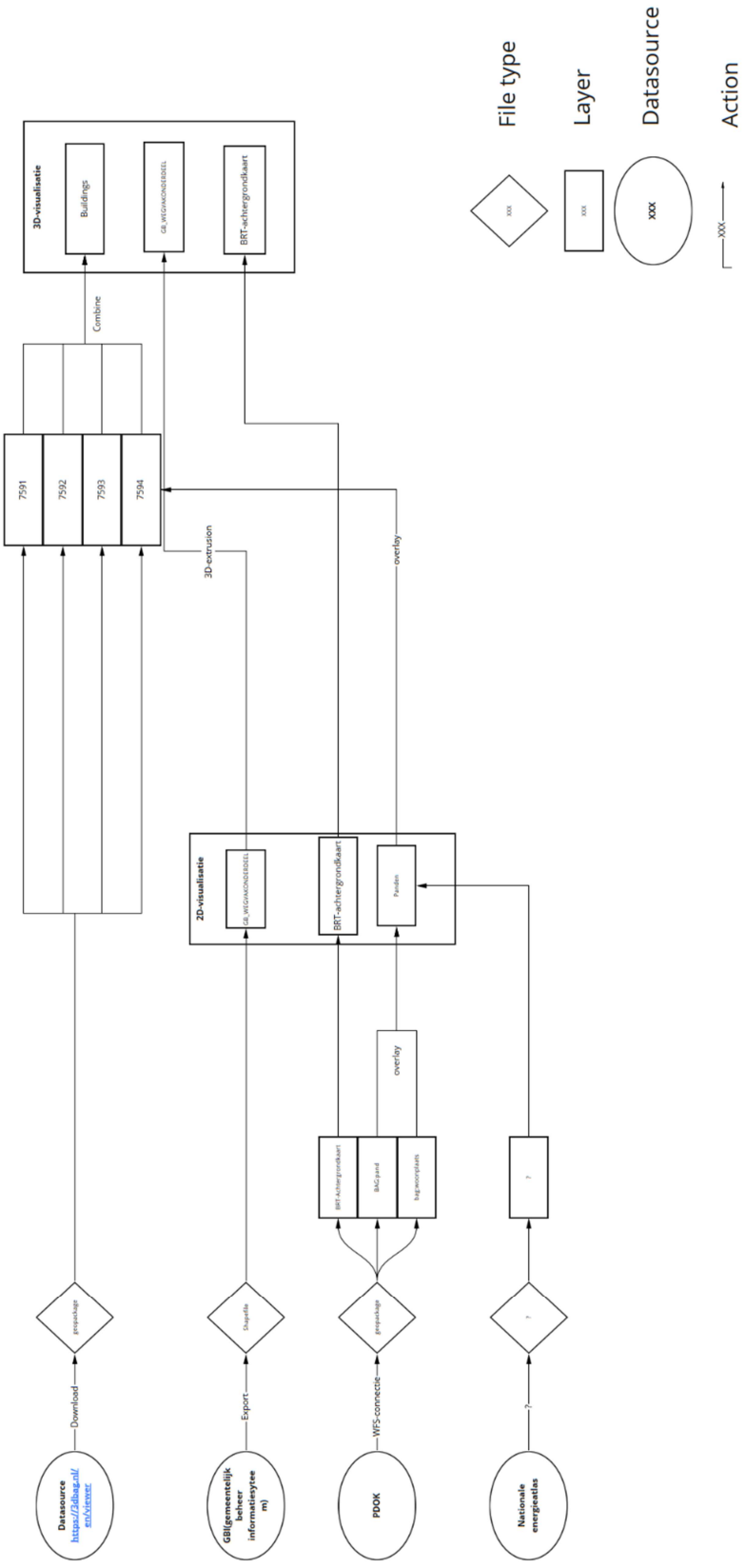


Figure 0.1 Flow chart concerning the circular use of materials (Ruiz, Ramón, & Domingo, 2019)

