Assessment and Visualization of Urban Mining Potentials: A Case Study in Amsterdam

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If you innovate based on passion, then you are on time.
If you innovate on the basis of urgency, then you are
certainly too late!

Michel Baars, New Horizon

Colophon

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Preface

Working for few years in various construction sites, enlightened my view of how construction process can be more efficient, and taught me ways of not doing a construction project. The eagerness to learn and explore more motivated me to pursue my study Construction Management and Engineering at TU/e.

Although during the time of pandemic, many of us experienced difficult and unusual moments in our lives, I have learned a lot about myself, my values, and my goals. Leaning no matter where and how the difficulties hit us, we have to handle them in a way not to deviate us from our goals.

After all, I want that thank the staff and lecturers in the department of Built Environment of TU/e for the knowledge and insight I gained. Most important of all, I want to thank Pieter Pauwels and Gamze Dane for their advice, support, and patience throughout my graduation project, which was the most exciting and challenging part of my master study.

At last, I would like to thank my family especially my sister Roya, and my close friends for their supports, kindness, and coping with my (at times) complicated behaviour to finish this chapter of my life.

Ramin Khoshnevisansari
June 2021

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Acronyms

AI	Artificial Intelligence
AMS	Amsterdam Institute for Advanced Metropolitan Solutions
BAG	Basisregistratie Adressen en Gebouwen
BE	Built Environment
BGT	Basisregistratie Grootschalige Topografie
BIM	Building Information Management
BoM	Bill of Material
CDW	Construction and Demolition Waste
ERP	Enterprise Resource Planning
EU	European Union
EXP AVAL	Expected Availability
GIS	Geographic Information System
IFC	Industry Foundation Classes
INST	Installation
IoT	Internet of Things
LCA	Life Cycle Analysis
MFA	Material Flow Analysis
OSM	Open Street Map
PUMA	Prospecting the Urban Mines of Amsterdam
QGIS	Quantum Geographic Information System
VR	Virtual Reality

Abstract

World environmental crisis has forced the nations to outline action plans to keep the negative impacts within a sustainable limit. Identifying main unsustainable industries, built environment contributes to highest shares in any aspect from resource consumption to waste production. Although targets have been set in Europe to achieve 100% circular economy, there seems to be not enough time for so much targets to be achieved. In the Netherlands, government has introduced a general action plans for circular economy, while local government authorities have started with blueprints of assessing urban mining potentials (referring to PUMA by municipality of Amsterdam). The PUMA report has identified lack of information as the main dilemma to accurately assess the urban mines of Amsterdam, hence, the urgency to establish an information system is discussed. In this study, the potential of total of six specially selected locations for both buildings and underground metal stocks have been assessed. The assessment consists of obtaining data from various sources to quantify and monetize the existing metal stocks in buildings (copper and steel), and underground cables (aluminium). Lastly, the attained information is linked to a web map using GIS tool that delivers the required information in a well-organized order to users. The users vary from designers who are designing buildings and look for second-hand material, to recycle plants who wish to collect cables in a more efficient way. The digital platform gives the opportunity for unlimited improvement to fit the information that any designer wishes to receive in order to rely on a second-hand building element.

Keywords: Circular economy, Urban mining, Digital construction hub, Information system, Web mapping, GIS, Building passport, Material passport

Summary

The modernization that has been followed by massive industrial development in the previous century, resulted in significant increase in population and exponentially the rise of needs for resources. Exploring the fascinating properties of certain metals caused recklessness and negligent over their extraction that eventually led to scarcity of certain metals. The more precious metals have become rare decades ago and therefore, the industry had no other way than reclaiming them from the no longer in-use devices that contained them. The concept of urban mining has raised from this approach around the 1980's for the more precious metals and has recently been discussed for other relatively less precious (but tediously in use) metals such as copper, steel, and aluminium.

As a result of environmental movements, circular economy concept has gained attention widely and has identified construction industry as one of the most resource consuming of all. Simultaneously, the construction and demolition wastes (CDW) have large share of waste amongst other identified waste sources. It is no longer an argument whether actions toward a more efficient and sustainable construction process should be taken or not. Many practices and achievements have led towards great success in development of various advance building technologies; however, the industry is still exploring and introducing new ideas and plans. Indeed, the results are not expected to happen overnight and developments may take years to maturely evolve. Although incredible methods and ideas have been introduced and already being in place for practice, there are still many gaps to be assessed and resolved.

Urban mining is a process that is dependable to attributes and characteristics of a city. Therefore, prospects of each city might be different from another. In the city of Amsterdam, where the focused area of this study is, the city has encountered lack of information as the main obstacle for a beneficial and productive urban mining approach. Furthermore, absence of an information system that hosts and uniformly makes information accessible is highlighted in the Prospecting the Urban Mines of Amsterdam (PUMA).

This research aims to introduce a centralized information system that is managed by a local authority, here referred to Municipality of Amsterdam as urban planner and coordinator among industry players. The research begins by suggesting the path towards exploring, identifying, collecting, and processing necessary information to find the urban mines constituted in underground (mainly power cables) and building stocks. Followingly, there has been six locations particularly selected to be assessed for their urban mine potentials. The assessment is conducted referring to, and obtaining information from various source and processed into an outcome that provides quantification of stocks in the selected locations. Although weakness and lacks have been encountered in the available data, it is still better that nothing and the assessment could be made. It is no argument that the data need to be improved in terms of accuracy and validity to be fit for a practical urban mining approach.

As the first step to assess the metal contents, the results highlighted the different potential amongst the selected locations. Comparison of metal contents with regards to length and also monetization of them, provides a better view of which makes decision making process easier. The result showed the aluminium content of as high as 48tons for Karperweg with total length of 310meter, to as low as 899kg for Titiaanstraat with 260meter length, concentrated in underground stocks. Considering the capacity of understocks per length of streets, the outcomes showed approximately 15tons and 1,7 tons per 100meter length for Karperweg and Prinses Irenestraat respectively. On the other hand, around 200kg per 100meter length for

Pieter Cornelisz Hooftsrtaat. The analysis obviously gives the idea to focus on Karperweg and Prinses Irenestraat for urban mining approach as they offer more revenue in possibly an easier extraction process due to allocation in a much less dense area. In addition to quantifications, the aluminium contents for underground stocks have been monetized to assess the revenue of stock recovery, put aside the exploitation cost. The outcome shows that in Karperweg the revenue can be as high as almost €29000 for 310meter length, and nearly €6800 for the whole 650meter length of Prinses Irenestraat. At this moment, financial feasibility can clarify whether or not to perform the urban mining, depending majorly on exploitation costs; and if yes, what procedures and considerations should be undertaken to conduct the mining operation.

Last but not least, as the main contribution of this study, the attained information is then linked to a map for enhanced comprehensibility of the potential users. The users, proposed recyclers for underground stocks and designers for building stocks, are given the opportunity to seek proper information in a well-organized manner for the stocks that become available in the area they are looking for. The map is created using GIS tools by attributing data to allocated locations, buildings as points, and underground stocks as lines representing the streets. The digital platform is part of the information system that requires to be verified and validate by a central organization. The parties involved need to provide verified and validated detailed information such as bill of material (BOM) to the system at the start of the primary use-cycle, and continuously track of action such as repair or maintenance to be recorded and upgraded in the digital platform. Towards the end of the primary use-cycle the defined secondary users are then able to access information of the material that will be available to be mined. It is crucial for the system to have all the parties involved in the life-cycle of a material to cooperate with the central organization to supply the unified standard information that can be accessible to everyone in a global format.

It is no doubt that only a proper information system in place is not sufficient to activate the industry actors to deploy urban mining approach. The culture needs to be framed in the system with the use of tools in hand such as policies and legislations, taxation and/or incentive defined within forms of contracts. As the concept of urban mining suggests, this needs to be initiated and coordinated with the help of central and local government authorities; namely the municipalities.

1. Urban mining; why?

In this chapter, the general concept behind the urban mining and benefiting from it as one of the approaches to a circular economy is discussed. More specifically in the research problem, the obstacles and difficulties in achieving a full-scale urban mining will be mentioned, followed by the structure of the research through the research questions. Lastly, the overall framework of the research and how the findings assist the industry to improve efficiency in urban mining of Amsterdam, will be presented.

1.1. Background

The world population, expecting to reach 9.7 billion by 2050 (United Nations, 2019); and in the meantime, urbanization, expecting to be at 68% (6.6 billion) by 2050 (United Nations, 2018), are rising so rapidly that coping with their needs for resources, and handling their waste production is becoming a world crisis. Together with rise in GDP, which brings along increase in per capita income, comes increase in demand for resources and of course increase in material consumption. If this process continues as it is, it brings along more dreadful environmental impacts caused by climate change, pollution and so on. With current pace, it is estimated that equivalent to resources of three planet earth will be required to satisfy the consumption of the world population by 2050 (European Commission, 2021).

In order to avoid such unsustainable growth, the resource consumption is required to be within the planetary boundary (European Commission, 2021), simply meaning the consumption needs to within a safe environmental limit based on sustainable developments (Steffen, et al., 2015). Planetary boundary (Status as of 2015, shown in Figure 1) demonstrates nine environmental processes that regulate the stability and resilience of the earth system (Stockholm Resilience Centre, 2015). As Figure 1 suggests, four of the nine boundaries have surpassed the safe limit for earth ecosystem. For the consumption to be within the safe environmental boundary, estimates notify that the resource efficiency is required to increase four-tenfold by 2050 (European Commission, 2021).

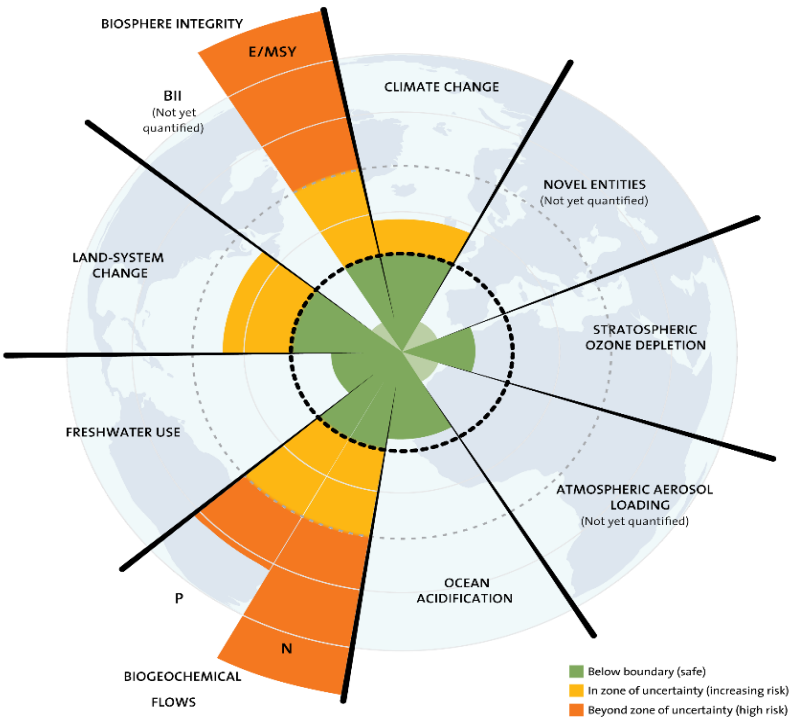


Figure 1: Planetary boundaries-status as of 2015 (Source: Stockholm Resilience Centre)

The crisis has pushed the European Union to introduce a roadmap to set in motion the resource efficiency initiative which was then followed by the circular economy initiative, resulting in Circular Economy Action Plan (CEAP) in 2015. As a result, the European Green Deal sets the vision of EU member states to achieve a climate neutral, resource efficient and a circular economy. In relation to the priorities addressed, the focus of the 2020 action plan is on design and production, together with aiming to maintain the material within the use cycle as long as possible. The design and production focus of industries are meant to achieve major waste prevention and management (European Parliament, 2021). Hence, setting the target of a 100% circular economy and climate neutrality by 2050 (Rijksoverheid, 2018).

On the basis of 2020 circular economy action plan, the products are designed to be sustainably durable, suitable for reuse, repair and recycle. Amongst the various measures that are considered within the action plan, one is being to focus on key value-chain (European Commission, 2021). Therefore, the calculations and estimates point out that the embedded potential for circular economy and resource productivity of three sectors of food, mobility, and built environment account for 60% of EU household budget and 80% share in resource consumption (European Commission, 2021).

Amongst the EU member states, Netherlands, with 28,5%, is having the highest circular material use rate. Meanwhile, being the largest exporter of waste with nearly 5,6 million tonnes in 2019 (European Commission, 2021). As a result, construction and demolition waste is accountable for the largest waste stream with 25 million tons in 2018, which is 40% share of the total waste produced (Wildeboer & Savini, 2019). Although, with more than 95% recycle rate in construction and demolition waste (Rijkswaterstaat, 2015), the Netherlands has already achieved the EU 2020 mandatory target to reach 70% re-use, recycle, and other recovery rate (Hu, Yang, & Xicotencatl, 2020), there are arguments that this rate includes downcycling while some materials can be qualified to be reused. Figure 2 demonstrates a conventional way of waste treating of construction and demolition waste (CDW) where Reinforced concrete is crushed; steel reinforcement possibly sold to recycling plants, and crushed concrete downcycled as base material for road construction.

Figure 2: In-situ demolition waste treatment in the Netherlands (Den Bosch, April 2021)

Promoting the use of secondary materials is on trend more than ever in order to bring the human operations back in a sustainable use margin. Several motives have come together to introduce urban mining as an efficient and potential approach for the achievement of a circular economy, targeting the approaches in the ladder of circularity

(EllenMacarthurFoundation, 2013). Lack of resources, especially metals, high cost and negative environmental impacts of transportation, unsustainable conventional mining and so on, are some of the pushing factors for urban mining to shine.

In theory, urban mining is referred to as reclaiming the material from compounds and elements present in the anthroposphere in the form of urban stocks such as buildings, infrastructure, and so on (Ghosh, 2020). The large concentration and intensity of metals in the anthroposphere due to the needs of the constantly increasing population is the reason behind the motivation to re-use and re-cycle the metals after their primary consumption cycle. Between 1990 to 2015, the raw material consumption increased by 26%, from 274ktons to 345ktons, and the population grew by 22% within the same period (Lederer, et al., 2019). Hence the development of the urban mining concept (Koutamanis, van Reijn, & van Bueren, 2016).

1.2. Research problem

Construction industry, in the Netherlands, plays an important role in the material flow of cities, taking into account for 50% of raw material consumption (Rijksoverheid, 2018). As present in Figure 3, in 2018 in Amsterdam, the volume of metals such as steel, and copper used in the built environment was respectively 15, and 1 kilo tons (Gemeente Amsterdam, 2020b). The built environment sector, comprised of buildings and infrastructure, is accountable for consuming more than 50% of the metals, such as steel, copper, aluminum, and zinc, globally (Beers & Graedel, 2007). As the numbers suggest, the material flow shows interest in implementing the urban mining approach. The Netherlands has been a pioneer in initiation and implementations of advanced circular methods in construction sector.

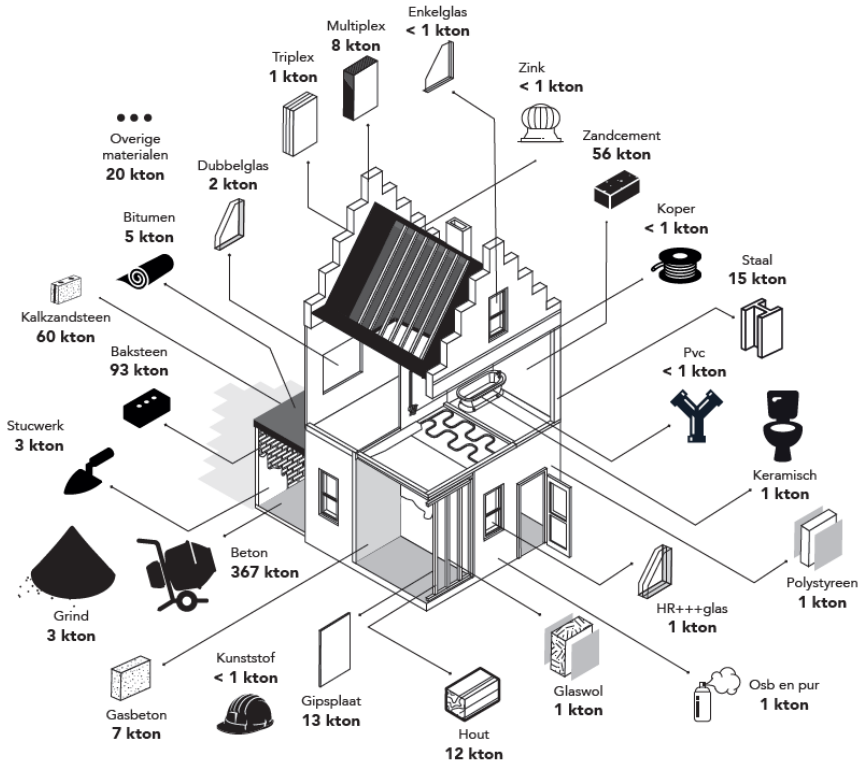


Figure 3: Material consumption in built environment sector, Amsterdam 2018 (Source: Amsterdam Circulair Monitor)

The development of methods and tools in the building technology commend the true potential to propose convincing and promising methods for sustainable construction developments. Various research and measurements have been conducted to quantify the

stock in urban areas; such as PUMA (Prospects of urban mines Amsterdam) and REPAiR (M. Alvarez-Mendez, 2020). Cities and municipalities have started to develop a road map towards the promotion of more circular construction that oversees urban mines as the potential source of raw material in the near future. Amsterdam as the initiator and the largest city of the country, followed by Rotterdam, Utrecht, and Amersfoort have taken steps and shown interests. According to an evaluation conducted in 2018 in Amsterdam, validated by one hundred Amsterdam expert organizations, circular economy was identified to be feasible and profitable (Gemeente Amsterdam, 2020c). The city of Amsterdam took the first step towards setting vision and roadmap for the circular economy in the Netherlands. Consecutively, the municipality of Amsterdam is assigned to have the stimulating and facilitating role to inform and activate the parties along (Gemeente Amsterdam, 2020c). With this regard, the city of Amsterdam has published four complementary documents to describe the strategies steps toward the 100% circular economy in 2050. The first document describes the 2020-2025 strategy to outline why and how Amsterdam is becoming circular. Second, the innovation and implementation program 2020-2021 that discusses in depth about the detail of projects and procedure that are taking place to accelerate the shaping of the circular economy. Third is the Monitor and describes how the circularity of Amsterdam can be measured. Lastly, the Amsterdam city doughnut model presents how the economic development is satisfied while the limits of the planet and society are not at risk (Gemeente Amsterdam, 2020a). In the first document, 2020-2025 strategy, three main sectors to focus have been identified and built environment is one of them. Furthermore, three ambitions have been described for the built environment to focus circular development, circular procurement policies, and circular upgrading of existing building environment (Gemeente Amsterdam, 2020a). The three ambitions are briefly described below:

- First ambition: The transition to circular development requires a joint effort
- Second ambition: The city sets the right example by formulating circular criteria
- Third ambition: A circular approach to the existing city

The process of urban mining for the built environment sector deals with challenges that are unique from other industries, for instance electronics. Scattered information about the quantity and other attributes of the material and components, imprecise estimations of the quantities are some of the factors which make it unfavorable for users to consider urban mining as integral part of their businesses. Furthermore, not only the unavailability of open data, but also the lack of these data is also what the industry is struggling with at the moment (van der Voet, et al., 2017). In addition to that, although a digitalized system is probably well-known and available within every organ involved in the life cycle of a material, they are not well-integrated together. In other words, information is often kept within one sector and not transferred to the others (Pehlken & Baumann, 2020). Absence of a central authority that generates the integration and cooperation among various parties involved in the demolition is another cause of complication. In order to efficiently benefit from the urban mining approach and define it as a feasible process, transparency and accuracy in data needs to be assured for the parties involved. Since the urban mining is not a very new concept and it has already been used for decades in the electronics industry mainly due to scarcity of the metals involved, it is also expected to happen soon for the less precious metals such as copper and steel in other industries. However, in order to expect the reclamation of the mines in the following decades, the platform for a smooth and profitable process needs to be built now.

There are various tools, methods and concepts flourishing in the built environment sector that a combination of them can lead us to an efficiency along the construction processes. Building Information Management (BIM) is already advancing and being widely used in the design phase prior to construction. Pehlken and Baumen (2020) emphasize on the importance and necessity of bill of material (BOM), of which can be generated from the BIM model, to be issued by the manufacturer and to be shared with other parties involved in the material life cycle (Pehlken & Baumann, 2020). Conceptually similar to the bill of material, material passport is introduced to provide clear identity of products and components that are used in a building or a service (Blok(3), Schouten, & Dasnois, 2020b). BIM models are also being used in the construction processes assisting logistic and project monitoring. Other tools such as Virtual Reality (VR), sensors in IoT, Geographical Information System (GIS) and many more are being extensively used for varieties of purposes in the built environment. For instance, the department of infrastructure and water management (Rijkswaterstaat) in the Netherlands, is already using sensors and IoT to collect data from their assets throughout the country, of which are then analyzed and provide pragmatic insights on operation, maintenance and replacements. In line with targets to improve design and resource efficiency in construction, it has become possible through the use of BIM for the

Furthermore, there are already many pilot projects involved in creating a platform of available stocks for potential reuse approach, like a market place of construction material; however, the lack of information and automation in the process is still missing. Although the progress is admirable and is one step forward towards the target, it is not what an actual user in real world industry would be willing to look for in a decent construction scale. It is understood that the user requires a smooth, easy, and properly informed process in order to be assured and encouraged for the transition. All in all, it should not be forgotten that with all being said, as long as the end price is not compatible, using new virgin material is rational, no matter how much effort is put into implementing a competent urban mining approach.

1.3. Research objective and questions

As discussed in section 1.2, the city of Amsterdam is the initiator for circular economy acts in the Netherlands. Followingly various studies and assessments have taken place in various sectors; namely the PUMA for assessment of urban mines in Amsterdam. With regards to the contribution of urban mining in a circular economy, it focuses on reuse and recycling of material or construction elements. Accordingly, being the most populated city in the Netherlands, of which the share of construction and demolition waste (65% of overall (Gemeente Amsterdam, 2020b)) is more than the national average (40% of overall (Wildeboer & Savini, 2019)), alongside the existence of urban mines assessments such as PUMA, makes Amsterdam the focused city of this research than can be used as a reliable model for other cities.

In accordance with current studies being conducted mainly in quantifying the available or hibernated stocks of material (mainly metals). This research aims at taking it one step further to sooth the needs and desires of the end user (or better say the new user) of the newly becoming available stocks. The end user might vary from a developer, designer, contractor, or a recycling company; however, in a more specific objective context, and that the reclaimed material are fit for reuse or at last recycling, the utilizers are described thoroughly below:

1. Designers: It addresses designers of structure and architecture of a building. The designer, needs to be given the assurance to reuse the elements that can be fit within

the requirements. For instance, if steel structure elements of a building to be demolished in the next one or two years fits within their requirements, with flexibility in design, they can use the same element in their design. The central digital hub provides them the assurance to verify, communicate, and procure the elements.

2. Recyclers: For less durable stocks that are no longer suitable to be reused, recycling is the next sustainable option. Cables, wires, pipes and so on, fall within this category. The platform assists the recycling plants to get involved in a more systematic collection of no longer feat for use metals.

Hence, the main objective of the research would be to provide a platform where the user is well informed of not only the quantity, but also the location, availability, and other attributes assigned to the material or elements they are looking for. It is not within the scope of this study to provide all of the mentioned information, but to introduce a publicly accessible platform for it. The acquired information is required to be provided and structured by parties along the supply chain, namely producer, designer, operator, and others if any. So basically, the ones that are going to use it later as well. To be more precise, the platform targets to deliver most useful, perhaps filtered, information to the designers who are willing to design and build a building that is going to be located nearby the urban mine that its' components are going to be available by the time the new project is going to be realized. In other words, the buildings act as temporary material storage for the future buildings.

With the research objective defined, the research questions are structured as below:

Main question: *How can the information on urban mines in the built environment be delivered to users efficiently?*

Sub-question 1: *How to quantify stocks (in use) for both buildings and underground services of Amsterdam with available open information?*
Sub-question 2: *What are the necessary tools or methods that need to be utilized and applied in the informative platform to the future users?*

1.4. Research approach

In this section, the overall layout of the research, that guides through answering the research questions, is going to be briefly discussed in phases. In addition, Figure 4 represents the flow diagram of this research approach and will be referred to in the following chapters in the given order.

Phase 1: The research begins with identifying available information and databases to help allocate and quantify the stocks in both buildings and underground services of the city of Amsterdam. In accordance with certain criteria, such as function integration, and quantity, various locations are chosen to be assessed. The assessment consists of collecting information, sometimes from various sources, and measuring the quantity of stocks on selected locations. One of the main purposes of this step is to demonstrate the effort that is required to quantify the stocks while the information is already available, but scattered. This phase focuses on answering research sub-question 1.

Phase 2: Then, the research is followed by preparing and organizing the measured assessments as a dataset that can be imported by a GIS software. GIS, as it will be discussed later in chapter 2, is one of the main tools to be utilized for urban mining. One of the main processes of this part is to generate the geographical coordinate points for every single building plot. For the underground services; however, the platform offers information to

street level. With that regard, information on dataset is allocated to a street segment, which consists of a number of sub-postcodes (i.e., 1071BM).

Phase 3: Once the datasets are prepared separately for buildings and underground stocks, they are added to the GIS software used (here QGIS 3.16) as two separate layers to the open street map. The processes comprise of different approach since the data types were differed.

- For buildings: The features are attributed as points to allocated building plots.
- For undergrounds: The features are addressed to a segment of the street that consists of a number of postcodes. Hence, the measured characteristics, are attributed to that segment of the street using the street network map. The method will be discussed in chapter 3 more deliberately.

Phase 4: The last phase of the research is to create a web map of the outputs in GIS, so that it is open to public, and it can be accessed by users. The layers of buildings and underground services will be presented as layers in separate maps.
Below, the flow diagram of the approach is demonstrated:

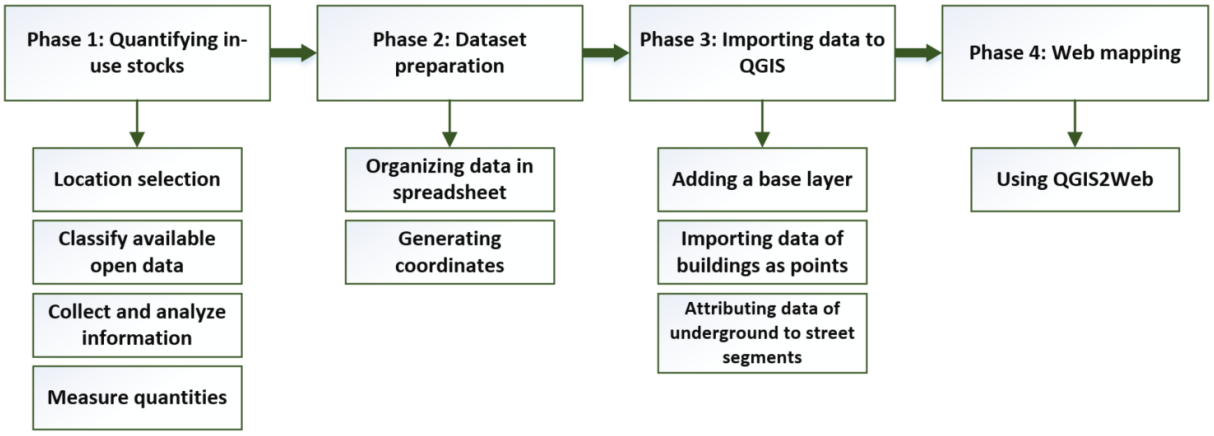


Figure 4: Research approach flow diagram

The phases briefly discussed above, will be described more thoroughly in chapter three, and the results and outcome of findings will be presented in chapter 4. Lastly, the research questions will be addressed and discussed through the context of the study.

2. The evolution of urban mining

This chapter represents the literature review of this study. It starts by discussing the concept and history of urban mining, and why it is beneficial. Then the current practices occurring in the Netherlands toward the achievement of the urban mining approach is presented.

Moving forward, the chapter argues the outcome of previous studies and what their highlights about the feasibility of urban mining in various locations are. The argument then flows into the methods and tools available in the industry and how they can be used in order to fill the identified gaps in the circular construction industry.

2.1. Urban mining; the history and concept

The concept of urban mining was known to be first introduced in the 1980's by Professor Hideo Nanjyo of the Research Institute of Mineral Dressing and Metallurgy at Tohoku University. It was initially implemented in practice and argued for the recovery of rare metals stocked in electrical and electronics wastes. The potentials of the urban mining concept led towards the re-availability of some rare metals such as europium and terbium (Recupel, 2015). Therefore, for some of these rare metals, urban mining is becoming the only source. Aside from that, the pureness of these rare and expensive metals from urban mining deposits is much richer than that of extracted natural ores, where there is 5grams of gold in a ton of its natural ore versus 200-250grams per ton in PC circuits, and 300-350grams per ton in cell phones (Caffarey, 2012). Therefore, not only urban mining helps the recovery of rare and valuable metals, but also it is more beneficial in terms of processing of natural ores, let aside the transportation. Adding to that, the negative environmental impacts implicated throughout the life cycle of elements is saved by the benefit of urban mining of them.

Through the past few decades, as a result of very high consumption and catastrophic extraction process of minerals from natural ores (De Haes, 2018), the concept of urban mining has evolved and found its way through to less valuable metals that are being at the edge of scarcity. These metals are widely used in cities with a high rate of urbanization and modernization. Although there are still many limitations and difficulties with implicating this concept in the real life, its publicity and rapid evolution is clearly giving the hint to act on it.

2.1.1. What is the difference between urban mining and waste management?

The difference between urban mining and waste management is drawn by a very thin line. Figure 5 displays the linear economy from d1 to d5, while for a circular economy, the scenario changes at d3 when the waste regains its' value and enters the urban mining system at d4. It is then decided to whether re-enter the material into use cycle (reuse or recycle), or else to send for treatment (d6) prior to landfill sink. Of course, as recognized, the recovery stage, which is defined as gaining energy from the no longer capable material to be reused or recycled, is missing here.

It clarifies the decision and intention of what the materials and elements are going to end up after their primary use cycle. In the traditionally described definition of linear economy, waste is referred to material ending up on landfills after their primary use cycle (Cossu, Salieri, & Bisinella). As development in technology and limitations in raw material, concepts of recovery (Biomass), and then recycling have been introduced and are now widely being implemented. While they fit in the concept of circular economy, they are still not sustainably good enough because they lose their primary properties and value to produce energy or to be downcycled, while being reused maintains their initial embedded value.

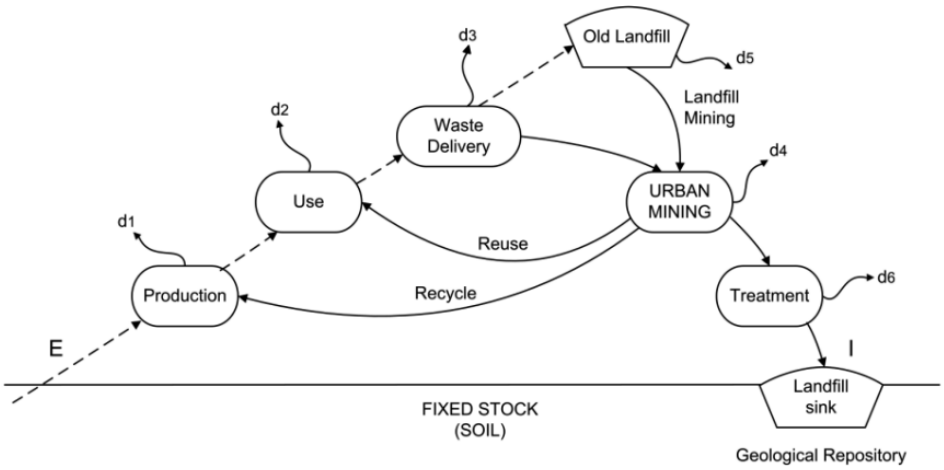


Figure 5: Role of urban mining in material life cycle (Source: https://www.urbanmining.it/public/documents/simposio/introduction-to-the-concept-of-urban-mining.pdf)

Some of the concepts introduced in the ladder of circular economy (EllenMacarthurFoundation, 2013) (see Figure 6), such as reusability, repair, refurbish, remanufacture, repurpose, and recycling of elements are what shine as the true meaning of urban mining. In the Figure 5, R3 to R8 are referred to as efficient approaches to urban mining.

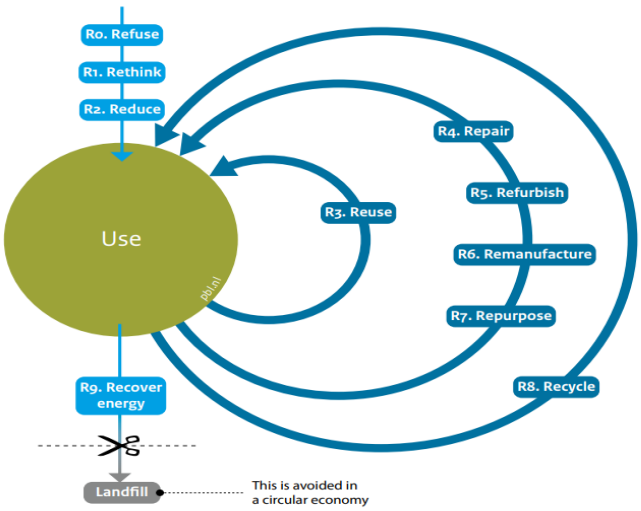


Figure 6: Ladder of Circular Economy (Source: PBL Netherlands Environmental Assessment Agency)

2.1.2. How can the society benefit from urban mining?

The main purposes behind urban mining are conservation of resources for the future, implication of less negative impacts on environment, and lastly the economic value that it brings by stocks exploitation (Ghosh, 2020). In addition, it is expected that in the next fifteen years the classic mining will not be able to meet the fast-growing need for certain metal supplies such as electrical appliances. Even so, this is already the case for some rare metals that the urban mining is becoming the only source (Recupel, 2015). Although conceptually convincing, recent studies show that the urban mining approach is not always economically beneficial. The study of Angelis-Dimakis et al, (2017) on assessing the urban mining potential in the city of Huddersfield suggests that due to features and characteristics of urban developments such as high density and complexities, the recovery of iron stocks is not economically feasible in the case of separate extraction (Holland & Angelis-Dimakis, 2017). In

addition, Krook et al., (2010), conducted a study on urban mining of metals in Sweden, and the study concluded that in cities, it is only profitable when integrated recovery of cables is performed for copper mining; however, in rural areas, both separate and integrated recovery seem to be profitable (Krook, Carlsson, Eklund, Frändegård, & Svensson, 2011). Separate recovery of stocks is basically digging the ground solely for the purpose of mining, or stocks extraction, while integrated recovery of stocks means the recovery that is done together with digging for the purpose of maintenance or installation (Holland & Angelis-Dimakis, 2017).

As Figure 5 demonstrated, in the linear economy, the materials and elements used to end up in landfills after their use cycle. The concept of material flow analysis (MFA) is developed in order to clarify the stream of material flow into a system (a country, city, etc.), which believes to be the fundamental and basic approach towards efficient urban mining. The material flow analysis is a widely used quantitative method to determine material flow stream (Wallsten, Magnusson, Andersson, & Krook, 2015). MFA, if done accurately, together with GIS allows a reliable estimation of mines, also known as stocks, and visualization of their location and routing throughout the city; however, it is not enough to enable profitable urban mining. Mainly because there is not enough information and grounds that guarantees the process to identify and collect the suitable elements.

The report of PUMA (Prospecting the urban mine of Amsterdam) (van der Voet, et al., 2017) suggests a two-step process to assess the potentials and limitations of urban mines as secondary sources of metals. The first phase is to build a database and construct a geological map of the mines in Amsterdam. This is done through analysis of material flow paired with GIS to map and locate the mines. The second part is the exploration and assessment the exploitation of the urban mines, which play a crucial role in the feasibility assessment of the urban mining approach (van der Voet, et al., 2017). The first part of the approach is discussed to be not fairly accurate to provide an aggregate outcome of the assessment. The GIS mapping often provides the database on urban or district level, however, for a proper assessment of urban mines, higher resolution of spatial distribution of mines, perhaps to street level, is required (Wallsten, Magnusson, Andersson, & Krook, 2015). All being said, GIS assessment is believed to be a useful tool to visualize geographical and spatial data (Chang, 2008), hence providing information to identify potential areas within a city for urban mining practices. Figure 7 demonstrates some fragments of the GIS map for steel and copper in Amsterdam.

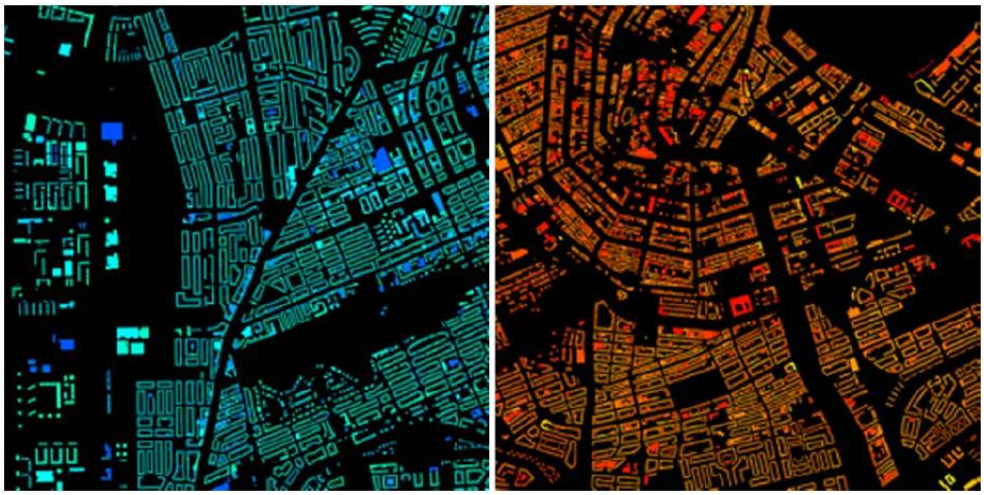


Figure 7: Fragments of copper (blue), and steel (red) presence in buildings, Amsterdam (Source: PUMA published by AMS)

It has already been discussed why GIS is essential as the first step towards urban mining potential assessment. The study by (Wallsten, Magnusson, Andersson, & Krook, 2015) combines MFA and GIS to evaluate the quantity and characteristics of hibernating stocks, which in their method introduction is referred to as phase 1, and then to assessing feasibility of stocks recovery, both technical and economic. The stocks that are no longer in use cycle and also have not entered the waste stream yet, are categorized as hibernating stocks (Bergbäck & Lohm, 1997), which are the target of Wallstern et al., 2015 case study in the city of Linköping, Sweden. The bottom-up MFA approach together with GIS analysis provided an aggregated characteristic and measure of the no longer in use cables underneath the city. An estimated 123tonnes of copper (1kg per person) was identified to be available for recovery. However, it is presented that not even for a single cable, it is profitable to perform a separate recovery. Figure 8 shows a scatterplot of cable revenue against its extraction cost in Swedish Krone. As it can be seen, all the values are negative. Therefore, it is suggested to perform an integrated recovery of hibernated cables (Wallsten, Magnusson, Andersson, & Krook, 2015).

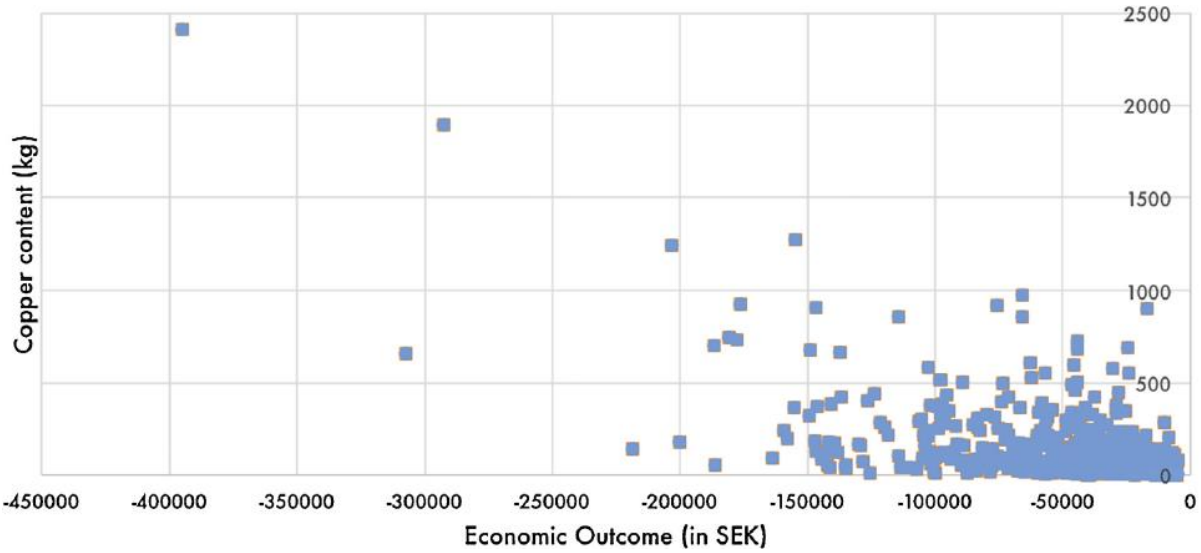


Figure 8: Copper content of hibernated stocks vs. Economic outcome for separate recovery of stocks (Source: (Wallsten, Magnusson, Andersson, & Krook, 2015))

Another study conducted identical to the study of Wallsten et. al., 2015 for Linköping, Sweden; was conducted for the manufacturing city of Huddersfield in north England. The study focused on mapping the spatial distribution of hibernating stocks such as power grids, telecommunication cables, water mains and natural gas supplies, all together constituting copper, aluminum and iron, followed by assessing exploitation options (Holland & Angelis-Dimakis, 2017). Likewise, this study also argues the cruciality of the extraction process. It identifies the extraction implications to be dependent on two parameters, first, urban relief; referring to density of the city (Holland & Angelis-Dimakis, 2017), and second, surface material; referring to the ground condition and its level of difficulty for digging (Wallsten, Magnusson, Andersson, & Krook, 2015). All in all, the study concluded that the approach of the urban mining for this case is also feasible only when an integrated process is undertaken.

Urban mining, in general, offers benefits in two ways, one is direct economic benefit from the value of stocks (monetization), and the other is the prevented negative environmental impacts. The negative environmental impacts are translated into costs for better comprehensibility and tangibility. These costs are called shadow costs, defined as an indication of the environmental quality of a material or element (de Bruyn, et al., 2010). In other words, it translates the negative environmental impacts of a good throughout its life

cycle, to cost indicators based on the impacts' weightage as one unified impact category (Hillege, 2019).

The recently published article from metabolic assessed the value of the more than 2 million tons of secondary material that become available in Northern Dutch provinces until 2030 from building demolition as €136 million, and also an equivalence of €4 million as environmental costs benefits (Blok(4), 2021). By all means, as discussed previously, the urban mining feasibility is not only the value reclaimed from the secondary material, but also the exploitation costs of them. Separate recovery of stocks (visualized in Figure 8) versus integrated recovery of them makes a big difference in bringing mining of underground services into practice. For the case study of Wallsten et. al., 2015 for the city of Linköping, the profitability of integrated recovery of underground cables is presented in a scatterplot in Figure 9. As outlined by the plot, only 2% (2.2 tons) of the total hibernated stocks identified are profitable to be mined in integration with other maintenance works which involve digging of the ground (Wallsten, Magnusson, Andersson, & Krook, 2015).

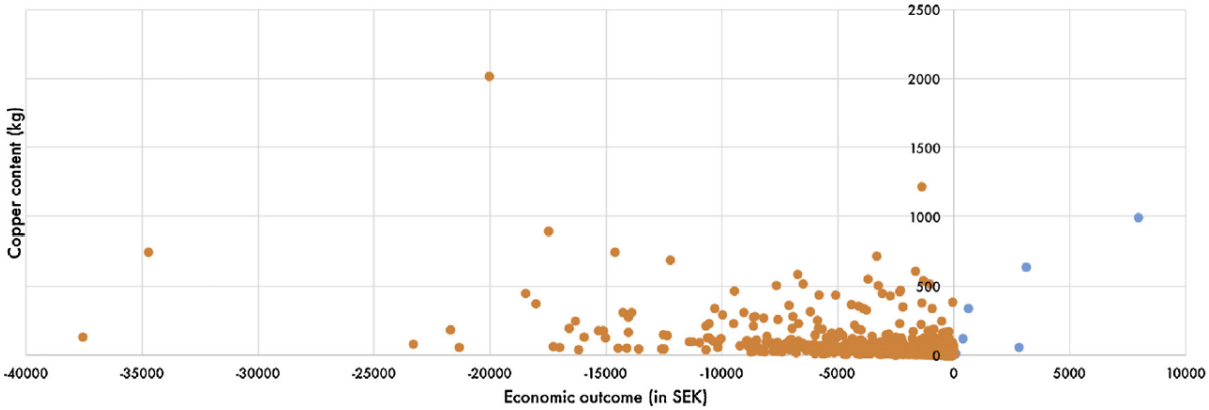


Figure 9:Copper content of hibernated stocks vs. Economic outcome for separate recovery of stocks (Source: (Wallsten, Magnusson, Andersson, & Krook, 2015))

2.1.3. Current practices in the Netherlands

The city of Rotterdam has set a target to reduce the use of raw materials by 50% in 2030 (Blok(4), 2021). The municipality estimated that by 2030, nearly 817,000 tons of material will become available upon demolition works in Rotterdam, of which 28,000 tons of steel and iron, 144 tons of copper, and 610 tons of aluminum will be available (Metabolic, 2020). In the urban mine of Rotterdam, the city has modeled the transition of buildings that are going to be newly built (green), demolished (red), renewed (yellow), or transformed (orange) (See Figure 10). This allows them to monitor and plan for the stream of waste and their end-of-life scenario. The environmental impacts and their recovered cost are also calculated for better understanding of the wealth they are dealing with. The analysis is narrowed down to construction elements and provides their amount of availability by 2030.

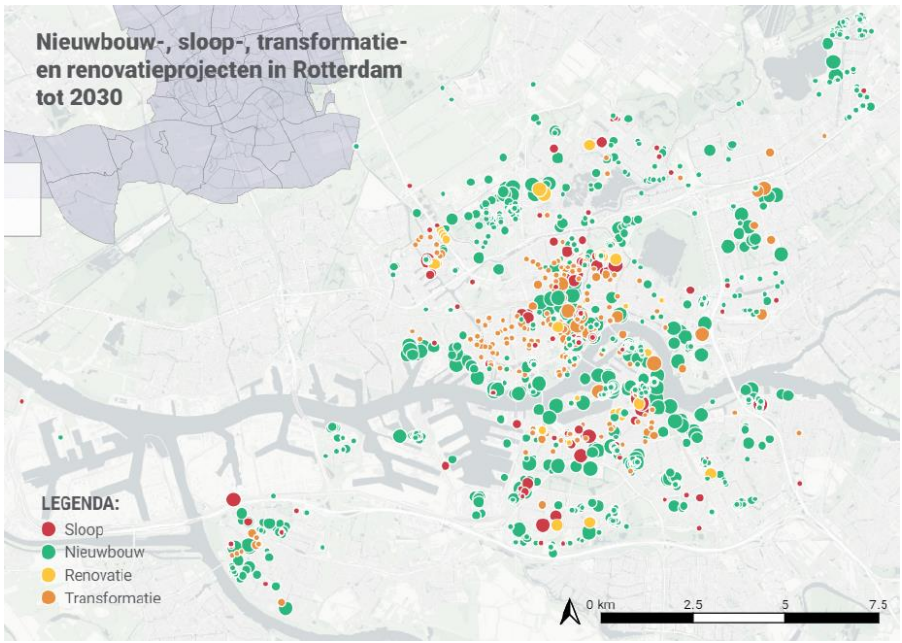


Figure 10: Planned construction, demolition, transformation, and renovation projects in Rotterdam until 2030 (Source: De urban mine van Rotterdam)

There is a solution offered for the city to establish a hub where the opportunity to reuse and recycle the construction elements at the highest possible rate is offered to consumers. Figure 11 draws the concept of this construction hub. It clearly demonstrates the streams of demolished material and how they can be of benefit for their secondary life cycle.