Appendix II: Dataflow Tool



Appendix III: GBI-dataset export

ID	**3316**
OBJECT_GUID	CCCE0CFB26E84B02E0400A0A57322187
Inspectiedatum	25-4-2019 00:00:00
Oneffenheden elementen	7
Verhardingstype	Elementen
Verhardingsfunctie	rijbaan
STD_Ondergrond	Zand
Binnen bebouwde kom	Y
Ondergrond	
KL_Inspectiegebied	Elementen
Openbare ruimte	Kunstenaarshoeve
Verhardingssoort	BSS keiformaat
Dwarsonvlakheid elementen	0
Oppervlakte	169.27
Breedte	5.81
Opmerking	
Voegwijdte elementen	0
Buurt	Matenhoeve
STD_Rijstrook	rechts
Wijk	Zuidoost
Wegtype	weg in woongebied
Aanlegjaar	1975
Geinspecteerd	Ja
KL_Jaar onderhoud	1988
Lengte	30.85
Rijstrook	Rijbaan rechts
Formaat verharding	
Functie Weg	
STD_Verhardingsfunctie	rijbaan
Voegvulling beton	
Reparatie scheurvorming	
Categorie / NGDW code	Rijbaan elementen
STD_Verhardingssoort	beton keiformaat
KL_Maatregeltoets	NEE
KL_PK_WORKFLOW	
Profielnummer	
Aanzien	matig
Afwatering	
Comfort	
Deflectiemeting	
K.O. oneffenheden elementen	
Duurzaamheid	voldoende
Materiaalverlies	1
Spoorvorming	
Stroefheidmeting	
K.O. randschade asfalt	
Veiligheid	matig
Vlakheid overige verharding	
Voeglengte	
Voegvulling beton	
Wegvakonderdeelnummer	3316
Woonplaats	Apeldoorn
Zetting	
STD_Structuurelement	Woongebied
Reparatievakken	
BOR data compleet	
Toelichting	
Oppervlak	169.2674542
Omtrek	73.40023852

Table 0.1 Field in GBI

Appendix IV: Set-up of the tool

In this section the details of how to set set-up a 3-dimensional environment based on available datasets.

Disclaimer: This tool is set-up in QGIS 3.22 Bialowieza, the steps that are described in this section can be different in later or earlier versions of QGIS. The datasets and maps that are used in this tool are specifically for the Netherlands. This means that these datasets cannot be used in other countries than the Netherlands.

1. **Download QGIS**
   The first step is to download the latest version of QGIS. QGIS can be downloaded by the following download link: https://www.qgis.org/nl/site/forusers/download.html

2. **Create a new project**
   After QGIS is downloaded the next step is to start a new project. To start a new project the project starter must make a choice how many users will have access to the file.
   1. *One-user*

   If the creator doesn't want to share his project with another QGIS user, the users can save the project on his own hard disk. Make sure to create a new folder to safe the layers and data set that will follow in the up-coming steps.

   2. *Multiple-users*

   If a new project is started make sure to create a new folder in a drive. This drive is the source of all the layers in this project. If another person is granted access to this drive, he can access the different files from his own computer. If the file is saved on a hard disk of a personal computer, all the layers must be download and redirected to the new computer. If this choice is made
      a) Open Qgis
      b) Click on project in the menu bar
      c) Click on new project
      d) Save the project under a logical name in a file describes as above.

3. **Download and use PDOK**
   After the QGIS-project is set-up, the next step is to download the PDOK plugin for QGIS. In PDOK you find open datasets of the government with current geo-information. These datasets are accessible through geo webservices and available as downloads. These maps are loaded in from the PDOK-plugin. PDOK uses a WFS connection to load in maps. This means that QGIS is constantly refreshing the data. These maps are only accessible if an internet is established. These maps and data are provided by the government of the Netherlands. These maps and datasets are available for the entire mainland of the kingdom of the Netherlands.