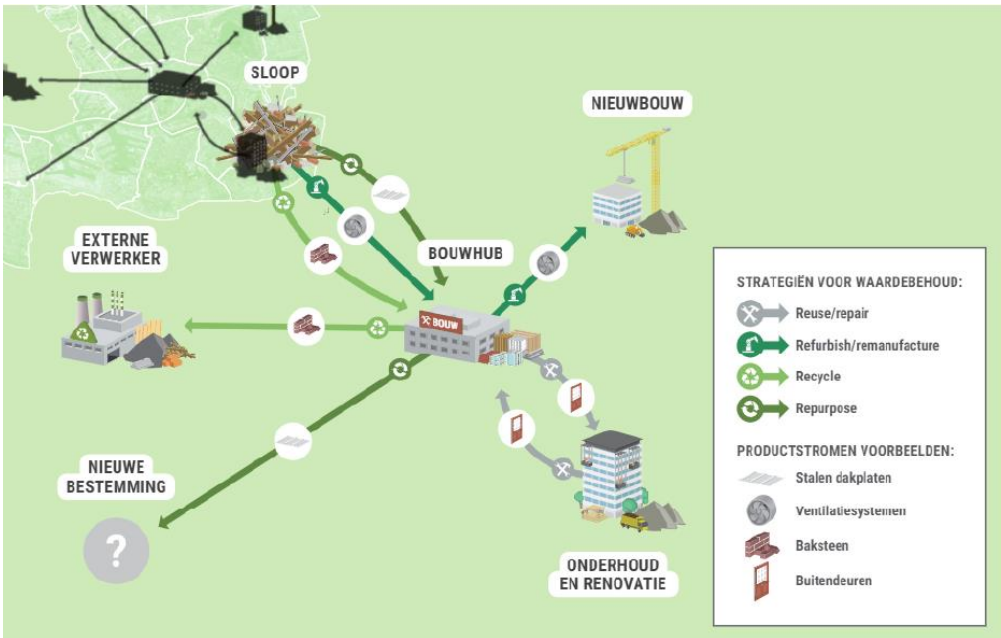


Figure 11: Demonstration of the role of a construction hub in a circular construction (Source: De urban mine van Rotterdam)

The conducted research indicates that reuse of only 1% of the waste (out of 817,000 tons) contributes to 8% to the prevention of harmful environmental impacts and nearly €43 million of value recovery. As discussed before, reusing of material allows us to maintain significant amount of value, such as embodied energy, transportation, and so on.

It should not be neglected that no matter how efficient and circular the construction sector becomes, with rapid growth in the region and the need for housing, offices and so on, the

circulation of material at highest rate, offers only up to 64% of the overall supplies needed for new constructions and/or transformations (EIB & Metabolic, 2019).

In another scenario, the very significant growing region of Utrecht is assessed. The U10 region (ten municipalities of Utrecht, Amersfoort, and the economic board of Utrecht) estimated the need of roughly 5 million tons of construction material for projects planned between 2018 to 2022, while the current share of supply through urban mining is at 20% of this demand (Blok(2) & Faes, 2020a). Accordingly, the city found the need to promptly implement the smoother adoption of urban mining (Blok(4), 2021).

Amsterdam, like Rotterdam, is aiming for reducing the use of virgin material 50% lower by 2030, while the goal to achieve 100% circular economy by 2050 stands there nationally (Gemeente Amsterdam, 2020a). The municipality of Amsterdam, in collaboration with Leiden university, TU Delft, De Waag Amsterdam, and Metabolic, published a report to evaluate the prospect of urban mines in Amsterdam (PUMA). The study assesses the limitations and potentials of the urban mining approach to be considered as a source of secondary metals, mainly in residential buildings (van der Voet, et al., 2017). The study suggests two phases to undertake for an urban mining assessment (van der Voet, et al., 2017):

a. Establishing a database with geological map of urban mines
b. Exploring exploitation options for urban mines

To conclude, the PUMA report suggests a proper maintenance and reservation of information of used material. Some studies that were discussed previously (Wallsten, Magnusson, Andersson, & Krook, 2015), identify the lack of information as one of the main obstacles to benefit from the buried, lost material that were potential urban mines. Both studies focusing on different cities of the Netherlands, clarified that the use of tools such as material passport and building passport are essential for the future of urban mining (van der Voet, et al., 2017) (Blok(4), 2021).

Of course, the scenarios and situations change over time and with continuous extraction of natural ores that lead to less reserves, the urban mining approach becomes more viable and beneficial. The amount of natural stock in our planet remains constant while it is transferred from natural mines to anthropogenic. Therefore, in the near future, the urban mines will act as the new source of materials and/or elements. The concentration of anthropogenic stocks is mainly within the buildings and infrastructure. The status in each of these categories is going to be discussed below.

2.2. Buildings as mines

Buildings are comprised of various functions such as residential, office, commercial, educational, entertainments and so on. Depending on the age of the buildings, the functions, and capacity, the material used in the buildings may differ. Older and low-rise buildings are less likely to include steel in their material composition. The case study of various buildings in Amsterdam, conducted by Metabolic, concluded that buildings with BAG registered construction year before 1900 are less likely to have steel in their load-bearing structure (Blok(1) & Roemers, 2017). Particularly for the city of Amsterdam, the PUMA report has prepared an extensive framework for assessment of building material stocks in Amsterdam. As a result, follow up research provided more in-depth insights of the situation in building sector.

Due to lack of information for existing buildings, the estimation methods are considered the most reliable approach to quantify the use of metals in buildings (Koutamanis, van Reijn, & van Bueren, 2016). Basically, two approaches are introduced for the estimation (Drakonakis, Rostkowski, Rauch, Graedel, & Gordon, 2007):

1. Top-down method: assesses the metal content in accordance with the quantity entered the use cycle and the amount that are considered at their end-of- life or waste. This method is directly related and addresses the use of MFA (Material Flow Analysis) that was discussed before.
2. Bottom-up method: Evaluates the volume of metals based on the inventories of products. For instance, for a building or an electronic device.

Depending on the availability of data, a suitable approach can be chosen for the estimation of the urban mines quantities. Therefore, for buildings, the second approach is proven to be more consistent and reliable at the moment (Beers & Graedel, 2007). Although the accuracy of the estimations of the second method falls under the soundness of available data (Ortlepp, Gruhler, & Schiller, 2015). What makes the estimation approach for buildings different with other components or products such as electronics or cars, is that any building in a city has likely different characteristics or requirements than the same building in another city, or even a district. Therefore, it makes it complicated to generalize the estimation for all the buildings (Gerst & Graedel, 2008). However, it appears that buildings built around the same time, with same function, height, and size, are likely to compose of similar metal contents (Blok(1) & Roemers, 2017).

The PUMA framework used the information on metal quantities together with information regarding residential buildings to create a map that reflects the urban mining potential of the city. The concentration of the approach is mainly on residential buildings, hence the elements comprising metals in residential buildings had been identified and categorized as structural elements, building services, façade and roof cladding, and lastly windows and doors. In order to provide a more reliable and comprehensive approach, PUMA correlated the estimations with building information of residential buildings. Although it is more reliable and preferred to use information from BIM, in the absence of it, estimation using available documents from existing buildings to measure the approximate metal contents can be sufficient. Even so, in the absence of drawings and design documentations, estimation of the metal contents of a building with less precision extracted from other sources of documents such as housing typology, and general measurements based on the type of structure and building services utilized in the building (Koutamanis, van Reijn, & van Bueren, 2016). In general, there are three sources that offer information about building typology, and certain features such as heights, age, floor area and so on. The information on these available open data, although very valuable, are not complete. Information related to building load-bearing structure, services, doors and windows, and façade and roof cladding are often not utterly available. Hence, PUMA structured a framework to calculate the estimates. Figure 12 is going to show the framework diagram of the estimations that was done by the PUMA team as a base for metal contents of residential buildings in Amsterdam (Blok(1) & Roemers, 2017).

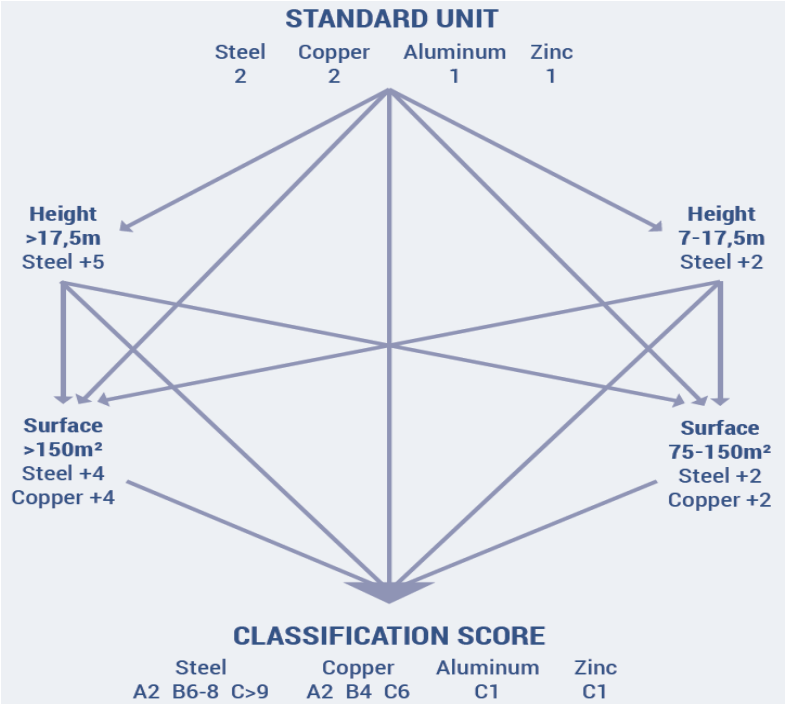


Figure 12: Estimation flowchart of building metal contents based on their features

Altogether, the framework made certain assumptions that lead towards the estimation of metals in buildings, as shown in Figure 8. However, after validations through visual inspections during random visits to a number of houses in Amsterdam, not all the assumptions were valid nor verified. Anyhow, the outcome is so far the only available datasets of metals for residential buildings in Amsterdam at hand. The dataset is discussed more thoroughly in section 3.2.2.2.

2.3. Underground stocks as mines

In the built environment, aside from buildings, lies significant volume of metals under the ground. These metals are often constituted as aluminum and copper in power and telecommunication cables, of which can often be found left in the ground after their primary use cycle (Leiden University, 2020). The main difference between stocks in the ground and stocks in buildings is that the stocks in building are rarely hibernated, as they are often in use or have entered the waste stream. The underground stocks are often left in the ground after their use cycle, hence categorized as hibernating stocks. Some studies have been conducted to assess the profitability of underground services, mainly power and telecommunication cables, extraction (Holland & Angelis-Dimakis, 2017) (Krook, Carlsson, Eklund, Frändegård, & Svensson, 2011) (Wallsten, Magnusson, Andersson, & Krook, 2015). The studies have come to a uniform conclusion that separate recovery of hibernating stocks is far from being profitable and the only feasible way to reclaim these stocks is to extract them while another digging is taking place for another maintenance or installation purpose, thus the integrated recovery is recommended. With regards to urban location and surface of the ground, Krook et al., 2015, have calculated the cost of underground cables recovery during a separate excavation in Sweden. (Krook(a), Svensson, & Wallsten, 2015). The calculated cost per meter of extraction varies from €86,78 (890SEK) to €39 (400SEK) depending on location and surface hardness, while the most common copper cable used in the city of Linköping values for €4,29 (44SEK) per meter long. A rough analysis represents that the separate recovery approach is far from profitability.

The integrated recovery, however, has its own weaknesses as it is totally dependent on other activities or failure/breakdowns that require excavation and also their location. Wallsten et. al., 2015 calculated that if the recovery of hibernating stocks would have taken place during maintenance works from 2003 to 2011, a volume of 7,2 tons of copper could have been reclaimed.

With all the studies discussed, the first and foremost step to undertake for the recovery of underground mines is to assess their economic potential, basically the profit they generate after recovery. Unfortunately, to my knowledge, there are not many studies assessing the underground services and their quantities in the city of Amsterdam. The PUMA report by AMS (Amsterdam Institute for Advanced Metropolitan Solutions) discusses the BGT (Basisregistratie Grootschalige Topografie) that furnishes with the information with spatial grid, pipes, cables, and so on (van der Voet, et al., 2017). The information can be accessed via PDOK viewer and it will be discussed in section 3.2.2.3. In addition, in order to provide the information on types, and position of cables to contractors who are planning to perform any construction, maintenance, and repair job, "Kadaster" offers a platform that offers the requested drawing documents upon request. This service is serving the purpose for ease and safety of any excavation works in the area; however, it is also a source of data about underground cables. More details about the platform are discussed in 3.2.2.4.

2.4. Monetization and shadow costs

In the exploitation phase, it is critical to put the focus on the value that the recovered material will generate. Literally, monetization is the action of converting an asset or a material into money (Cambridge Dictionary, 2021). Although from environmental perspective, the mining of stocks after their primary use cycle, offers great benefit over the traditional mining; in practice, the industry is not at a stage to prioritize environmental effects over financial benefits. Therefore, it is logic that if the generated revenue of the recovered material does not offer a profit over its' exploitation costs, then it will not be considered for further approaches of urban mining.

To assess the revenue made by mining, it is not as simple as calculating the price of one kilogram of the material. There are several limitations that affect the accuracy of value analysis of recovered mines (M. Alvarez-Mendez, 2020). The price variation is depending on the volume of purchase, different prices of material depending on their location, and to whom they are sold, whether they are the intermediary, processor, or the user of the material. In addition, the status of the reclaimed stock is important as well. Whether it is suitable to be reused or else it needs to be sent for recycling, which includes additional processing and environmental costs to become a component to be used again. Nevertheless, the exploitation cost is not discussed here and solely the value of recovered mines is discussed. Since clarifying the indirect costs discussed above are very subjective and not within the scope of this study, the prices received from digital sources on the web are going to be presented, compared, and be the source of assessment.

2.4.2. How much does 1kg of recovered metal worth?

For copper scrap, it is classified into various levels of value. The cleaner and brighter with no extra particle, and uncoated, falls under the best and most valuable scrap copper (See Figure 13) (SpaceShanty, 2020). Other types of copper scrap such as copper tubes or pipes, coated or insulated wires, and those with stronger and thicker insulation layers fall respectively under less valuable copper scraps that are purchased by scrap buyers. The price of unstripped

industrial cable is approximately at €2,6 per kilogram ($1.4 per pounds), while it can go up to €2,85 per kilogram ($1,54 per pounds) if uncoated (SpaceShanty, 2020).

Figure 13: Bare bright copper wire (stripped) (Source: ToughNickel)

Another source of scrap metal price quotation is from a company in the Netherlands, who actively purchases various types of metals and electronics (KH Metals, 2021). The hand peeled copper also known as bare bright copper shown in Figure 13, is valued at €6 per kilogram. Table 1 below, shows the value of other metals related to this study from this source.

Table 1: Price list of scrap metals (Source: KH-Metals)

Type of Scrap	**Price (€/kg)**
Old copper hand peeled	6,00
Copper	5,20
Old cable	1,80
Old zinc	1,20
Old aluminum	0,60
Heavy melting scrap (e.g., steel beam)	0,20

The prices above are described for the recycling of metals. For rough understanding about the difference it will make if the material is not scrapped but re-used, the price of new steel beam is also searched. An HEA160 beam without blasting or any processing weighing 31kg/m is priced at €33,72 per meter long (Source: https://www.limtrade.nl/hea-160), meaning €1,088 per meter. Comparing to the price of heavy metals scraps, the new products is around five times higher, let aside the other costs involved such as recycling, re-processing, and environmental costs and impacts. Thus, the comparison shows the loss of value in recycling instead of reusing, in a more tangible language.

2.4.3. Implications of shadow cost

As discussed previously, shadow cost is defined as the cost of negative environmental impacts with weightage of different emission categories considered, translated into a uniform measure to be more tangible and representing the overall impact. In a democratic country like Netherlands, shadow cost can be a potential tool to implement policies on industry players and businesses to take environmental changes and goals into account (Chevalerias, 2015). One of the main benefits of reusing the construction components after their first use cycle, is to avoid the environmental impacts of recycling and production for the second time; that leads to the reduction of shadow cost. To be more specific, throughout the life cycle assessment

(LCA) of a product, the environmental impacts from production, consumption, and waste is assessed, and is translated into the LCA shadow cost (de Bruyn, et al., 2010). Now, if a material does not enter the hibernating or waste stream, it can save costs and pollution by being recycled and reused, preferably.

2.5. Life time of components

Indicating the life time of various components of a building is an essential step for assessment of prospects of urban mining. Aside from gaining knowledge and awareness about the revenue of the mines, it is important to know when they will be available. In a nutshell, a building consists of various layers (Duffy, 1990), a concept that was later developed by (Brand, 1994) to introduce the six "Shearing Layers" diagram.

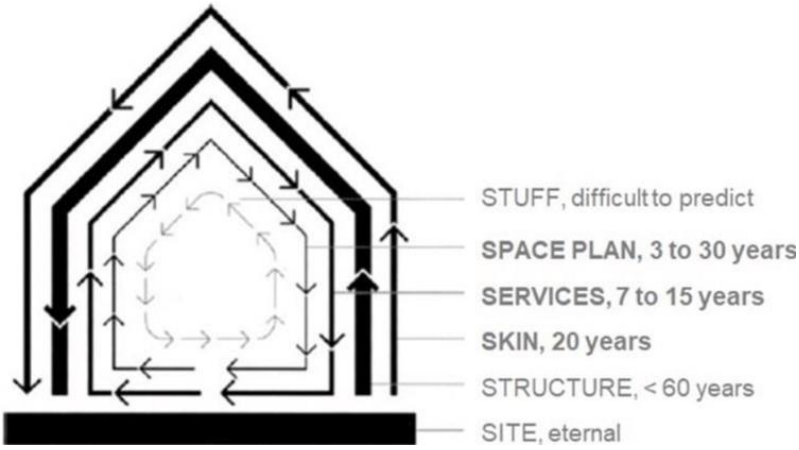


Figure 14: Shearing layers (Building) (Brand, 1994)

As Figure 14 presents, the various layers of the building have various life time. The concept suggests, although the building functions as a whole, it should not be treated and rehabilitated as a whole. In a sustainable construction concept, change and facilitating the change should be allowed (Pereira, Post, & Erkelens, 2005) for different layers in different period of time.

In the table below, the approximate life time of the material, considering their function, that are going to be assessed in this research, is provided. In addition to the life time, the fraction of their usage in the relative industry is indicated.

Table 2: Estimated life time and end-use fraction of most common metals used in building and infrastructure

Type of Metal	**Reservoir**	**Estimated life-time (Years)**	**Reference**	**End-use fraction (%)**	**Reference**
Aluminum	Building and construction	30-50	(Martchek, 2006) (Melo, 1999)	25	(European Aluminum Association, 2006)
Aluminum	Infrastructure-Power cables	30-40		18	
Copper	Building and construction	25-40	(Spatari, Bertram, Gordon, Henderson, & Graedel, 2005)	50	(Joseph, G.; International Copper Association, 1998)
Copper	Infrastructure-Power and telecom cables	50		22	
Iron	Building and construction	30-50	(Muler, Wang, Duval,	50	(Muler, Wang, Duval, &

			& Graedel, 2006)		Graedel, 2006)

Information on other metals used in the building and construction sector is also available but not mentioned in this report since the information was not going to be used or referred to. However, they can be found in the article of "In-use stocks of metals: Status and implications" (Gerst & Graedel, 2008).

2.6. Literature review; A conclusion

The discussions conducted in chapter 2, lead to a conclusion that is going to be discussed in this section.

The leading environmental crisis caused by over consumption and polluting industries resulted in struggle and thrive for adapting technologies to increase efficiency in all systems sustainability. As a result of resource efficiency, urban mining is introduced as one of the advantageous approaches towards more adequate use of material. To initiate the theory into practice, many researchers in various locations, have started by identifying the potential and the benefit that urban mining can give use. Using various tools such as GIS, the studies have evolved through exploring exploitation options for urban mines, and concluded that many systematic foundations could be implemented in the past so that they could be of interest today.

As the cities in the Netherlands have proceeded with blue prints of the path towards circular economy path, many gaps have been identified. Lack of information is the main shortcoming for urban mining in Amsterdam, as addressed by PUMA. As demonstrated in Figure 11, the combination of all methods, systems, and tools, can gather to establish a centralized hub or a platform, where users (as described in section 1.3) can be sufficiently informed.

In the following chapters, the research approach and outcomes of this study are presented.

3. Methodology

3.1. Introduction

This chapter begins with describing the conceptual framework of this research objective. As discussed in chapter 1 and later in chapter 6, the urban mining requires an information system that is coordinated and managed by the municipality of Amsterdam as the urban planner. Additionally, the three ambitions of the built environment sector towards a circular economy process highlighted the importance of the joint effort to the transition to circular development. It is the contribution and effort of all parties to involve and assist the achievement of simulating the process digitally. Being able to visualize the status of stocks and procedure for the users, in addition to bringing the concept closer to reality helps with realism of urban mining approach tremendously. The intention proposed in conceptual diagram below, does not only reflect to centralization and digitization at entry, but also throughout the primary use-cycle. Meaning that, any activity such as maintenance, change of function, replacement and so on, must be digitally recorded and be validated within the system protocols.

Figure 15 demonstrates the proposed process towards illustrating a central web map as a platform that bridges the communication between suppliers and users of secondary stocks. Nonetheless, the conceptual diagram below briefly delivers the intention of the platform; however, various groundworks such as communication system and pricing need to be structured in advance. It is the role of municipality to take this initiative and define the uniform system for all parties.

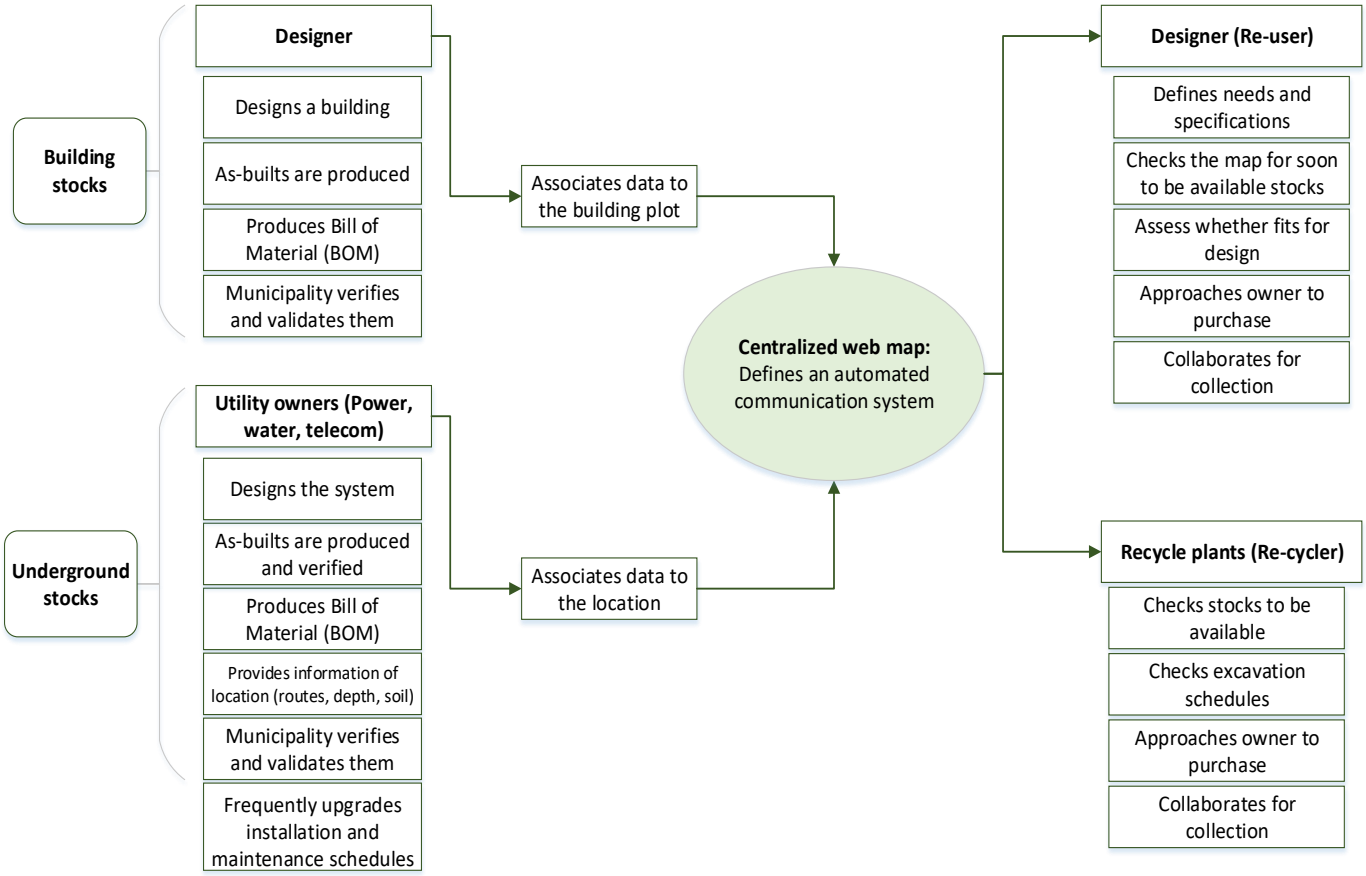


Figure 15: Conceptual diagram of the research objective

As part of the scope of this study, the approach to completion of this research is divided into the following four phases as described in chapter 1, figure 4. The research approach intends to evaluate the available databases and assess the quantities of building and underground stocks at selected location. Lastly, the outcome is visualized in a web map that represents and illustrates the proposed centralized web map mentioned in figure 15.

Phase 1: Quantifying the in-use stocks: As the focus of the research is on metals on buildings and underground services, first the approach to collect openly availably information in order to assess the urban mine potentials is assessed (Section 3.2).
The section starts with discussing the concept behind the selection of the six locations to be assessed. Following the selection of locations, the available databases that were used in this research for data collection will be discussed thoroughly.
Then, the approach to extract required data from the datasets and databases were explained, and lastly the calculation of metal contents is discussed separately for buildings and underground stocks.
Phase 2: Second, once the data are collected and processed, the dataset spreadsheet is created in accordance with the requirements of the web map generator.
Phase 3: Then, the prepared datasets are uploaded to a base map in Quantum Geographical Information System (QGIS). The approaches undertaken to organize the dataset for a more competent visualization on a GIS map are discussed in this section.
Phase 4: Last but not least, the map is exported to web to demonstrate how the user of the platform, will be able to visualize and benefit from the classified information.

3.2. Quantifying in-use stocks

The study of this project focused on finding urban mining potentials of selected neighborhoods in Amsterdam where they are expected to have higher possibility of resources recovery. Due to the higher market value and demand of metals, the focus of this study is as well on metals. The types of metals to be evaluated depend on the types and the nature of the metals used in services to be evaluated in both buildings and underground services. Nonetheless, the existence and accuracy of databases can affect the focus of the study on certain metals.

In the sub-sections below, the methods and procedure leading to the outcome of this study is discussed.

3.2.1. Location selection

It was discussed in the previous section, why the city of Amsterdam was chosen. In this sub-section, the theory behind the selection of three neighborhoods to be evaluated in terms of their urban mining potentials, is going to be discussed. In order to provide a more reliable and concrete results, the study was done to street levels, therefore several criteria had been in place for the selection of the location. As the selection measures of street-level location was implicit, two locations in each neighborhood were selected, assessed, and compared. Hence a total of six locations were selected. In this sub-section, the discussion will be about the selection of certain neighborhoods and then the streets that the urban mining potentials were assessed.
The locations of the research were selected in a two-step process. Firstly, was to select neighborhoods (postcode zone) where a relatively fair integration in terms of function and construction year is satisfied. And secondly to identify a location, to street level, where based

on observations were assumed to include more valuable metal, and also representing unique and diverse features. In this section, each step is going to be discussed individually below:

1. Selection of a postcode zone

The selection of the neighborhood is done basically in accordance with the average year of construction. This is followed by considering the density of existing monuments in the neighborhoods.

As mentioned, the main concept behind the selection of suitable location was to select a location that represents the medial range in Amsterdam. As it can be seen in Figure 16 (circled in purple), the area between the center of Amsterdam and the A10 ring is where the new and old are integrated. As the city evolved from inside out, the combination of very old and also new buildings can be observed in this area.

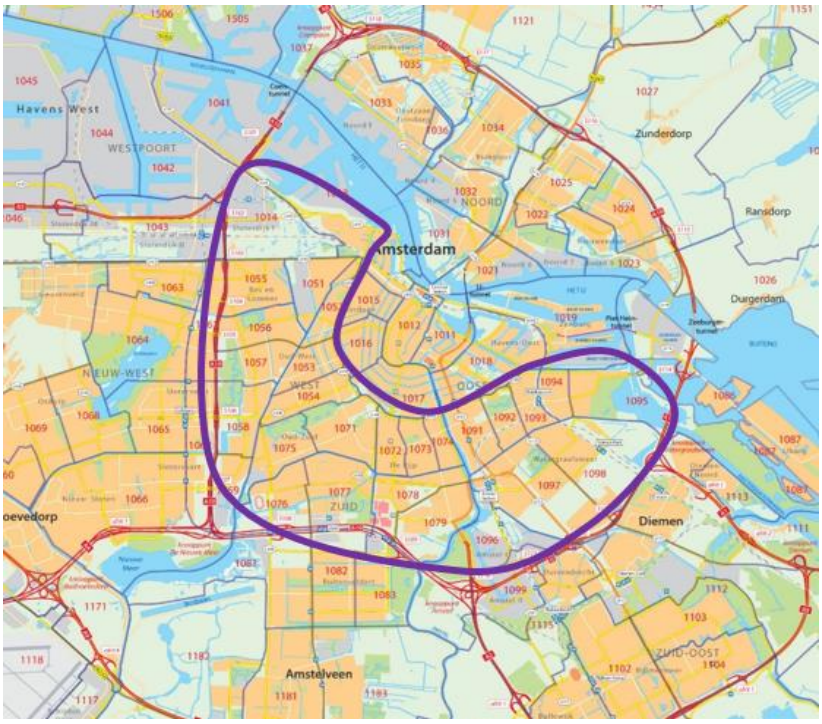


Figure 16: Postcode division map of Amsterdam with the outer centrum area circled

- Age of buildings

It is usually the case that cities grow from the center to the sides, hence the more historical, and older buildings and infrastructure in the centers. Therefore, as it gets further to the center, newer developments appear. This is exactly the case for the city of Amsterdam as well. Thus, it was intended to select areas where a mixture of old and new buildings is chosen. Although slightly different, it was not intended to select areas that are too historical, old, or too new, and modern. Figure 17 demonstrates the growth of Amsterdam with brown representing the oldest (before 1860) to orange (1860-1919), yellow (1920-1939), and green towards the rest shows 1940 and onwards (Municipality of Amsterdam, 2019).

Figure 17: Amsterdam growth map with outer centrum circled in red

- Monumental buildings density

With high density of monuments in Amsterdam, it is already a major attribute of the city that is undeniable. Therefore, it was tried to pick locations with slightly lower concentration, but not lowest, of monuments in them. Figure 18, shows the concentration of national (blue), and municipal (red) monuments (Municipality of Amsterdam, 2019).

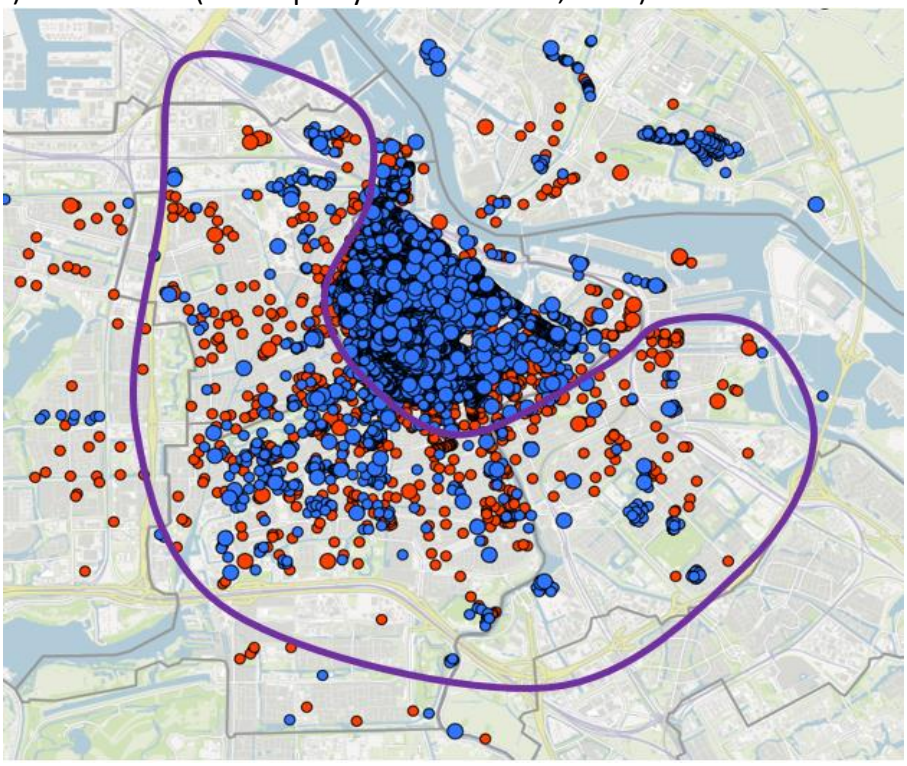


Figure 18: Amsterdam monumental map with outer centrum circled in purple

The outer centrum area clearly demonstrates a medium density of monuments, together with representing an average in terms of establishment age for the city of Amsterdam. Therefore, it was decided to focus on this zone for the selection of a suitable location for this study.

2. Selection of a potential street

After selecting the neighborhoods, six streets in overall three neighborhoods were chosen. This selection was based on the visual observation of various criteria that are presented in more details in table 3. Each street represents a unique characteristic and that is what makes the approach more valuable for further decision makings and focus points. Before looking into the unique characteristics pointed out in table 3, which mainly highlights details related to buildings, the main general criteria were to observe the density of underground stocks. Hence, the map on PDOK viewer was referenced. As Figure 19 suggests, the bolder colored lines represent more quantity of underground cables.

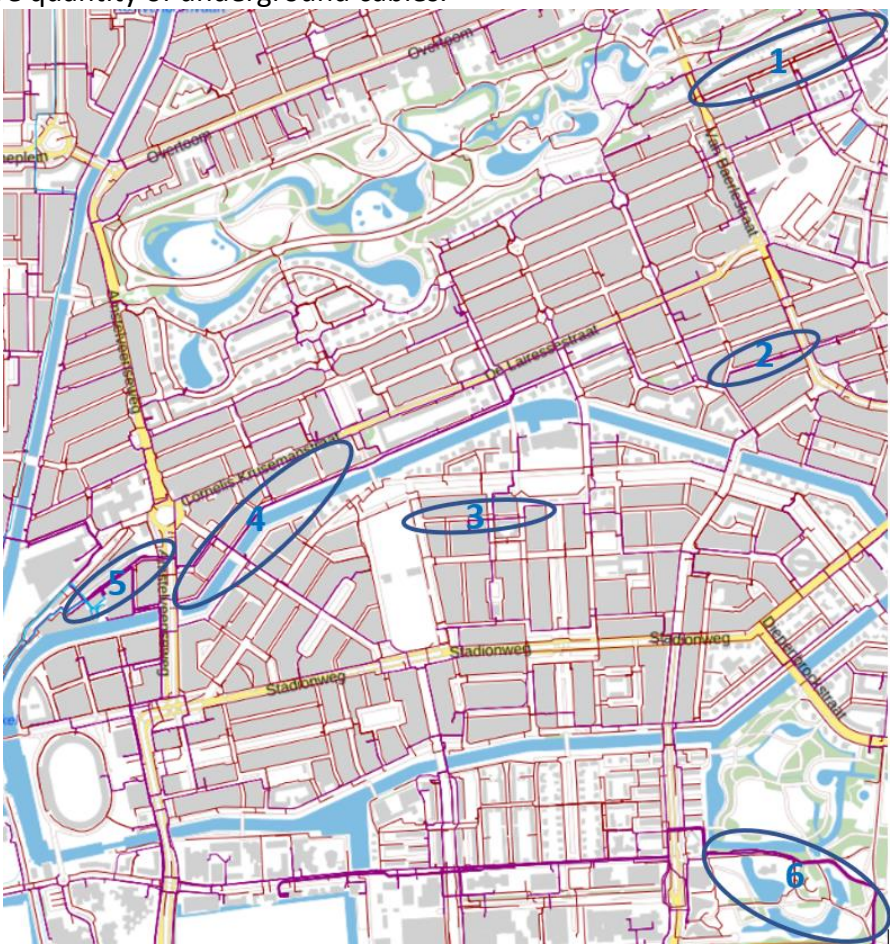


Figure 19: Underground stocks concentration in six locations within three neighborhoods

Table 3: List of selected locations and their main characteristics

Number	Location (Postcode+Street name)	Differentiating characteristics
1	1071-Pieter Cornelisz. Hooftstraat	Majority of Brand shops integrated in residential plots; combination of very old and new buildings
2	1071-Ruysdaelstraat	Combination of old and new residential plots with relatively high cable concentration
3	1077-Titiaanstraat	Majority residential plots all being built in the 1920's

4	1075-Pieter lastmankade	High cable concentration alongside the river at one side
5	1075-Karperweg	Much less residential buildings and existence of a sub-station with high voltage cable underneath
6	1077- Prinses Irenestraat	Located within a park; no buildings, relatively high underground stock concentration

The locations are intended to have various characteristics for comparison. One of the main factors differentiating them is the density of buildings or urban objects. For instance, in location 6, the wide-open location has the lowest density, while location 5 is relatively low, until location 1 that is a highly dense street. Figures 20 and 21 show the photos of locations 1 and 6. Figure 35 shows a more tangible view of density in each location.

Figure 20: Photo of location 1: Pieter Cornelisz Hooftstraat; Combination of shops and residential plots

Figure 21: Photo of location 6: Prinses Irenestraat; Large underground stocks with no buildings; lowest density

3.2.2. Data collection

The collection of data for this project followed a progressive flow in order to obtain the data needed from the available databases. These data were used to identify potential locations, as some have been referred to in the previous sub-section, finding the information related to metal contents in buildings for each sub-postcode zone in Amsterdam, figuring out the routes and quantity of underground electricity cables, and so on. In table 4, each of the data sources

is presented briefly and in the sub-chapters below the sources of information are described more specifically.

Table 4: List of data sources used to collect data

Sub-chapter	Data type	Source address	Description
3.2.2.1	Postcode's information	Allecijfers.nl	Building function integration Building age classifications
3.2.2.2	Building metal contents (PUMA)	Github	Building metal contents (Estimates)
3.2.2.3	Underground stocks	PDOK	Functions, quantities, and routes
3.2.2.4	Underground stocks	Kadaster	Types, size, material, and installation date
3.2.2.5	Building plots	Parallel	Building address, and construction year

3.2.2.1. Postcode information

General information such as number of building plots, berths (In Dutch: Ligplaatsen) and standing plots (In Dutch: Standplaatsen), status of each building function share, construction periods of buildings and so on, are provided in the AlleCijfers.nl (https://allecijfers.nl/postcode/). This database helped in analyzing various neighborhoods in order to assess the status of buildings, their density and their ages for neighborhood selection. By entering a postcode to the search box, the information regarding a postcode zone, as shown in Figure 22, is provided.

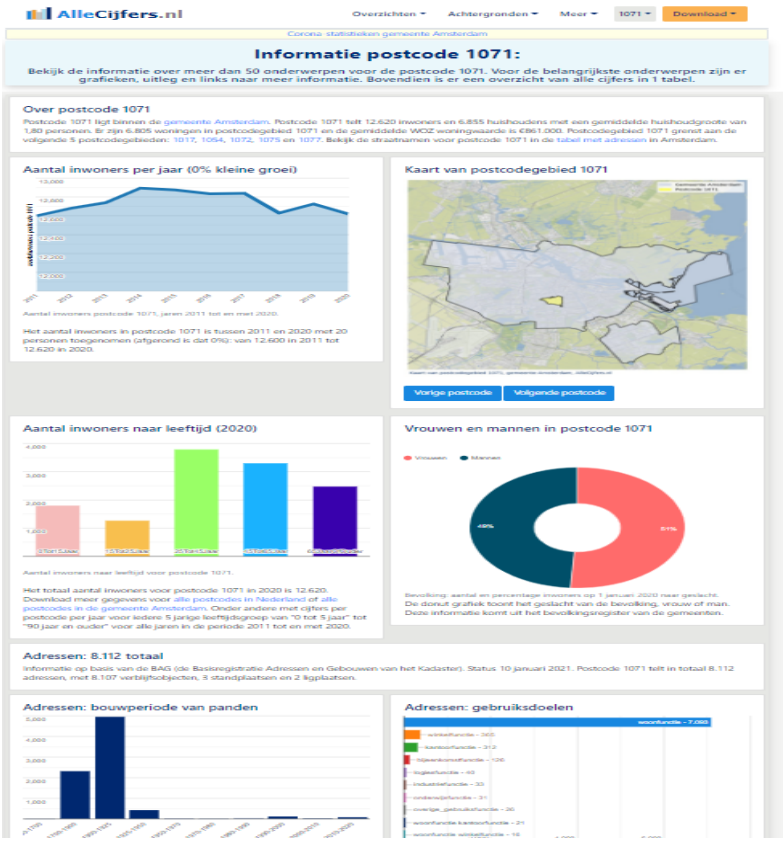


Figure 22: Sample of user interface of Allecijfers.nl providing information regarding postcode zones

3.2.2.2. Estimates of buildings metal contents

The information regarding all the copper and steel contents of sub-postcode zones (i.e., 1018LW) in Amsterdam is provided in the dataset generated by the Waag Society under the term "puma" (Prospecting the Urban Mines of Amsterdam) in github (https://github.com/waagsociety/puma) (De Waag Society, 2018). The metal contents provided in this dataset is provided in .csv, and is based on estimations of classified buildings according to puma databases on addresses and buildings. The estimations were done based on assumption frameworks set by "Waag society". Figure 23 below demonstrates how the dataset originally looks like, while Figure 24 demonstrates the data for the targeted neighbourhood.

vbo_id	pand_id	postcode	huisnumm	huisletter	huisnumm	oppervlakt	pandhoogte	gebruiksdc	copper_pc	steel_poin	copper_cl	steel_class	copper_kg	copper_kg	steel_kg_n	steel_kg_max
3,05E+14	3,05E+14	1391HW	55	A		379	474.377.844.911.746	woonfunc	6	6	A	B	35	80	600	1000
3,05E+14	3,05E+14	1391HW	56			517	796.486.925.172.753	woonfunc	6	8	A	B	35	80	600	1000
3,05E+14	3,05E+14	1391HA	53			357	722.785.458.090.531	woonfunc	6	8	A	B	35	80	600	1000
3,05E+14	3,05E+14	1391HA	53			357	722.785.458.090.531	industriefu	0	0						
3,05E+14	3,05E+14	1391HA	46			209	897.993.600.419.626	woonfunc	6	8	A	B	35	80	600	1000
3,05E+14	3,05E+14	1391HW	55			177	749.234.522.545.631	woonfunc	6	8	A	B	35	80	600	1000
3,05E+14	3,05E+14	1391HA	42			520	779.835.357.168.908	woonfunc	6	8	A	B	35	80	600	1000
3,05E+14	3,05E+14	1391HW	54			95	68.918.284.034.204	woonfunc	4	4	B	C	15	55	500	900
3,05E+14	3,05E+14	1391HA	48			176	798.104.624.626.352	woonfunc	6	8	A	B	35	80	600	1000
3,05E+14	3,05E+14	1391HA	51			151	702.125.389.219.221	woonfunc	6	8	A	B	35	80	600	1000
3,05E+14	3,05E+14	1391HA	49			344	812.856.347.110.234	woonfunc	6	8	A	B	35	80	600	1000
3,05E+14	3,05E+14	1391HA	50			71	483.068.896.938.573	industriefu	0	0						
3,05E+14	3,05E+14	1391HW	63			330	792.464.053.809.204	woonfunc	6	8	A	B	35	80	600	1000
3,05E+14	3,05E+14	1391JG	41			537	808.955.828.657.256	woonfunc	6	8	A	B	35	80	600	1000
3,05E+14	3,05E+14	1391JG	42			161	745.986.353.858.465	woonfunc	6	8	A	B	35	80	600	1000
3,05E+14	3,05E+14	1391JG	43			270	793.747.137.996.187	woonfunc	6	8	A	B	35	80	600	1000
3,05E+14	3,05E+14	1391JG	43			270	793.747.137.996.187	industriefu	0	0						
3,05E+14	3,05E+14	1391HA	44			151	567.179.217.626.037	woonfunc	6	6	A	B	35	80	600	1000
3,05E+14	3,05E+14	1391HA	41			80	152.104.063.837.497	woonfunc	4	6	B	B	15	55	600	1000
3,05E+14	3,05E+14	1391HA	47			115	718.438.967.093.197	woonfunc	4	6	B	B	15	55	600	1000
3,05E+14	3,05E+14	1391HA	45			103	739.456.954.888.506	woonfunc	4	6	B	B	15	55	600	1000
3,05E+14	3,05E+14	1391JG	36			59	794.161.440.168.706	woonfunc	2	4	C	C	5	35	500	900
3,05E+14	3,05E+14	1391JG	35			313	794.161.440.168.706	woonfunc	6	8	A	B	35	80	600	1000
3,05E+14	3,05E+14	1391JE	33			365	78.975.459.987.984	woonfunc	6	8	A	B	35	80	600	1000
3,05E+14	3,05E+14	1391JE	29			135	712.697.138.384.772	woonfunc	4	6	B	B	15	55	600	1000

Figure 23: puma-addressen metal contents estimation dataset

Copper	Class Amin	Class Amax	Class Bmin	Class Bmax	Class Cmin	ClassCmax
1071AA	35	80	30	110	0	0
1071AB	70	160	105	0	20	140
1071AC	245	560	45	0	20	140
1071AD	105	240	60	0	5	35
1071AE	210	480	45	0	10	70
1071AG	280	640	60	0	10	70
1071AH	140	320	120	0	10	70
1071AJ	70	160	90	0	0	0
1071AK	490	1120	180	0	65	455
1071AL	35	80	60	0	10	70
1071AM	35	80	30	0	10	70
1071AN	0	0	45	0	10	70
1071AP	0	0	120	0	5	35
1071AR	105	240	90	0	55	385
1071AS	420	960	90	0	10	70
1071AT	0	0	105	0	50	350
1071AV	0	0	195	0	0	0
1071AW	70	160	75	0	35	245
1071AX	35	80	120	0	35	245
1071AZ	0	0	60	0	15	105
1071BA	70	160	195	0	45	315
1071BB	105	240	90	0	20	140
1071BC	70	160	180	0	65	455
1071BD	105	240	120	0	45	315
1071BE	315	720	15	0	0	0
1071BG	105	240	120	0	30	210
1071BH	0	0	225	0	20	140
1071BJ	280	640	180	0	35	245

Steel	Class Amin	Class Amax	Class Bmin	Class Bmax	Class Cmin	ClassCmax
	0	0	1800	3000	0	0
	7200	10800	1800	3000	500	900
	7200	10800	3000	5000	0	0
	5600	8400	600	1000	0	0
	7200	10800	1200	2000	0	0
	9600	14400	1200	2000	0	0
	8000	12000	2400	4000	0	0
	6400	9600	0	0	0	0
	19200	28800	4200	7000	4000	7200
	800	1200	3600	6000	0	0
	2400	3600	1200	2000	0	0
	0	0	3000	5000	0	0
	0	0	4800	8000	500	900
	4800	7200	8400	14000	0	0
	12000	18000	1800	3000	1000	1800
	4000	6000	3000	5000	3500	6300
	4800	7200	4200	7000	0	0
	2400	3600	5400	9000	1000	1800
	4000	6000	2400	4000	3500	6300
	0	0	2400	4000	1500	2700
	4800	7200	8400	14000	2000	3600
	1600	2400	4800	8000	1500	2700
	9600	14400	4200	7000	4000	7200
	4000	6000	6600	11000	2000	3600
	8000	12000	0	0	0	0
	7200	10800	4800	8000	0	0
	3200	4800	6600	11000	2000	3600
	1600	2400	10800	18000	3500	6300

Figure 24: Metal contents of all areas within postcode zone 1071 using excel "SUMIFS" formula, extracted from puma-addressen dataset

The classifications of different classes of Copper and Steel in the dataset is based on area and heights of buildings. These classifications are explained thoroughly in the report issued by Metabolic (Blok(1) & Roemers, 2017).