How to download the plugin:

a) click on Plug-ins in the menu bar
b) click on manage and install
c) not installed
d) search for PDOK
e) install PDOK services plugin and PDOK Locate server

If all the steps are followed correctly this menu will appear in your toolbar:

Click on the blue symbol and search for the background maps that need to be loaded in for the tool. The map and datasets are loaded in by double-clicking on the desired map. The maps and dataset that are used for this tool are:

1. 3-BRT-achtergrondkaart
2. 110-pand
3. 969-gemeenten2020 or 892-CBSwijken_2020

Clarification: The Number is the number that PDOK has assigned to the data source, the name is the name of the data source.

4. Export and GBI-export

In GBI the dataset about the roads is saved. GBI is a closed a secured environment where not every employee has access to. To include this data, ask the GBI administrator to provide a geopackage of the GBI data that need to be included in the tool.

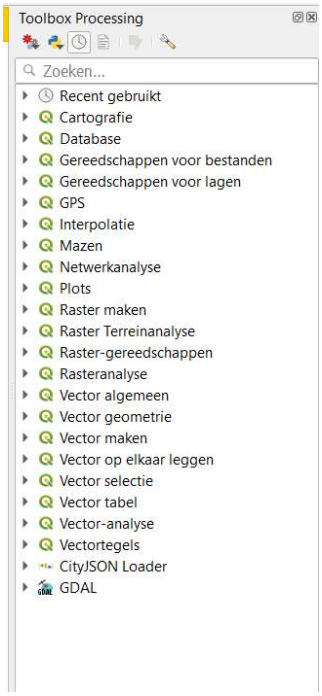
5. Download 3D-BAG

This dataset is used to visualize the data acquired from QGIS into a 3D environment. The download link for this dataset is: https://3dbag.nl/en/download. It is possible to have a preview of the 3D visualisation of the tile that is chosen. This viewer can be used to have a preview of the exported dataset. BAG-viewer: https://3dbag.nl/en/viewer. 3D-BAG is a program developed by the university of Delft This program is using data from the AHN and BAG to make an digital shape of all the buildings in the Netherlands.

a) Open the link
b) Click on pick a tile
c) Select the tile that need to be visualised in 3D
d) Confirm selection
e) Download the geopackage (.GPKG file)
f) Save the geopackage in your project folder
g) Drag the geopackage in QGIS

If all the steps are followed correctly the tile is now loaded in to the QGIS environment.

6. Combining maps



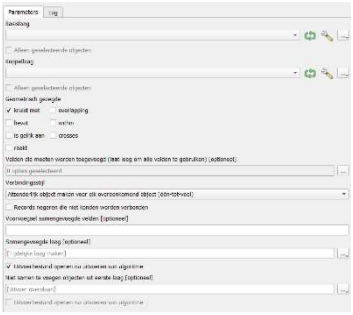
In this step the data from PDOK is combined with the 3D-layer, this is necessary for the last and final step to visualize the data that is needed.

How to use the plugin:

a) click on Plug-ins in the menu bar
b) click on manage and install
c) click on installed
d) check the box of toolbox

if every step is done right the following toolbox will appear on your screen. The next step is to bind the data from the layer "*110-pand*" to the 3D-BAG file. Operate this way:

a) Click in the toolbox on vector common
b) Click in pair vector based on location
c) Fill-in the parameters



This algorithm takes an input vector layer and creates a new vector layer that is an extended version of the input vector layer, with additional attributes in its attribute table. The additional attributes and their values are taken from a second vector layer. A spatial criterion is applied to select the values from the second vector layer that are added to each object from the first layer in the resulting layer.

7. Apply filters

The last step is to apply filters to the layers, these filters can visualize the differences of the parameters in the layer

a) Right-click on the layer
b) Go to properties
c) Go to 3D-view
d) Set view to rule based
e) Create the desired view