3.2.2.3. Underground electricity cables – routes and quantities

After obtaining the metal contents of buildings, it is time to analyze the underground services. For electricity cables, it is possible to find the routes and quantity of cables from PDOK viewer (https://www.pdok.nl/viewer/). PDOK viewer, also seen an overview in Figure 19,

demonstrates the routes and the quantities of electricity cables, with different color codes. In addition, it is also possible to view the sub-stations and distribution boxes as well. The only downside of this database is that it does not provide the types of cables, but the function of the cable (i.e., high voltage or medium voltage). Figure 25 shows how the database looks like in web when various features are selected. Zooming into details allow the counting of cables.

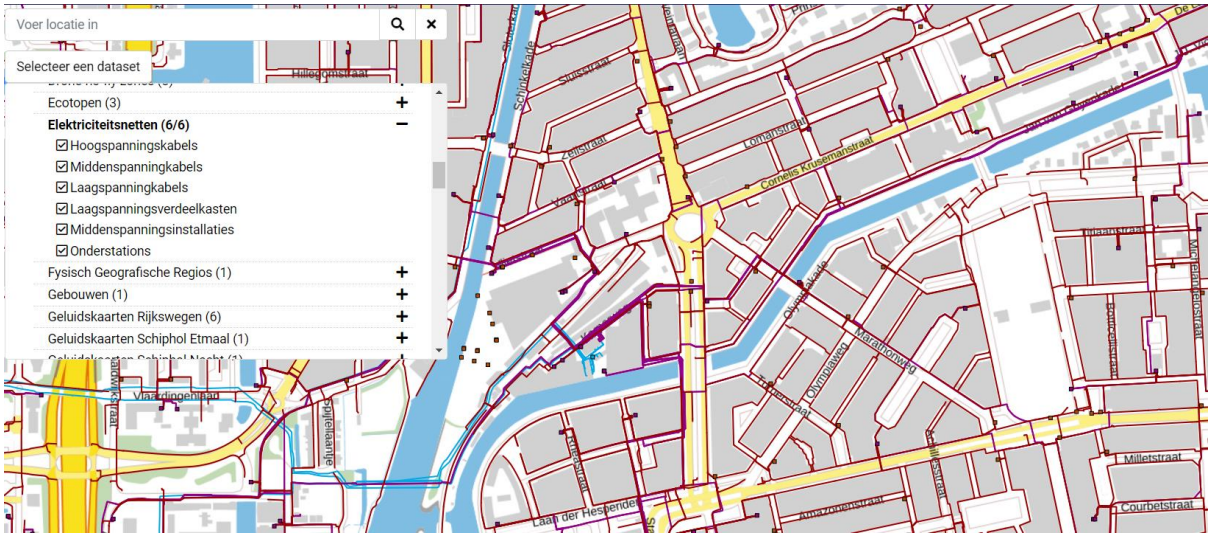


Figure 25: PDOk viewer demonstrating low to high voltage cables routes and quantities

3.2.2.4. Underground services – types and quantities

While PDOK viewer only provides the routes and quantity of cables, Kadaster (https://formulieren.kadaster.nl/graafmelding_klic) offers the types of cables and their details through the KLIC-Melding services. The information is received upon filing a request using DigiD from the Kadaster website. Kadaster accumulates data from various utility owners such as Liander and provides it to the user. Sample of the information received for postcode 1071 is shown in figures below for both Gas and Electricity grids.

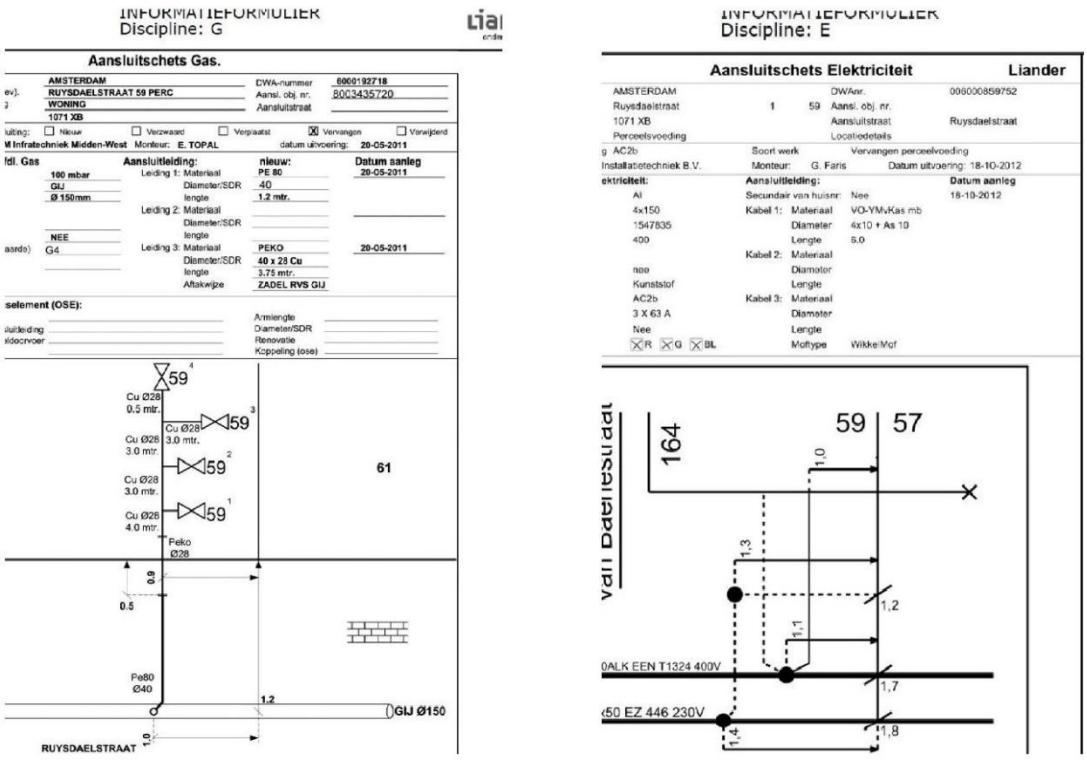


Figure 26:Sample of information received from Kadaster through KLIC-Melding

3.2.2.5. Building plots

The database of the building plots allows us to observe information related to building numbers, sub-postcode zones and the building construction year (see Figure 27) in a web map. Although the database does not solely tally with the reality, it provides sufficient information for the desired purpose. The parallel map is derived from the 3D BAG database (TU Delft, 2020). BAG stands for Basisregistratie Adressen en Gebouwen, a map database with land registries of all buildings in the Netherlands.

Figure 27: parallel providing the information on building plots according to 3D BAG database

Another web map that offers information about building heights is called "Gebouwhoogte van Nederland" (https://apps.webmapper.nl/gebouwen/#14.55/52.35501/4.87865/-58.4/60) which provides building heights. By pointing at the buildings, the height of buildings appears (see Figure 28). The downside of this web map database is that it does not provide any other information, such as building plot number or the sub-postcode zone, than the building heights, therefore, it is required to incorporate this dataset with the Parallel database to find out the height of a targeted building plot.

Figure 28: Sample of 3D map of the building heights

3.2.3. Metal contents; Calculation methods

In this section, the calculation method of metal contents, using the datasets and databases discussed in section 3.2.2, is going to be presented. The calculations are based on the available data and, especially for the underground services, they are rough estimations.

3.2.3.1. Buildings

The calculation of metal stocks in buildings was much easier as the dataset of PUMA (section 3.2.2.2) was available based on estimation method described in section 2.2. Although there were some downsides to the dataset, at the moment this is the best available data that can be relied and is publicly accessible. The downsides of the dataset are listed below:

- The dataset was published and based on inventories of 2018. Thus, some new buildings have been built/registered since then, as per visual inspection to the location of study.
- Only residential buildings have been examined. While in some of the selected postcode zone (i.e., 1071) the integration of building function is relatively higher than other locations.
- Due to inconsistencies, that was also described in PUMA framework and also in section 2.2, only copper and steel stocks had been taken into account. Hence, aluminum and zinc are put aside.
- Looking into the building plots and their postcodes in the dataset, it is identified that the postcodes are not accurately assigned to the building plots.
- Since there was an estimation mainly based on height and construction year of buildings, and certain quantity of metals is assigned to each type, for the building with more than one residential space, the quantity is multiplied with that of the same building with only one residential space. For instance, building plot 16 is identical to building plot 18; however, there are two residential units in plot 18 (18A, 18B). So, then the quantity of metals estimated for 18 is double the quantity of 16.
- Lastly, the stock of copper and steel for each class (depending on heights and gross floor area of buildings) had been given a minimum and maximum estimation. Therefore, in this study the average was calculated.

The rather straight forward calculation method of stocks in buildings is described below:

a. From the excel dataset derived from “github” (shown in section 3.2.2.2), the data for the required postcode and building function are filtered and then the quantity of copper and steel for each building plot is calculated using the “SUMIF” formula below for both minimum and maximum amount, and then taking the average of the sums.

   =SUMIFS(N2:N600000; $C2:$C600000; "1075LA"; $D2:$D600000; "9")

   The formula above provides the sum of minimum copper stocks for building plot number 9 in postcode 1075LA.

   Figure 29 below shows an example of how the data in PUMA dataset are presented after filtration for postcode 1071LA.

716 =SUMIFS(N2:N600000; $C2:$C600000; "1075LA"; $D2:$D600000; "9")

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
	vbo_id	pand_id	postcod	huisnun	huislett	huisnun	oppervl	pandho	gebruik	copper_	steel_p	copper_	steel_cl	copper_	copper_	steel_k	steel_k	nax
6	3,63E+14	3,63E+14	1075LA	9		1	73	########	woonfunc	2	4	C	C	5	35	500	900	
7	3,63E+14	3,63E+14	1075LA	9		4	73	########	woonfunc	2	4	C	C	5	35	500	900	
8	3,63E+14	3,63E+14	1075LA	9		H	72	########	woonfunc	2	4	C	C	5	35	500	900	
9	3,63E+14	3,63E+14	1075LA	9		3	72	########	woonfunc	2	4	C	C	5	35	500	900	
0	3,63E+14	3,63E+14	1075LA	9		2	59	########	woonfunc	2	4	C	C	5	35	500	900	
3	3,63E+14	3,63E+14	1075LA	7		H	165	########	woonfunc	6	8	A	B	35	80	600	1000	
4	3,63E+14	3,63E+14	1075LA	7		2	67	########	woonfunc	2	4	C	C	5	35	500	900	
5	3,63E+14	3,63E+14	1075LA	5		H	167	########	woonfunc	6	8	A	B	35	80	600	1000	
6	3,63E+14	3,63E+14	1075LA	7		3	67	########	woonfunc	2	4	C	C	5	35	500	900	
7	3,63E+14	3,63E+14	1075LA	5		3	67	########	woonfunc	2	4	C	C	5	35	500	900	
8	3,63E+14	3,63E+14	1075LA	5		2	67	########	woonfunc	2	4	C	C	5	35	500	900	
9	3,63E+14	3,63E+14	1075LA	5		1	51	########	woonfunc	2	4	C	C	5	35	500	900	

Figure 29:Extracted information required for acquired sub-postcode zones, from PUMA datasets of building stocks estimations

3.2.3.2. Underground stocks

The underground stocks focused are inclusive of water supply pipes, sewerage, gas supply, and cables, either power or telecommunication. After receiving the information of underground services from Kadaster (3.2.2.4), it was clarified that the only metal content existed is in the power cables. Furthermore, for the gas pipe, it was believed that copper pipes were used, however; the information received from Kadaster showed that polyethylene pipes (PE) are used, and only the connection from the public grid to each consumption unit constitutes of copper (see Figure 26, left picture). The calculation method of the metal contents for underground services in the selected streets is described below:

a. First the existence of cables in PDOK viewer was analyzed by checking all the housing plots one by one, as seen and described in section 3.2.2.3. Then, the one with most cables in front of it was chosen to request the underground details from KLIC Melding, also referred to as Kadaster, as the database is called.
b. Once the information was received, the types of low and medium voltage cables could be defined (see Figure 26, right picture). Then placed in the spreadsheet to calculate the metal content.
c. For the metal content calculation, not just the cable diameter was needed, but also the conversion rate of which indicates how much of metal content is present in one meter of cable. The conversion rate for aluminum cable is 2,7 (Bargh News, 2017). Hence, the cable diameter, multiplied by the conversion rate, gives the aluminum content of 1 meter long of that cable in grams.

   For example: for 230v cable, the diameter is 150mm;

   Therefore, 150*2,7= 405grams=0,405kg
d. The outcome of section c, is then multiplied by the length of the cable in particular street. The length of the cable is simply obtained by using the measurement tool in PDOK viewer as shown in Figure 30.

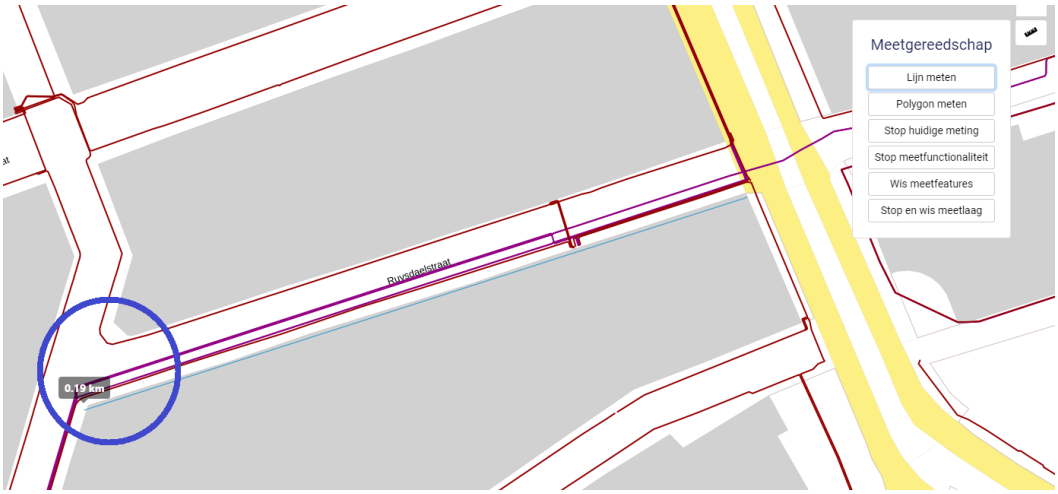
e. 

Figure 30: Measuring length of the cables existed in Ruysdaelstraat (1071), Amsterdam (Source: PDOK viewer)

f. Once the cable cross sectional diameter, the aluminum cable conversion rate, and the cable lengths in total, are multiplied by each other and divided by 1000, the content of cables classified based on voltage is obtained in kilogram. Figure 31 below shows an example of the underground services calculation spreadsheet.

Ruysdaelstraat-1071-Amsterdam

Length of street: 190m

Type of stock	Function	Component	Cross section diameter	Conversion rate	Length m	Total content kg	Installation date
Aluminium	Power cable	230V	150	2,7	419,5	169,8975	18/10/2012
	Power cable	400V	600	2,7	577,5	935,55	18/10/2012
						1105,4475	

Figure 31: Calculation of metal contents of underground cables in Ruysdaelstraat, Amsterdam

Nonetheless, it was realized that the high-voltage cable present in location 5, Karperweg, is not mentioned in the documents from Kadaster, therefore, according to the information provided in the TenneT grid map, the cable capacity is assumed to be 150kv (TenneT, 2021) with cross-sectional diameter of 1000mm.

3.3. Dataset preparation

Once the data are extracted and/or calculated as described in previous sub-chapters, they should be organized in a way that is readable for the software and the platform that they are going to be presented. In other words, the data may need to be processed in a way that it is intended to be delivered to the users. In this section, the preparation of datasets of findings is going to be discussed separately for both buildings and underground stocks.

3.3.1. Building dataset

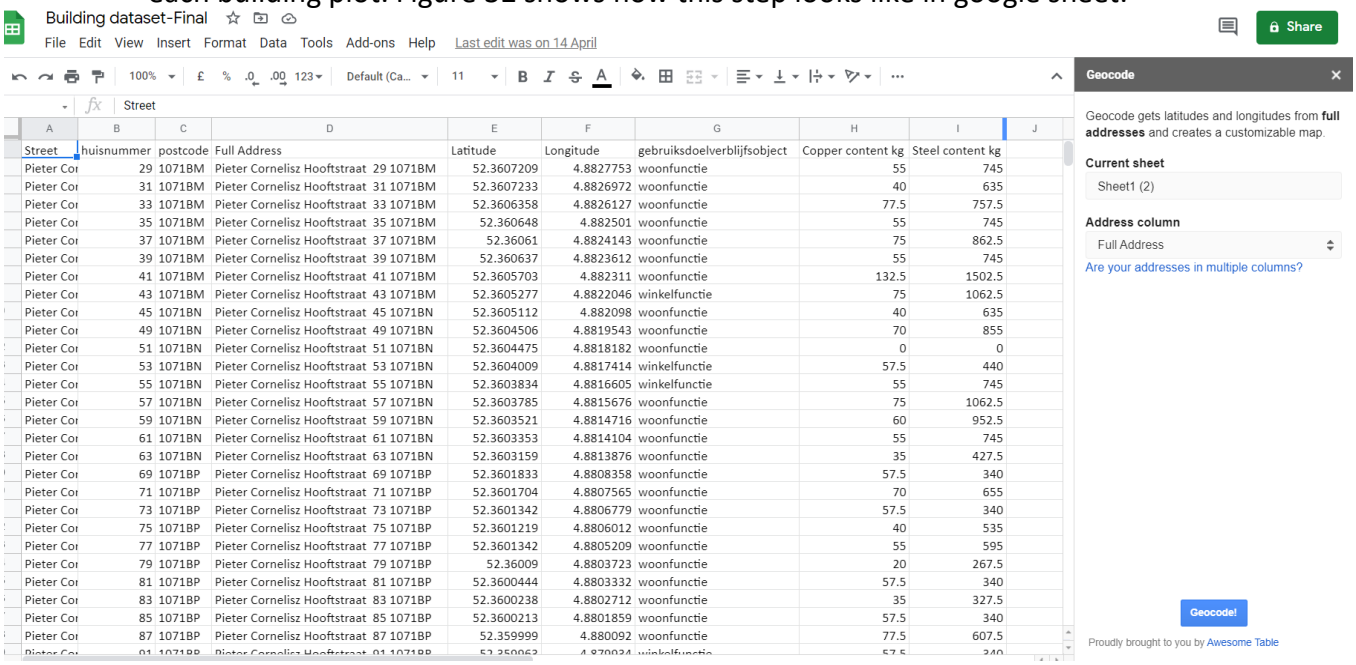
The building dataset is used to deliver the required information in an organized way to the user. In order to do this, first the items are listed:

- Street name
- Building plot (House number)
- Postcode
- Building function
- Construction year
- Copper content-Derived from procedure described in 3.2.3.2.
- Steel content-Derived from procedure described in 3.2.3.2.

The information above is respectively entered in a spreadsheet. In addition to the above, it is required to allocate to building plots, the geographical coordinates which enable us to locate

the points that represent the houses in GIS map. The process of generating the coordinates is described below:

- The coordinates are generated using the add-ons in Google Play, hence an application called “Awesome Table” is added.
  The excel file in google drive must be saved as google sheet so that the add-ons buttons are enabled.
- Moving forward to the Awesome Table geocoding, Street name, House number, and Postcode are combined to be considered as the full address column of which the geocoding uses to generate the latitudes and longitudes.
- Once the geocode is run, the latitude and longitude columns are added to the google sheet automatically the application starts generating the coordinates for each building plot. Figure 32 shows how this step looks like in google sheet.



Street	huisnummer	postcode	Full Address	Latitude	Longitude	gebruiksdoelverblijfsobject	Copper content kg	Steel content kg
Pieter Cor	29	1071BM	Pieter Cornelisz Hooftstraat 29 1071BM	52.3607209	4.8827753	woonfunctie	55	745
Pieter Cor	31	1071BM	Pieter Cornelisz Hooftstraat 31 1071BM	52.3607233	4.8826972	woonfunctie	40	635
Pieter Cor	33	1071BM	Pieter Cornelisz Hooftstraat 33 1071BM	52.3606358	4.8826127	woonfunctie	77.5	757.5
Pieter Cor	35	1071BM	Pieter Cornelisz Hooftstraat 35 1071BM	52.360648	4.882501	woonfunctie	55	745
Pieter Cor	37	1071BM	Pieter Cornelisz Hooftstraat 37 1071BM	52.36061	4.8824143	woonfunctie	75	862.5
Pieter Cor	39	1071BM	Pieter Cornelisz Hooftstraat 39 1071BM	52.360637	4.8823612	woonfunctie	55	745
Pieter Cor	41	1071BM	Pieter Cornelisz Hooftstraat 41 1071BM	52.3605703	4.882311	woonfunctie	132.5	1502.5
Pieter Cor	43	1071BM	Pieter Cornelisz Hooftstraat 43 1071BM	52.3605277	4.8822046	winkelfunctie	75	1062.5
Pieter Cor	45	1071BN	Pieter Cornelisz Hooftstraat 45 1071BN	52.3605112	4.882098	woonfunctie	40	635
Pieter Cor	49	1071BN	Pieter Cornelisz Hooftstraat 49 1071BN	52.3604506	4.8819543	woonfunctie	70	855
Pieter Cor	51	1071BN	Pieter Cornelisz Hooftstraat 51 1071BN	52.3604475	4.8818182	woonfunctie	0	0
Pieter Cor	53	1071BN	Pieter Cornelisz Hooftstraat 53 1071BN	52.3604009	4.8817414	winkelfunctie	57.5	440
Pieter Cor	55	1071BN	Pieter Cornelisz Hooftstraat 55 1071BN	52.3603834	4.8816605	winkelfunctie	55	745
Pieter Cor	57	1071BN	Pieter Cornelisz Hooftstraat 57 1071BN	52.3603785	4.8815676	woonfunctie	75	1062.5
Pieter Cor	59	1071BN	Pieter Cornelisz Hooftstraat 59 1071BN	52.3603521	4.8814716	woonfunctie	60	952.5
Pieter Cor	61	1071BN	Pieter Cornelisz Hooftstraat 61 1071BN	52.3603353	4.8814104	woonfunctie	55	745
Pieter Cor	63	1071BN	Pieter Cornelisz Hooftstraat 63 1071BN	52.3603159	4.8813876	woonfunctie	35	427.5
Pieter Cor	69	1071BP	Pieter Cornelisz Hooftstraat 69 1071BP	52.3601833	4.8808358	woonfunctie	57.5	340
Pieter Cor	71	1071BP	Pieter Cornelisz Hooftstraat 71 1071BP	52.3601704	4.8807565	woonfunctie	70	655
Pieter Cor	73	1071BP	Pieter Cornelisz Hooftstraat 73 1071BP	52.3601342	4.8806779	woonfunctie	57.5	340
Pieter Cor	75	1071BP	Pieter Cornelisz Hooftstraat 75 1071BP	52.3601219	4.8806012	woonfunctie	40	535
Pieter Cor	77	1071BP	Pieter Cornelisz Hooftstraat 77 1071BP	52.3601342	4.8805209	woonfunctie	55	595
Pieter Cor	79	1071BP	Pieter Cornelisz Hooftstraat 79 1071BP	52.36009	4.8803723	woonfunctie	20	267.5
Pieter Cor	81	1071BP	Pieter Cornelisz Hooftstraat 81 1071BP	52.3600444	4.8803332	woonfunctie	57.5	340
Pieter Cor	83	1071BP	Pieter Cornelisz Hooftstraat 83 1071BP	52.3600238	4.8802712	woonfunctie	35	327.5
Pieter Cor	85	1071BP	Pieter Cornelisz Hooftstraat 85 1071BP	52.3600213	4.8801859	woonfunctie	57.5	340
Pieter Cor	87	1071BP	Pieter Cornelisz Hooftstraat 87 1071BP	52.359999	4.880092	woonfunctie	77.5	607.5

Figure 32: Geocoding in google drive, using Awesome Table geocoding application

In Figure 32, the geocoding panel can be observed on the left, and the finalized spreadsheet with columns discussed above can be seen as well. the complete spreadsheet is presented in Appendix A.

3.3.2. Underground dataset

The main difference between the type of data for building and underground was that the buildings are to building levels, hence points in the GIS map, while underground stocks are presented in street levels, hence lines. Therefore, the approach of data entry in QGIS is different from buildings.

The information regarding the underground stocks for the selected locations in this study, were not meant to be directly imported to QGIS. The data was calculated and gathered in a spreadsheet for referral. The method for data visualization in QGIS will be described in next sub-chapter. Below, the details for underground spreadsheet and steps to prepare it, is described, and Figure 33 represents the example of the dataset. The complete dataset is presented in Appendix B.

- Street name, postcode and full address are filled first.

- From the data by PDOk and Kadaster (3.2.2.3, and 3.2.2.4) the material and function of cables, depending on their voltage transmission, comes next.
- Then the quantity is presented as calculated based on method described in section 3.2.3.2.
- After that the Installation date (In accordance with information given in documents provided by Kadaster) is entered.
- Lastly the expected availability is presented, which is basically the installation year plus the advised life time for power cables discussed in section 2.5, table 2.

Street	Postcode	Full Address	Material	Function	Quantity	Installation date	Expected availability
Pieter Cor	1071 BM	Pieter Cornelisz Hooftstraat 1071 BM	Aluminum	Power cable	1158,3	2012	2042-2052
Pieter Cor	1071 BN	Pieter Cornelisz Hooftstraat 1071 BN	Aluminum	Power cable		2012	2042-2052
Pieter Cor	1071 BP	Pieter Cornelisz Hooftstraat 1071 BP	Aluminum	Power cable		2012	2042-2052
Pieter Cor	1071 BR	Pieter Cornelisz Hooftstraat 1071 BR	Aluminum	Power cable		2012	2042-2052
Pieter Cor	1071 BS	Pieter Cornelisz Hooftstraat 1071 BS	Aluminum	Power cable		2012	2042-2052
Pieter Cor	1071 BZ	Pieter Cornelisz Hooftstraat 1071 BZ	Aluminum	Power cable		2012	2042-2052
Pieter Cor	1071 CA	Pieter Cornelisz Hooftstraat 1071 CA	Aluminum	Power cable		2012	2042-2052
Pieter Cor	1071 CB	Pieter Cornelisz Hooftstraat 1071 CB	Aluminum	Power cable		2012	2042-2052
Pieter Cor	1071 CC	Pieter Cornelisz Hooftstraat 1071 CC	Aluminum	Power cable		2012	2042-2052
Pieter Cor	1071 CD	Pieter Cornelisz Hooftstraat 1071 CD	Aluminum	Power cable		2012	2042-2052
Pieter Cor	1071 CE	Pieter Cornelisz Hooftstraat 1071 CE	Aluminum	Power cable		2012	2042-2052
Ruysdaels	1071 XB	Ruysdaelstraat 1071 XB	Aluminum	Power cable	1105,45	2012	2042-2052
Ruysdaels	1071 XC	Ruysdaelstraat 1071 XC	Aluminum	Power cable		2012	2042-2053
Ruysdaels	1071 XH	Ruysdaelstraat 1071 XH	Aluminum	Power cable		2012	2042-2054
Ruysdaels	1071 XJ	Ruysdaelstraat 1071 XJ	Aluminum	Power cable		2012	2042-2055

Figure 33: Sample underground stocks dataset

3.4. Data representation in GIS web map

Once the datasets are well-organized and prepared in way presentable to the users, it is time to visualize them in the GIS map as layers. As the purpose of this study suggests the platform that can be utilized by user for receiving sufficient information for urban mining enhanced efficiency, the role of this part of the research becomes very crucial.

In this chapter, the detailed procedure to transfer the data discussed in 3.3 to the GIS map is going to be discussed. The QGIS version 3.16 is used for this purpose. The layers are added over the OpenStreetMap (OSM) tiles, therefore, the OSM was added to the layers from the XYZ tiles in browser panel. Then the import of building and creation of underground stocks dataset are described in the following sections.

3.4.1. Building metal contents; Building plots

Importing of the building dataset as points features is a rather simple procedure which are described below step by step.

1. The dataset is first added as a spreadsheet layer from the Layer tab.
2. Once the location of the file is browsed, and the headers are ticked to be the first line,
3. The Longitude and Latitude columns that were previously generated using Awesome Table application, are assigned to X field and Y field respectively (See Figure 34)
4. The default reference system is defined for the Coordinate Reference System (CRS)
5. Lastly the data are previewed within the same window to avoid discrepancies, and then to move forward with creating the layer by pressing OK.

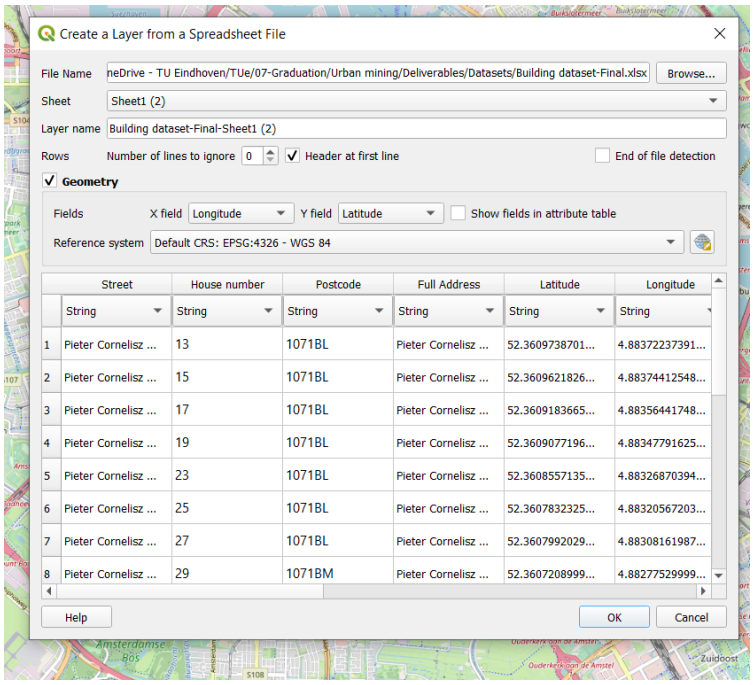


Figure 34: Procedure for importing building dataset as point features to QGIS 3.16

Once the layer is created, the building plots, in accordance with generated coordinates will appear as points over the OSM layer. Figure 35 shows these points together with the Feature window of the information they offer on the left.

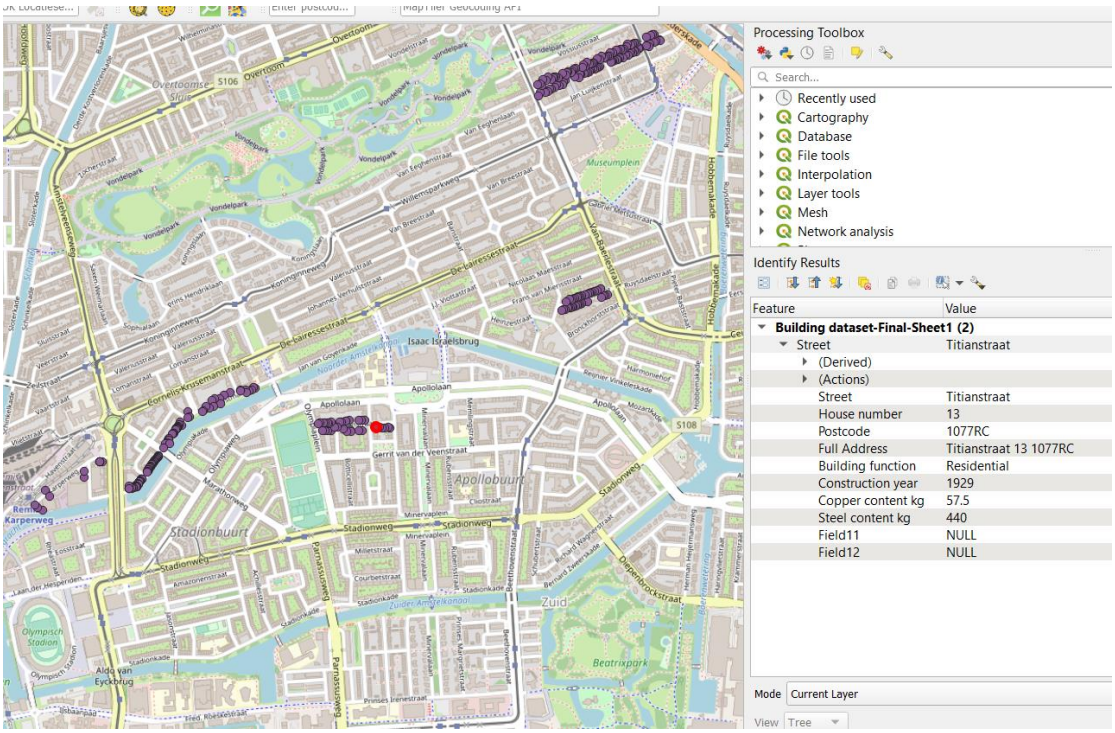


Figure 35: Representation of building layer and the features they represent

Once the points were visualized, it has been encountered that few points (two in total) are way off from the actual location of the building plot they belong to. For that reason, the coordinates were adjusted manually so the points are located precisely on the location of the building.

3.4.2. Underground metal contents; Street networks

The procedure for visualizing the underground stocks on the GIS map was rather more complicated than that of buildings layer. For underground map, since it is meant to bring about the information on street level, the data are presented as lines; lines that represent a street segment. Below the step-by-step procedure is described with figures for better understanding.

1. The QuickOSM plugin is used as a tool to select required urban attribute and establish is as a layer (See Figure 36)

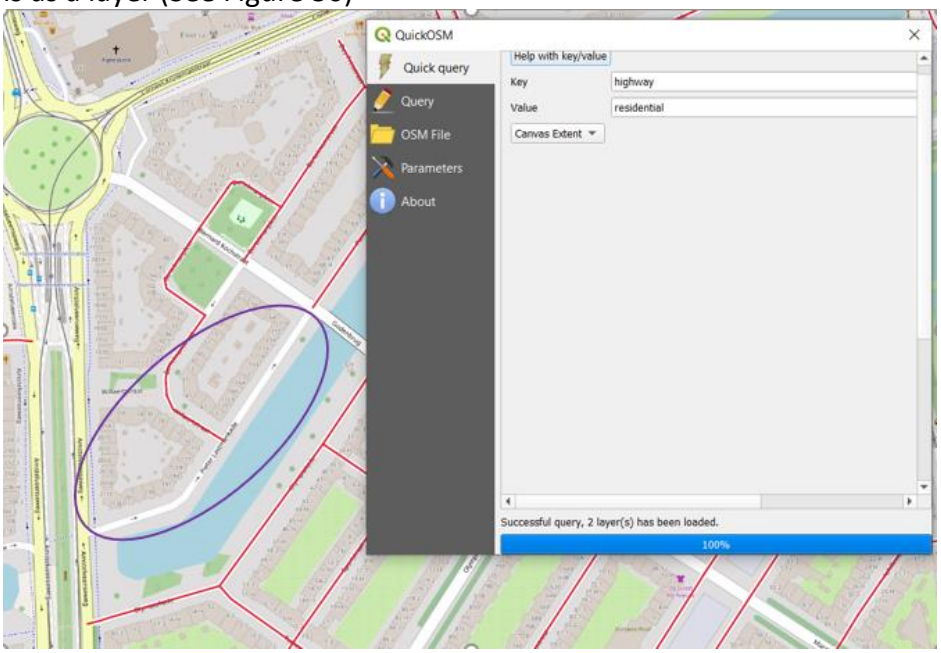


Figure 36: QuickOSM layer generation and the layer on OSM

As the figure represents, on the left side, the red lines represent the *Highways* as the key and the *residential* as the value; However, as the purple circle highlights, the part of a selected street (Pieter Lastmankade) is not categorized as residential, although the street is residential. For this reason, the value had to be changed to unclassified, and as it can be seen in Figure 37, the segment of Pieter Lastmankade is added to the layer; different layer than the residential value though.

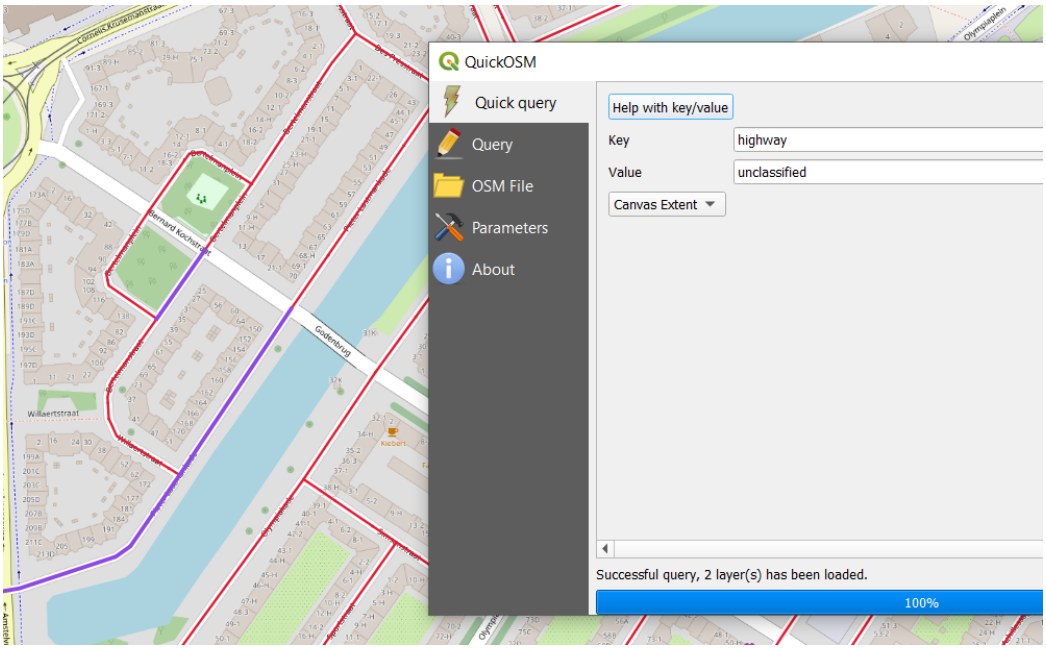


Figure 37: QuickOSM unclassified highway layer

In addition to the case for Pieter Lastmankade segment, the location of Prinses Irenestraat also required a different value in QuickOSM. For Prinses Irenestraat, which is located at a park, the cycleway value had to be chosen.

2. Once the desired attributes are added as layers, the required street segments are selected from the form view of attribute table. In order to avoid confusion and better organization, the selected segments can become the only visible. Figure 38 shows how this step is done in QGIS.

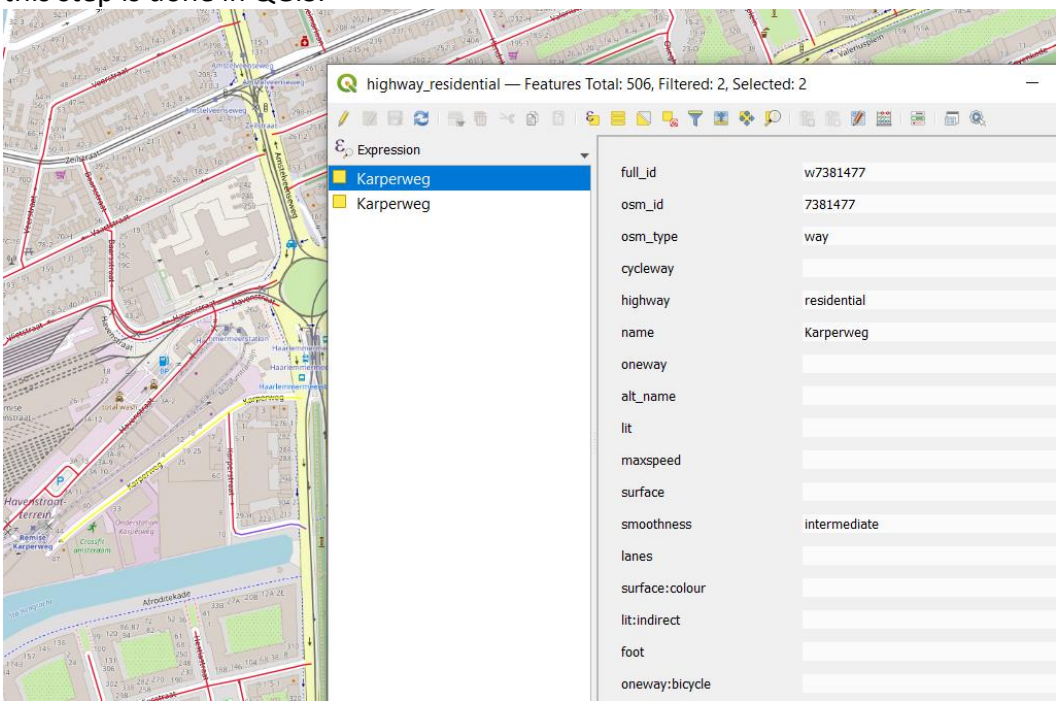


Figure 38: Selection of the required street segments in form view of attribute table

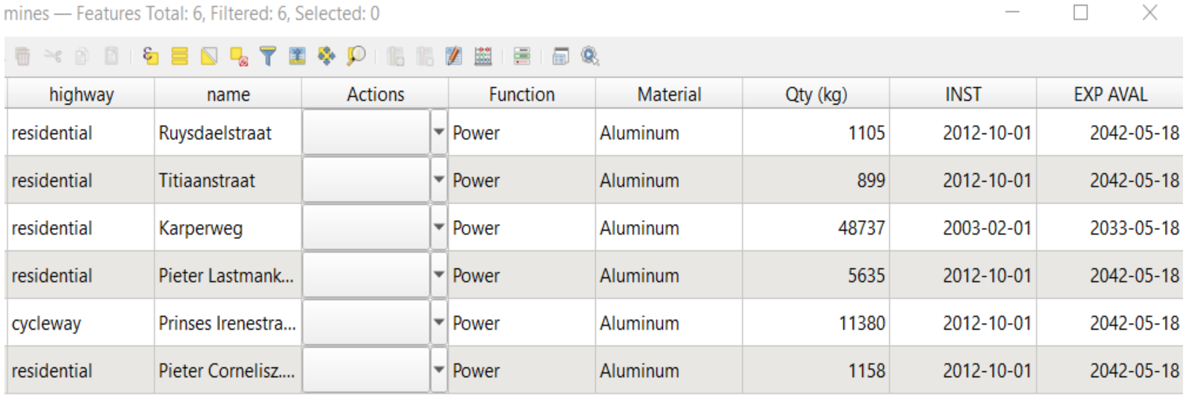
It can be observed in the figure that there are two segments for the street Karperweg. In this case, these two segments need to be combined. In order to do that, the vector layer is first exported and the selected features (Segments of Karperweg) are saved as ESRI shapefile. Therefore, it will appear as one segment in the new layer.

The same approach must be done for other streets and the required selected street segments. Once the new layers are added to the layers panel, then the layers must be combined in order to create a unified layer which includes all the six streets. The combination of the layers is done using MMQGIS plugin. Figure 39 shows the final product of this step.

Figure 39: Outcome of street segments combined

Nevertheless, it needs to be added that in some cases, the street segment is unnamed in the attribute table. In this case, the unnamed features must be checked manually to find them and add them to the layer.

3. The combined layer in step 2, provides us with a neat attribute table of only six streets in it. Now the information gathered in the underground dataset need to be attributed to these streets. This is done using the Toggle editing function at the attribute table. The original fields attributed to the streets can be deleted and the new ones as per the dataset can be added. Figure 40 shows the final look of the attribute table.



mines — Features Total: 6, Filtered: 6, Selected: 0

highway	name	Actions	Function	Material	Qty (kg)	INST	EXP AVAL
residential	Ruysdaelstraat		Power	Aluminum	1105	2012-10-01	2042-05-18
residential	Titiaanstraat		Power	Aluminum	899	2012-10-01	2042-05-18
residential	Karperweg		Power	Aluminum	48737	2003-02-01	2033-05-18
residential	Pieter Lastmank...		Power	Aluminum	5635	2012-10-01	2042-05-18
cycleway	Prinses Irenestra...		Power	Aluminum	11380	2012-10-01	2042-05-18
residential	Pieter Cornelisz....		Power	Aluminum	1158	2012-10-01	2042-05-18

Figure 40: Underground stocks mapping-Attribute table editing

Both buildings and underground stocks datasets are now attributed to their location on the map and the data can be visualized in the map.

3.5. Web mapping; QGIS2Web

Last phase of the research methodology, also described as phase 4, is to visualize the accomplished map in web. This procedure is made very easy with the use of plugins as well. In this study, QGIS2Web is used as the plugin to publish the map on web. This section ends by describing the web mapping procedure using this plugin.

1. Once the plugin is opened in order to create the web map, the export to web map window opens, including all the layers existed in the layers panel (See Figure 41).
2. The headers of each dataset are listed and the option is given to us to choose each header, also called the label, is required to be shown in the web map.
3. Once the settings are done, the map can be previewed and then exported to web as shown in Figure 41.

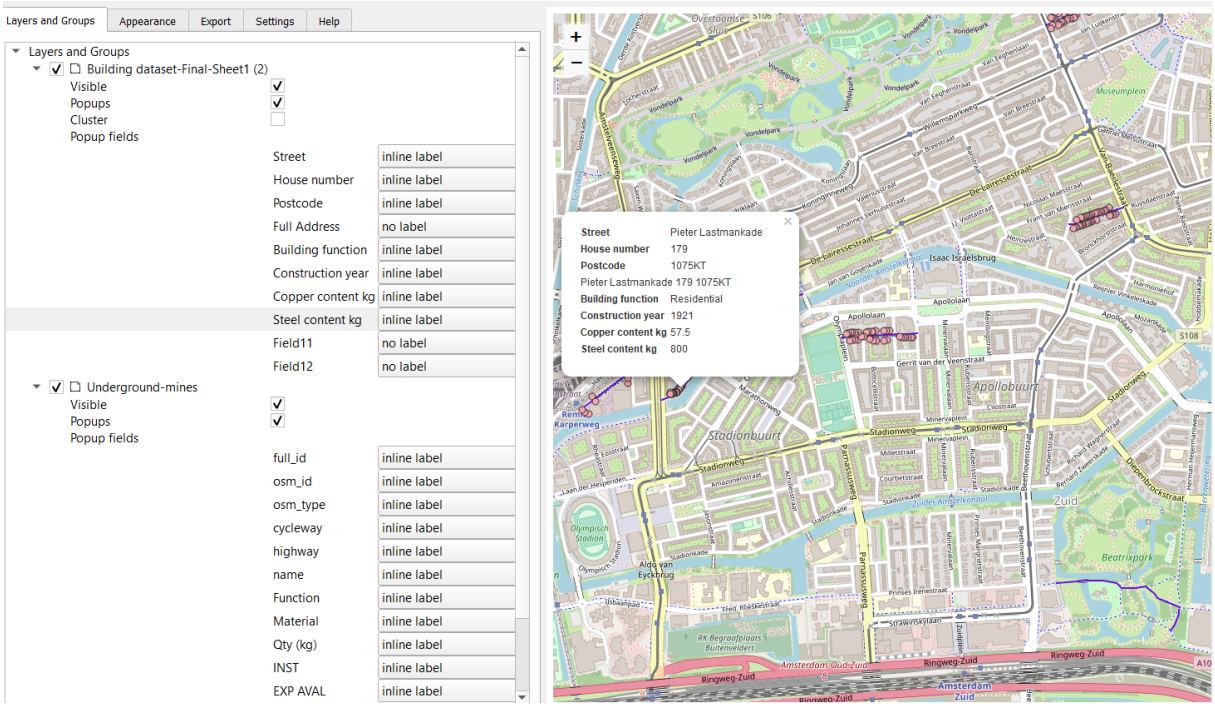


Figure 41: Exporting the maps to web using QGIS2Web

3.6. Methodology; A conclusion

The objective of this study, as discussed in 1.3, is mainly to simulate a centralized digital platform that offers thorough information to target users in order to benefit from second hand materials. In order to present the platform and visualize the outcomes, actual data had been collected, processed, analyzed and used to demonstrate a rather reliable result. The information from various data sources were collected and assessed manually to achieve the outcome, a process that in the conceptual framework, it is proposed to be automated for more validity and reliability. Another point to highlight, is that the downsides and the obstacles that are present in terms of data collection with currently available sources are clarified. In short, the study did not only target to just present the visualization platform, but also what it takes to assess the urban mines with current available information.

4. Results and discussion

4.1. An overview

In sub-chapter 3.4, the method of calculation of quantity of available (in-use) mines in the selected locations of this study was discussed. In this chapter, the results of the study in accordance with the phases described in chapter 1 will be presented.

The chapter starts by displaying and discussing the results from calculation and extraction of metal contents for both underground and building stocks. Then, it continues with providing the outcome of visualizing the data in a GIS map and lastly the web map.

4.2. Metal contents

This section analyzes the metal contents of buildings and underground stocks street per street. The copper content in buildings is assumed to be existed in the wiring and also the internal gas pipes of buildings. Whereas the steel is assumed to be constituted majorly in the building structure and minorly in other services and frames. The classification in tables related to buildings stocks is to sub-postcode level, meaning the quantities given are the cumulative of several building plots within a sub-postcode zone. The section continues by comparing the outcome of the comparison as valuable findings for urban mining potential of locations with varying features (Previously discussed in section 3.2.1). In addition, the selected streets do not have the same length and therefore the density of stocks, mainly undergrounds, will be analyzed per 100 meters of length as well.

The following results focus more on identifying suitability of potential street amongst the selected locations. As discussed in section 3.3, the data presented below have been processed further to fit the purpose of this study and the visualization in the map.

4.2.1. Pieter Cornelisz Hooftstraat-1071

In accordance with the location orders introduced in table 3, table 5 presents the quantities of copper and steel contents for a segment of Pieter Cornelisz Hooftstraat. Followingly, table 6 provides the calculation details for underground stocks of this segment of location 1, the Pieter Cornelisz Hooftstraat.

Table 5: Building stocks of location 1: Pieter Cornelisz Hooftstraat to sub-postcode level

Length of Street:		500m	
Postcode	Function	Copper content kg	Steel content kg
1071 CE	Residential	340	13900
1071 CD	Residential	325	15300
1071 CC	Residential	167,5	7400
1071 CB	Residential	297,5	13100
1071 CA	Residential	322,5	13900
1071 BL	Residential	590	11500
1071 BM	Residential	400	17200
1071 BN	Residential	340	15200
1071 BP	Residential	417,5	10700
1071 BR	Residential	442,5	18200
1071 BS	Residential	190	9500
1071 BZ	Residential	217,5	10300
1071 BX	Residential	265	8800
		4315	**165000**

Table 6: Underground stocks of location 1: Pieter Cornelisz Hooftstraat to street level

Length of Street:		500						
Type of stock	Function	Component	Cross section diameter	Conversion rate	Length m	Total content kg	Installation date	Expected Availability
Aluminium	Power cable	230V	150	2,7	2380	963,9	18/10/2012	2042
Aluminium	Power cable	400V	600	2,7	120	194,4	18/10/2012	2042
						1158,3		

As the outcome of both buildings and underground stocks suggests, there is a sum of 165 tons of steel, 4,3 tons of copper in buildings, and around 1 ton of aluminum lying under the ground. Monetizing the quantities, there will be €33000, €23700, and €695 worth of metals respectively. Although for the buildings the calculated amount is only to provide a comprehension of the value to deal with in urban mining, it is not practically reliable to consider the cumulative value of several buildings. The monetization is calculated using the unit prices presented in table 1. Furthermore, the expected availability of stocks in undergrounds is approximately stated based on installation date provided in the documents provided by Kadaster (Section 3.2.2.4), and the estimated life time discussed in table 2. Hence, for the case of this location, the thirty years life-time of underground cables is added to their installation year, which results in the expected availability of these cables to be reclaimed by year 2042.

4.2.2. Ruysdaelstraat-1071

Table 7 and 8 respectively present the building and underground stocks of the selected length of location 2; Ruysdaelstraat.

Table 7: Building stocks of location 2: Ruysdaelstraat to sub-postcode level

Length of street:		190m	
Postcode	Function	Copper content kg	Steel content kg
1071 XB	Residential	1085	47000
1071 XH	Residential	1027,5	31000
1071 XC	Residential	970	38200
1071 XJ	Residential	480	19600
		3562,5	**135800**

Table 8: Underground stocks of location 2: Ruysdaelstraat to street level

Length of street:		190m						
Type of stock	Function	Component	Cross section diameter	Conversion rate	Length m	Total content kg	Installation date	Expected Availability
Aluminium	Power cable	230V	150	2,7	419,5	169,8975	18/10/2012	2042
Aluminium	Power cable	400V	600	2,7	577,5	935,55	18/10/2012	2042
						1105,4475		

The findings from metal quantity assessments of Ruysdaelstraat with length of 190meter are presented above, and the results suggest that although the quantities are less than the previous streets', there is higher density and concentration of metals for both buildings and

undergrounds. With less than half the length of Pieter Cornelisz Hooftsrtaat, Ruysdaelstraat constitutes around 136 tons of steel, 3,5 tons of copper in buildings, and 1,1 tons of aluminum as underground stocks. The monetization discusses respectively metal worth of €27000, €18000, and €663 of financial value.

4.2.3. Titiaanstraat-1077

The third location to present the results for buildings and underground services in tables 9 and 10 respectively, is Titiaanstraat.

Table 9: Building stocks of location 3: Titiaanstraat to sub-postcode level

Length of street:		260m	
Postcode	Function	Copper content kg	Steel content kg
1077RC	Residential	380	2967,5
1077RD	Residential	382,5	2985
1077RE	Residential	330	2902,5
1077RG	Residential	507,5	4162,5
1077RH	Residential	507,5	4072,5
1077RJ	Residential	415	3495
1077RK	Residential	472,5	3535
1077RL	Residential	370	3070
		3365	**27190**

Table 10: Underground stocks of location 3: Titiaanstraat to street level

Length of street:		260m						
Type of stock	Function	Component	Cross section diameter	Conversion rate	Length	Total content kg	Installation date	Expected Availability
Aluminium	Power cable	230V	150	2,7	1158,8	469,314	2012	2042
Aluminium	Power cable	400V	600	2,7	265	429,3	2012	2042
						898,614		

The location of Titiaanstraat comprises of the lowest metal contents amongst the selected six locations. Although the length is not the lowest, the number of registered buildings in this street is low. Comparing to other streets, the metal contents in underground stocks is also lower and that is probably due to a smaller number of buildings which means less consumption, and therefore, less power lines. The metals contents and their financial value are respectively 27 tons of steel valued at €5000, 3,36 tons of copper valued at €17000, and lastly 898 kilograms of aluminum valued at €539.

4.2.4. Pieter Lastmankade-1075

In this section, measured building and underground stocks of location 4, Pieter Lastmankade are provided in tables 11 and 12.

Table 11: Building stocks of location 4: Pieter Lastmankade to sub-postcode level

Length of street:		630m	
Postcode	Function	Copper content kg	Steel content kg
1075KJ	Residential	360	13000
1075KK	Residential	1112,5	29600
1075KL	Residential	715	18700

1075KM	Residential	430	12500
1075KN	Residential	562,5	16900
1075KT	Residential	1610	42900
		4790	**133600**

Table 12: Underground stocks of location 4: Pieter Lastmankade to street level

Length of street:		630m						
Type of stock	Function	Component	Cross section diameter	Conversion rate	Length	Total content kg	Installation date	Expected Availability
Aluminium	Power cable	230V	150	2,7	1438,5	582,5925	2012	2042
Aluminium	Power cable	400V	600	2,7	3119	5052,78	2012	2042
						5635,3725		

Analyzing the values attained from metal stock assessments of Pieter Lastmankade Street, show that the values are relatively around the same numbers as the first location. However, looking at the location of this street, one side of the street is a canal and therefore, no buildings at one side. The buildings at the other side of the street consist of approximately 133,6 tons of steel and 4,8 tons of copper which are valued at €26700 and €25000, respectively. Nevertheless, it can be observed in table 12 that the volume of medium-voltage cable passed through this street is relatively high that makes the total aluminum contents constituted as underground stocks in this street nearly 5,6 tons which are monetized at €3400.

4.2.5. Karperweg-1075

The fifth location was a unique location with a sub-station inside. The sub-station has incoming high-voltage cables and therefore, the metal contents of underground stocks in this street is the highest amongst others. On the other hand, most of the buildings in the street have functions other than residential, hence, not accumulated in the buildings metal contents estimates. Tables 13 and 14 present the results for buildings and underground stocks in this street.

Table 13: Building stocks of location 5: Karperweg to sub-postcode level

Length of street:		310m	
Postcode	Function	Copper content kg	Steel content kg
LA	Residential	435	9600
LB	Residential	227,5	9500
LC	Residential	455	10900
		1117,5	**30000**

Table 14: Underground stocks of location 5: Karperweg to street level

Length of street:		310m						
Type of stock	Function	Component	Cross section diameter	Conversion rate	Length m	Total content kg	Installation date	Expected Availability
Aluminium	Power cable	230V	150	2,7	3384,5	1370,7225	2003	2033
Aluminium	Power cable	400V	600	2,7	28206	45693,72	2003	2033
Aluminium	Power cable	150kv	**1000**	2,7	619,4	1672,38	2003	2033
						48736,8225		

The location of Karperweg is uniquely selected due to the low density of buildings and the existence of a sub-station in this street. With regards to the buildings, the street comprises of mostly non-residential buildings, therefore, not high value of (residential) buildings stocks. 30 tons for steel with value of €6000, and 1,1 tons of copper with value of €5700 exist in the residential buildings of this street. On the other hand, the quantity of stocks underground reaches as high as 48 tons with financial value of approximately €29000. It also needs to be mentioned that the installation date of underground stocks at Karperweg was in 2003, therefore, the expected availability is earlier than the rest of the locations, in year 2033.

4.2.6. Prinses Irenestraat-1077

The last location to be assessed has also a unique feature. The segment of Prinses Irenestraat that was assessed is located in a park at postcode 1077 of Amsterdam. Meaning there are no buildings, but only bike and pedestrian path. Table below shows the result of underground stocks for this location.

Table 15: Underground stocks of location 6: Prinses Irenestraat to street level

Length of street:		650m						
Type of stock	Function	Component	Cross section diameter	Conversion rate	Length m	Total content kg	Installation date	Expected Availability
Aluminium	Power cable	230V	150	2,7	740	299,7	2012	2042
Aluminium	Power cable	400V	600	2,7	6840	11080,8	2012	2042
						11380,5		

Although the underground stocks do not represent a significant value, due to open space, no motorized traffic, and soft ground (no asphalt), it is considered a potential location for urban mining of underground stocks. the underground stocks are quantified at 11,4 tons of aluminum which is valued around €6800. The expected availability, like other locations except Karperweg, is also in year 2042.

4.3. Street by street comparison

Section 4.2 presented the findings about metal contents for all the six selected locations. In this section, only the underground stocks of streets will be compared. Since the buildings' stocks can be assessed per building plots, it is not of high added value to compare them in street level; those plots with higher potentials can be filtered from the dataset (Appendix A).

This analysis helps to find a more potential location among others. Logically, longer streets have more stocks to be mined; however, at some cases, the shorter streets, or those with less density, are more suitable for urban mining. In addition, the stocks are monetized as per given literature in table 1, section 2.4.2.

4.3.1. Metal content; overall vs. per meter long

This section shows graph visualization of outcomes from tables presented in section 4.2. Nonetheless, the metal content is given per 100m long for better visibility in the graph. From the graph, the streets with higher metal density can be identified. Obviously, location 5, due to the power sub-station, has significant volume of metals in a relatively short street, hence, it can be identified as a potential focus point. In addition, the bars of Prinses Irenestraat, and the fact that it has no building at surroundings, and no traffic, show that it can be considered as a potential source in the future. As discussed in the literature review, one of the

disadvantages of separate recovery of underground stocks, is the cost of excavation related operation.

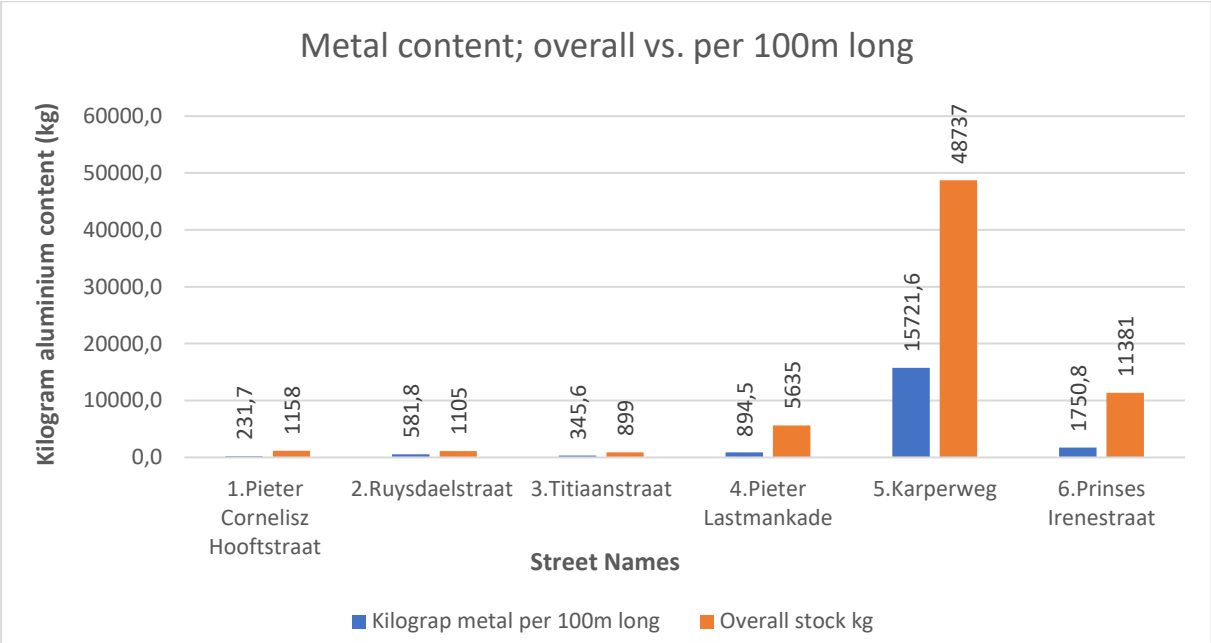


Figure 42: Comparison graph of overall metal contents per street (Whole length vs. per 100m long)

4.3.2. Financial potential per street vs. per meter long

Without doubt, the financial benefit is the reason that users can be motivated to undertake urban mining approach for the no longer in-use material recovery. This section presents a tangible status of financial revenue that each of the six locations in this study can generate. Although the exploitation cost is not taken into account, it can be logically concluded that for a revenue as low as 600€, the reclamation of stocks is far from being profitable unless it is performed in an integrated excavation process with no cost. On the other hand, the feasibility can be assessed for streets with more potentials such as Karperweg or Prinses Irenestraat with respectively €29000 and €6800 worth of metals.

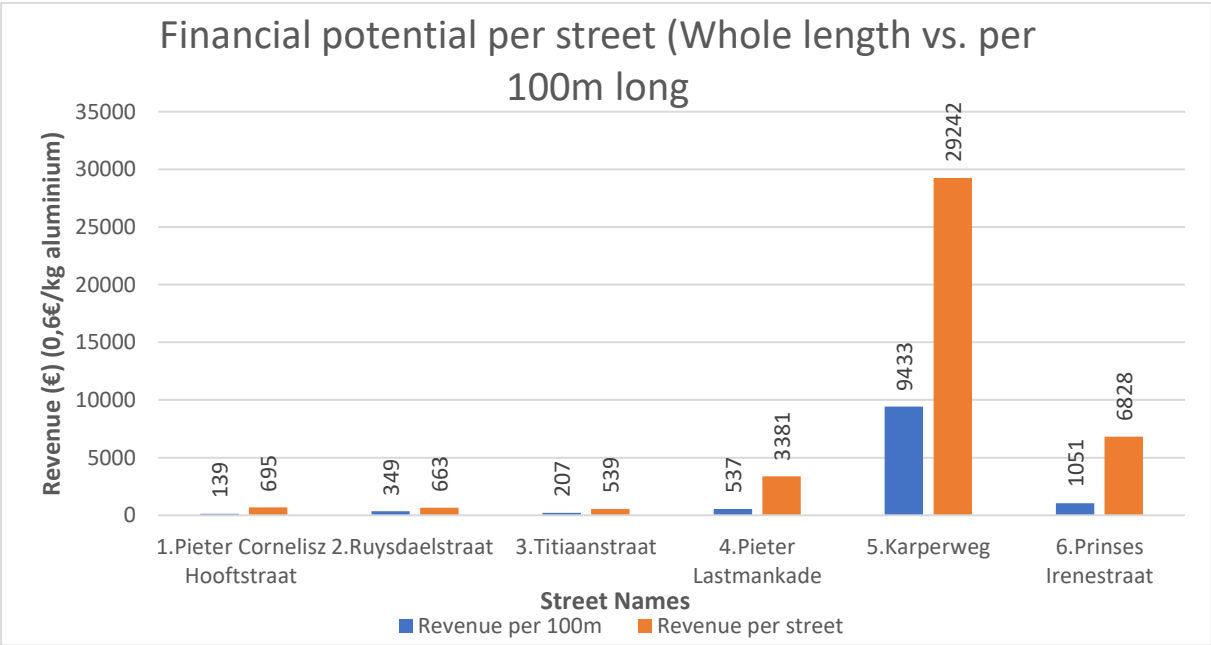


Figure 43: Comparison graph of financial potential per street (Whole length vs. per 100m long)

4.4. Web map and user interaction

Last but not least, section 4.4 presents the final outcome of this project which was discussed as phase 4 of the research approach. The results demonstrated in previous section, help the users to identify potential locations that can be profited for the urban mining approach. The created web map; however, not only provides the information regarding metal contents, it offers more organized and accurate data about urban mines. Knowing exact location and characteristics of the mines, assists the users with easier and more reliable exploration process that can be trusted and therefore, more likely to be considered for the urban mining approach.

Figure 44 shows the information that appear by clicking on a building plot of which the content was calculated and assessed in this study. Furthermore, Figure 45 shows the information related to one of the selected locations, Pieter Lastmankade, once clicked on the street.

Figure 44: Finalized web map-user view of Building plots stocks

As pointing at one of the buildings in Titiaanstraat, the findings discussed in previous sections, appear in a pop-up window and enables the user to be informed of the stock availability, and contents for every single building.

Figure 45: Finalized web map-user view of underground stocks

Selecting a street (as visualized as lines in the map) offers the information regarding type of component that constitutes the stock, type of material, and the expected availability. The gathered and organized information are presented in a pop-up window in the map so the user can be informed well of all the attributes and features with a click.

4.5. Results; A conclusion

The result presented in the previous section, demonstrated the outcome of assessment of urban mines in the six selected locations. Monetizing the stocks and comparing the revenue they make if they are reclaimed, brings the attention back to studies done for the city of Linköping in Sweden, and Huddersfield in the UK. As the findings for separate and integrated stock recovery in Linköping represented in Figures 8 and 9, majority of the stocks are not feasible to be exploited with integrated recovery, and none with separate recovery. Figure 43, confirms the validity of the findings by Wallstern et al., 2015, showing the revenue made for some of the streets' underground stocks is so little that does not worth taking the effort and costs. For instance, the potential revenue that can be made by reclaiming the underground stocks of the whole Pieter Cornelisz Hooftstraat is as little as €696. Considering the costs of exploitation, the statement can strongly be made that the urban mining for this case is far from being financially feasible. However, for other locations such as Karperweg, and Prinses Irenestraat, with respectively €29200 and €6800, further assessments for integration recovery and exploitation costs need to be performed. Not getting far from the root of the problem, which was the lack of information and absence of an information system, the accumulated information is presented in a uniform platform that uses a map to locate the mines and present their characteristics to the potential users.

5. Discussion

As discussed in details in chapter 3, one of the intentions of performing the first phase of this research was to explore and classify the available information from the existing open databases. This approach brought the downsides of the key databases to the surface; which was indeed the purpose to experience assessing the urban mines using these databases to recognize where the improvement is required. In this section, these downsides will be discussed. First the general encountered gaps will be presented, followed by drawbacks identified for building and underground stocks assessments, respectively.

5.1. General factors

In general, three main issues were faced during the assessment of metal content within the framework of this study.

Lack of documented data: As highlighted in PUMA, lack of information is the main obstacle to an efficient urban mining approach. In the near past, the information related to construction process, such as drawings, correspondences and as-builts were not properly documented or at least made accessible to others. For instance, absence of material specifications, and no record of maintenance and/or replacement of services are some of these useful inaccessible information that could majorly contribute to a more informative platform.

Scattered information: The methodology clearly expresses that in order to finalize the validated assessment of the metal contents, various data had to be collected from various sources. The scattered information and having to collect them from various sources, of which it was encountered that they may not be in line with each other, causes incompetency on its own. In addition, trouble and inaccuracy for the users who are referring to them. Discrepancy of the information in PDOK viewer with those received from Kadaster is one example that will be discussed further in 5.3.

Information system: It is very important to have the documents uniformly organized and easily accessible and readable by everyone. With wide opportunities that data science is offering us today, proper set up of information that allow integration and correlation with available tools and methods is not out of reach. Digitizing the available information in order to implement them in a digitalized process allows a more accurate and quicker assessment process. Assessment and validation in this study, mainly had to be done manually which increases the chance of mistake and hence, incompetency. Even though the existence of rough drawings is still better than nothing, their validity and correctness should be controlled and checked by a centralized authority to make sure they are accurate and also comprehensible by the users. For instance, a metal recycler might not be aware or to be able to assess how much copper exists in 1 meter of a 20kv power cable.

5.2. Building related factors

This section discusses solely around the important aspects of building stocks. It cannot be denied to realize that the focus of urban mining assessments in the Netherlands are mainly related to buildings. This is perhaps due to more tangibility of effect of building sector to material flow and waste stream. Although a very classified and broad assessment was done under the assumptions of PUMA for residential buildings in Amsterdam, discrepancies and faults have been found within the outcome of the assessment. Nevertheless, having no information at all with probably inexistence of any drawing related to the buildings that age as late as two hundred years ago is understandable, and therefore, even this dataset with all its downsides is very much appreciated.

Overall: The outcome of the assessment of the PUMA metal contents provides the estimate of maximum and minimum amount of metal contents. The assessment is done in accordance assumption made based on surface area, height and construction year of buildings. Hence, not very explicit.

Discrepancies: Several faults were identified in the process from the information provided in the dataset. Discrepancies between building numbers and the postcode they are located in (See Figure 46), in addition to having no data for buildings that are not residential while there were buildings categorized as residential while in reality are shops (Buildings in Pieter Cornelisz Hooftstraat), are the identified inaccuracies of the PUMA building metal contents dataset.

Inaccuracies: As mentioned, the assessment of the building dataset is based on assumptions based on building surface area, heights and construction year. It is realized that the buildings are assessed per residential unit as indicated in the dataset with house number additionals. While a building plot may consist of several housing unit, but it is generally the same as the building plot next to it that consisted of one residential unit, has been counted with same metal contents estimated for each residential unit instead of being combined as one factor. In other words, for example, a building plot of one residential unit has 20kg of copper, whereas the same building plot with two residential unit has 40kg of copper.

A	B	C	D		F	G	H	I	J	K	L	M	N	O	P	Q
vbo_id	pand_i	postco	huisnummer	huisnt	huisnummertoevoeging	opperv	pandhi	gebruil	copper	steel_c	copper	steel_c	copper	copper	steel_k	steel_k na
3,63E+14	3,63E+	4 1071CA	50		1	104	########	woonfunc	4	6	B	B	15	55	600	1000
3,63E+14	3,63E+	4 1071CA	52		1	70	########	woonfunc	2	4	C	C	5	35	500	900
3,63E+14	3,63E+	4 1071CA	54		2	121	########	woonfunc	4	6	B	B	15	55	600	1000
3,63E+14	3,63E+	4 1071CA	54		2	132	########	woonfunc	4	9	B	A	15	55	800	1200
3,63E+14	3,63E+	4 1071CA	56		1	132	########	woonfunc	4	9	B	A	15	55	800	1200
3,63E+14	3,63E+	4 1071CB	56		3	71	########	woonfunc	2	4	C	C	5	35	500	900
3,63E+14	3,63E+	4 1071CB	56		1	65	########	woonfunc	2	4	C	C	5	35	500	900
3,63E+14	3,63E+	4 1071CB	58		2	65	########	woonfunc	2	4	C	C	5	35	500	900
3,63E+14	3,63E+	4 1071CC	58		1	161	########	woonfunc	6	11	A	A	35	80	800	1200
3,63E+14	3,63E+	4 1071CA	58		2	148	########	woonfunc	4	9	B	A	15	55	800	1200
3,63E+14	3,63E+	4 1071CB	60		1	104	########	woonfunc	4	6	B	B	15	55	600	1000
3,63E+14	3,63E+	4 1071CB	62		3	52	########	woonfunc	2	4	C	C	5	35	500	900
3,63E+14	3,63E+	4 1071CB	62		1	56	########	woonfunc	2	4	C	C	5	35	500	900
3,63E+14	3,63E+	4 1071CB	64		2	56	########	woonfunc	2	4	C	C	5	35	500	900
3,63E+14	3,63E+	4 1071CC	64		2	55	########	woonfunc	2	4	C	C	5	35	500	900
3,63E+14	3,63E+	4 1071CC	66		1	55	########	woonfunc	2	4	C	C	5	35	500	900
3,63E+14	3,63E+	4 1071CB	68		1	44	########	woonfunc	2	4	C	C	5	35	500	900
3,63E+14	3,63E+	4 1071CB	68		2	108	########	woonfunc	4	6	B	B	15	55	600	1000
3,63E+14	3,63E+	4 1071CB	70		2	56	########	woonfunc	2	4	C	C	5	35	500	900
3,63E+14	3,63E+	4 1071CB	70		1	56	########	woonfunc	2	4	C	C	5	35	500	900
3,63E+14	3,63E+	4 1071CB	72		2	54	########	woonfunc	2	4	C	C	5	35	500	900
3,63E+14	3,63E+	4 1071CB	72		1	54	########	woonfunc	2	4	C	C	5	35	500	900
3,63E+14	3,63E+	4 1071CA	74		2	52	########	woonfunc	2	4	C	C	5	35	500	900
3,63E+14	3,63E+	4 1071CA	74		1	62	########	woonfunc	2	4	C	C	5	35	500	900
3,63E+14	3,63E+	4 1071CB	76		1	92	########	woonfunc	4	6	B	B	15	55	600	1000
3,63E+14	3,63E+	4 1071CB	76		2	90	########	woonfunc	4	6	B	B	15	55	600	1000
3,63E+14	3,63E+	4 1071CA	76		1	61	########	woonfunc	2	4	C	C	5	35	500	900
3,63E+14	3,63E+	4 1071CA	80		2	62	########	woonfunc	2	4	C	C	5	35	500	900
3,63E+14	3,63E+	4 1071CC	82		1	100	########	woonfunc	4	6	B	B	15	55	600	1000
3,63E+14	3,63E+	4 1071CA	82		2	136	########	woonfunc	4	6	B	B	15	55	600	1000
3,63E+14	3,63E+	4 1071CC	84		1	55	########	woonfunc	2	4	C	C	5	35	500	900
3,63E+14	3,63E+	4 1071CC	84		2	55	########	woonfunc	2	4	C	C	5	35	500	900
3,63E+14	3,63E+	4 1071CA	86		1	185	########	woonfunc	6	8	A	B	35	80	600	1000
3,63E+14	3,63E+	4 1071CB	86		2	97	########	woonfunc	4	6	B	B	15	55	600	1000
3,63E+14	3,63E+	4 1071CB	88		1	56	########	woonfunc	2	4	C	C	5	35	500	900
3,63E+14	3,63E+	4 1071CB	88		2	53	########	woonfunc	2	4	C	C	5	35	500	900
3,63E+14	3,63E+	4 1071CC	90		2	100	########	woonfunc	4	6	B	B	15	55	600	1000
3,63E+14	3,63E+	4 1071CA	90		2	55	########	woonfunc	2	4	C	C	5	35	500	900
3,63E+14	3,63E+	4 1071CA	92		1	70	########	woonfunc	2	4	C	C	5	35	500	900
3,63E+14	3,63E+	4 1071CA	100		3	55	########	woonfunc	2	4	C	C	5	35	500	900
3,63E+14	3,63E+	4 1071CC	102		1	109	########	woonfunc	4	9	B	A	15	55	800	1200
3,63E+14	3,63E+	4 1071CC	104		2	106	########	woonfunc	4	9	B	A	15	55	800	1200
3,63E+14	3,63E+	4 1071CA	104		3	55	########	woonfunc	2	4	C	C	5	35	500	900
3,63E+14	3,63E+	4 1071CA	106		2	55	########	woonfunc	2	4	C	C	5	35	500	900
3,63E+14	3,63E+	4 1071CA	106		1	55	########	woonfunc	2	4	C	C	5	35	500	900

Figure 46: Discrepancies in PUMA residential building metal content dataset

5.3. Underground related factors

The urban mining of underground stocks is paid less attention to in the urban mining initiatives by cities, as they do not have significant share in the material consumption together with waste stream. This is due to the fact that they are often left under the ground after their primary use-cycle as discussed in the literature. In this section, the views regarding data

collection, and the quality of the collected data for underground stocks in this study is discussed.

Elements' composition: It was assumed in the beginning that the underground cables and also gas pipes are comprised of copper. The collected information on underground services clarified that the cables are made of aluminum and public gas pipes are often polyethylene (PE) pipes. Only the gas pipe network within each building is often composed of copper. With this regard, the feasibility of mining for power cables are compromised due to much lower financial value of aluminum in comparison with copper.

Data availability: The information on underground stocks is not classified like the one for buildings. As explained in the methodology, the information obtained from different sources had to be overlayed to achieve a relatively reliable outcome. The provided documents that contained the type of underground services, which are provided to contractors basically to prevent damages during excavation works, are not open to public, and comes with a cost. Adding to that, the fact that the required information is provided as per a requested building plot, makes it a hassle to have a validated dataset of all underground services within a street or a neighbourhood.

Furthermore, as described in chapter 3, the metal contents of underground stocks were assessed by taking inputs from various sources; mainly PDOK viewer and documents from Kadaster. For the street of Karperweg, where a sub-station is located and high-voltage cables exist (according to PDOK viewer), the high-voltage cable was not present in the documents received from Kadaster. Aside from the fact that this conflict makes the information in hand unreliable, the specifications for this cable had to be researched from other sources. Since the main purpose of this study was to introduce an informative public platform for urban mines, detail of these specifications is not of highest importance. Knowing the uniform and standard types of cables used for the city of Amsterdam, it is not a mystifying matter to clarify this feature and creating a reliable database of the underground cables and the attributes assigned to them.

Service log: It is not clear whether a history log is existing or not to the extent of authors' knowledge in this study. Nonetheless, as proposed in section 3.1, in order to track, plan, and make conclusive decisions for products, keeping record of all the maintenance and installation history is very crucial. Of course, this information must be available to relative parties to be aware of planning and schedule to prepare for an efficient mining. This leads to a proper communication which makes the urban mining of underground stocks more profitable and real.

6. Conclusion

In summary, this study focused on introducing a platform that can be sufficiently inform the potential users of urban mining of available mines. In order to structure such platform, actual assessment of mines in the city of Amsterdam with the use of openly available data was conducted. The outcome of the assessment, which responded to research sub-question 1, used as the inputs to demonstrate the final outcome of the study. The final outcome, contributing to the main research question, is the web map that locates the urban mines with assigned attributes to adequately deliver the required information to users. In the following sections of this chapter, more in-depth discussions about the bolded contribution of this research are going to be discussed.

6.1. Potential points for improvement

In every process that involves the coordination of various parties, communication is the key. A decent and proper communication is the one with accuracy, validity, comprehensibility, and reliability. The process of urban mining, is the process that involves all the parties throughout the life-cycle of a product. Starting from manufacturer to the end-user are required to participate and coordinate well for an effective resource efficient approach of urban mining. At the current stage, these parties often keep the information of the product to themselves and usually archived once the product is out from their inventory. This is probably the reason behind the claim stated in PUMA regarding the lack of information being the main obstacle for urban mining in Amsterdam. Consecutively, "The urban mine of Rotterdam", that is previously cited in chapter 2, discussed the importance of a construction hub that activates and boosts the coordination amongst all the parties in the life-cycle of a product. The centralized authority is responsible to update and maintain all the information during the use-cycle. Additionally, the central hub is responsible to validate and verify the received data. Such operation, requires implementation of a standardized system and organization that is uniformly established and followed by all industry players who are involved in the process. Hence, a proper and sound information is transferred to the next user.

Responding to the main research question of this study, the digital platform presented in 4.4 as the web map is proposed to be the service offered by the proposed central construction hub. This is what the PUMA called urban mining information system, with municipality of Amsterdam playing the central role as the urban planner, and furthermore, in line with the three ambitions set for the built environment as described in section 1.2. In order to supply the hub with valid information to be used in the web map, various tools and methods are there to use which then contributes to research sub-question 2. Most importantly a GIS tool is used as the main platform which embeds the features and the location of the mines and presents them to the user. To improve, the generation of material passport by the manufacturer, upgraded by the designer and builder, is very critical to enhance the possibility of reusing elements rather than simply recycling them.

Creation of a product passport for underground stocks, incorporating all the features and properties allows the user, which for this case are mainly metal recyclers, to be properly informed of availability and potential of the mines. As for underground stocks, it is the role of the central hub to maintain an effective communication among the utility owners and recyclers to coordinate for the integrated recovery of material in terms of planning and scheduling.

As for the buildings, designers are introduced as the main interactors of this platform. In more detail, designers are referred to structural and architectural designers. As the building composition suggests, the elements made of metal and aluminum are often those that suit reusability. The copper elements, often cables and pipes, have shorter life-time and are often fit for recycling. Since, based on facts and figures, it is understood that recycling is already at a satisfactory stage in the Netherlands, the reusability of material is what the resource efficiency struggle is for. The outcome presented in chapter 4 for buildings, is absolutely insufficient for a designer to refer to for considering the re-use of elements in a building assessed in this study. There are a wide range of other information that need to be developed and come along so that a designer is convinced enough to use second hand elements. In order to sufficiently inform a designer about an element that they may wish to consider to reuse, a complete material passport with valid building passport that includes all the necessary information about an element needs to be presented to them. For example, to reuse a steel beam, in addition to the physical properties and load bearing capacity, overall structural analysis of the building is required for their decision. A steel beam might be of good and sufficient properties, but it might have reached the fatigue life. In addition to the information, communication and procurement need to be organized in a way to avoid space occupation, and time and cost implication. The implementation of BIM has already taken place and the abovementioned information can be found in the recent building processes, therefore, the creation of the digital platform that includes the new buildings is just the matter of connection and integration.

In addition to discussions regarding the tools to supply information to the web platform, urban research methods can be used to identify the potential locations. As discussed in section 4.2, there are various conditions that can affect the potentiality of a location. The uniquely selected locations represent different attributes that affect their suitability as a potential location for mining. These attributes can be assessed and analyzed using urban research methods to provide their mining feasibility explicitly.

6.2. Future studies

In section 3.1, the conceptual framework of this research intention was proposed. It did not fall within the scope of this study to perform the whole outline thoroughly. However, it is important to discuss the extensive studies that may be followed accordingly for the full-scale implementation of the framework discussed. Therefore, in the sub-sections below, main two proposed potential future studies to be undertaken are going to be discussed.

6.2.1. System automation

The downsides discussed in the discussion section, can widely be resolved by implementing an automated system for data management. Scattered data that are mostly kept within each individual company involved along the life-cycle of material, need to come together in a platform for more reliable processing and provision. Digitalizing the process is the first thing that comes to mind. Although many companies are already practicing fully digital process in their activities, it is still a lack for many organizations in the industry. Adding to that, digitalizing with a tailored format for each party is not efficient and consistent, therefore, in addition, it is important to introduce and structure a uniform global format for the whole system. A format that is agreed and being conducted by all companies involved. Lastly, as the urban planner and the owner of the system, the central organization needs to establish a portal for the information entered to be accessible for further verification and validation which then can

be registered, assigned to the location, and published. The portal technically represents the overall structure proposed in section 1.3.

6.2.2. Legal aspects

Last but not least, introducing a well-organized informative platform that offers all the necessary information to the potential users is necessary but not sufficient. A very important part of circular economy is innovation in, and implementation of new ways of business. There are scenarios discussed in the PUMA that assess how the pushing force behind the urban mining can be formulated. Like the methods and tools discussed in technical aspects, there are tools that can be used to boost the implementation of circular economy approaches with the force of local government. As much as there is urgency to implement new decree, values and integrity of industry actors must be respected as well. It does not fall within the scope of this research to discuss the implementation strategies; however, some of these tools and methods that can be deployed within new forms of contracts, are listed below and very briefly discussed.

Policies and legislations: Taking advantage of legal forces to implement new regulations.
Incentives and discounts in taxation: The use of secondary material, and implementation of methods that contribute to a more resource efficient construction industry to be awarded in the form of incentive or tax alteration.
Use of environmental tax and shadow costs: Opposite the previous point, to implicate higher environmental tax and shadow cost for less resource efficient solutions.
Compensations: Following the previous factor, compensation in a form of contribution or an environmental rehabilitation act.

Another gap and confusions identified within the implementation of urban mining approach and bringing the theory into practice is the pricing, that can on itself be widely studies with collaboration of parties in the industry such as contractors, suppliers, and developers. The controlled pricing system must be defined and established within the contract forms and followed by the two sides of the agreement.

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Appendix A

House number	Postcode	Full Address	Latitude	Longitude	Building function	Construction year	Copper content kg	Steel content kg
13	1071BL	Pieter Cornelisz Hooftstraat 13 1071BL	52,36097387	4,883722374	Residential	1883	57,5	800
15	1071BL	Pieter Cornelisz Hooftstraat 15 1071BL	52,36096218	4,883744125	Residential	1883	57,5	800
17	1071BL	Pieter Cornelisz Hooftstraat 17 1071BL	52,36091837	4,883564417	Residential	1895	57,5	800
19	1071BL	Pieter Cornelisz Hooftstraat 19 1071BL	52,36090772	4,883477916	Residential	1895	162,5	3200
23	1071BL	Pieter Cornelisz Hooftstraat 23 1071BL	52,36085571	4,883268704	Residential	1895	57,5	900
25	1071BL	Pieter Cornelisz Hooftstraat 25 1071BL	52,36078323	4,883205672	Residential	1895	105	3000
27	1071BL	Pieter Cornelisz Hooftstraat 27 1071BL	52,3607992	4,88308162	Residential	1895	92,5	2000
29	1071BM	Pieter Cornelisz Hooftstraat 29 1071BM	52,3607209	4,8827753	Residential	1904	55	1500
31	1071BM	Pieter Cornelisz Hooftstraat 31 1071BM	52,3607233	4,8826972	Residential	1896	40	1500
33	1071BM	Pieter Cornelisz Hooftstraat 33 1071BM	52,3606358	4,8826127	Residential	1904	40	1600
35	1071BM	Pieter Cornelisz Hooftstraat 35 1071BM	52,360648	4,882501	Residential	1904	55	1800
37	1071BM	Pieter Cornelisz Hooftstraat 37 1071BM	52,36061	4,8824143	Residential	1897	112,5	2800
39	1071BM	Pieter Cornelisz Hooftstraat 39 1071BM	52,360637	4,8823612	Residential	1897	55	1800

41	1071BM	Pieter Cornelisz Hooftstraat 41 1071BM	52,3605703	4,882311	Residential	1897	110	3600
43	1071BM	Pieter Cornelisz Hooftstraat 43 1071BM	52,3605277	4,8822046	Residential	1897	97,5	2600
45	1071BN	Pieter Cornelisz Hooftstraat 45 1071BN	52,3605112	4,882098	Residential	1905	77,5	1800
49	1071BN	Pieter Cornelisz Hooftstraat 49 1071BN	52,3604506	4,8819543	Residential	1905	55	1800
51	1071BN	Pieter Cornelisz Hooftstraat 51 1071BN	52,3604475	4,8818182	Residential	1905	20	800
53	1071BN	Pieter Cornelisz Hooftstraat 53 1071BN	52,3604009	4,8817414	Residential	1905	57,5	1000
55	1071BN	Pieter Cornelisz Hooftstraat 55 1071BN	52,3603834	4,8816605	Residential	1905	55	1800
57	1071BN	Pieter Cornelisz Hooftstraat 57 1071BN	52,3603785	4,8815676	Residential	1905	75	2600
59	1071BN	Pieter Cornelisz Hooftstraat 59 1071BN	52,3603521	4,8814716	Residential	1905	75	2600
61	1071BN	Pieter Cornelisz Hooftstraat 61 1071BN	52,3603353	4,8814104	Residential	1896	55	1800
63	1071BN	Pieter Cornelisz Hooftstraat 63 1071BN	52,3603159	4,8813876	Residential	1896	35	1000
69	1071BP	Pieter Cornelisz Hooftstraat 69 1071BP	52,3601833	4,8808358	Residential	1898	35	800
71	1071BP	Pieter Cornelisz Hooftstraat 71 1071BP	52,3601704	4,8807565	Residential	1898	72,5	1500
73	1071BP	Pieter Cornelisz Hooftstraat 73 1071BP	52,3601342	4,8806779	Residential	1898	20	700
75	1071BP	Pieter Cornelisz Hooftstraat 75 1071BP	52,3601219	4,8806012	Residential	1898	55	1500

77	1071BP	Pieter Cornelisz Hooftstraat 77 1071BP	52,3601342	4,8805209	Residential	1875	92,5	1600
79	1071BP	Pieter Cornelisz Hooftstraat 79 1071BP	52,36009	4,8803723	Residential	1875	57,5	800
81	1071BP	Pieter Cornelisz Hooftstraat 81 1071BP	52,3600444	4,8803332	Residential	1875	35	800
83	1071BP	Pieter Cornelisz Hooftstraat 83 1071BP	52,3600238	4,8802712	Residential	1875	57,5	700
85	1071BP	Pieter Cornelisz Hooftstraat 85 1071BP	52,3600213	4,8801859	Residential	1875	20	700
87	1071BP	Pieter Cornelisz Hooftstraat 87 1071BP	52,359999	4,880092	Residential	1875	72,5	1500
91	1071BR	Pieter Cornelisz Hooftstraat 91 1071BR	52,359963	4,879934	Residential	1875	35	800
93	1071BR	Pieter Cornelisz Hooftstraat 93 1071BR	52,3599699	4,8798764	Residential	1875	167,5	3800
95	1071BR	Pieter Cornelisz Hooftstraat 95 1071BR	52,3598536	4,8798554	Residential	1908	20	700
99	1071BR	Pieter Cornelisz Hooftstraat 99 1071BR	52,3598941	4,8796306	Residential	1876	20	700
103	1071BR	Pieter Cornelisz Hooftstraat 103 1071BR	52,359777	4,879206	Residential	1891	40	1400
105	1071BR	Pieter Cornelisz Hooftstraat 105 1071BR	52,359745	4,879103	Residential	1875	40	1400
107	1071BR	Pieter Cornelisz Hooftstraat 107 1071BR	52,359651	4,8789828	Residential	1875	112,5	2400
109	1071BR	Pieter Cornelisz Hooftstraat 109 1071BR	52,3596579	4,8790731	Residential	1875	75	2200
111	1071BR	Pieter Cornelisz Hooftstraat 111 1071BR	52,35963	4,8788769	Residential	1877	90	2600

113	1071BR	Pieter Cornelisz Hooftstraat 113 1071BR	52,35965	4,878753	Residential	1877	90	2300
115	1071BS	Pieter Cornelisz Hooftstraat 115 1071BS	52,359589	4,8786938	Residential	1877	20	800
119	1071BS	Pieter Cornelisz Hooftstraat 119 1071BS	52,3595333	4,8785284	Residential	1877	55	1800
121	1071BS	Pieter Cornelisz Hooftstraat 121 1071BS	52,3595269	4,8784301	Residential	1877	35	100
123	1071BS	Pieter Cornelisz Hooftstraat 123 1071BS	52,3594678	4,8783483	Residential	1875	55	1600
125	1071BS	Pieter Cornelisz Hooftstraat 125 1071BS	52,3594405	4,8782527	Residential	1875	20	700
131	1071BS	Pieter Cornelisz Hooftstraat 131 1071BS	52,359439	4,877963	Residential	1875	40	1400
133	1071BS	Pieter Cornelisz Hooftstraat 133 1071BS	52,3593193	4,8779073	Residential	1875	75	2200
16	1071BX	Pieter Cornelisz Hooftstraat 16 1071BX	52,36112404	4,88347086	Residential	1885	60	2200
18	1071BX	Pieter Cornelisz Hooftstraat 18 1071BX	52,36112158	4,883377653	Residential	1873	95	3400
20	1071BX	Pieter Cornelisz Hooftstraat 20 1071BX	52,36110479	4,883291823	Residential	1873	35	1000
22	1071BX	Pieter Cornelisz Hooftstraat 22 1071BX	52,36104705	4,883102727	Residential	1873	75	2200
32	1071BZ	Pieter Cornelisz Hooftstraat 32 1071BZ	52,3608873	4,8825794	Residential	1904	20	700
34	1071BZ	Pieter Cornelisz Hooftstraat 34 1071BZ	52,3608802	4,8824913	Residential	1904	20	700
36	1071BZ	Pieter Cornelisz Hooftstraat 36 1071BZ	52,3608588	4,882417	Residential	1904	55	1500

38	1071BZ	Pieter Cornelisz Hooftstraat 38 1071BZ	52,3608172	4,8823382	Residential	1904	70	1600
40	1071BZ	Pieter Cornelisz Hooftstraat 40 1071BZ	52,3608498	4,8821855	Residential	1904	20	700
42	1071BZ	Pieter Cornelisz Hooftstraat 42 1071BZ	52,3607693	4,8821566	Residential	1885	55	1500
44	1071BZ	Pieter Cornelisz Hooftstraat 44 1071BZ	52,360699	4,881991	Residential	1885	75	2200
46	1071BZ	Pieter Cornelisz Hooftstraat 46 1071BZ	52,360704	4,88201	Residential	1885	20	700
48	1071BZ	Pieter Cornelisz Hooftstraat 48 1071BZ	52,360676	4,881932	Residential	1885	20	700
50	1071CA	Pieter Cornelisz Hooftstraat 50 1071CA	52,3606993	4,881833	Residential	1885	35	1000
52	1071CA	Pieter Cornelisz Hooftstraat 52 1071CA	52,3606622	4,8817227	Residential	1872	35	1000
54	1071CA	Pieter Cornelisz Hooftstraat 54 1071CA	52,3606664	4,8816197	Residential	1872	55	1800
56	1071CA	Pieter Cornelisz Hooftstraat 56 1071CA	52,3602869	4,8805068	Residential	1872	60	2400
58	1071CA	Pieter Cornelisz Hooftstraat 58 1071CA	52,3606097	4,8814801	Residential	1872	90	2400
60	1071CA	Pieter Cornelisz Hooftstraat 60 1071CA	52,3606052	4,8813366	Residential	1872	35	1000
62	1071CA	Pieter Cornelisz Hooftstraat 62 1071CA	52,360504	4,881294	Residential	1872	55	1700
64	1071CA	Pieter Cornelisz Hooftstraat 64 1071CA	52,360489	4,881214	Residential	1872	40	1400
66	1071CA	Pieter Cornelisz Hooftstraat 66 1071CA	52,360459	4,881144	Residential	2018	57,5	1000

68	1071CA	Pieter Cornelisz Hooftstraat 68 1071CA	52,360444	4,881063	Residential	2018	70	1800
70	1071CB	Pieter Cornelisz Hooftstraat 70 1071CB	52,3604872	4,8809139	Residential	1900	40	1400
72	1071CB	Pieter Cornelisz Hooftstraat 72 1071CB	52,3604066	4,8808478	Residential	1900	55	1500
74	1071CB	Pieter Cornelisz Hooftstraat 74 1071CB	52,3604108	4,8807448	Residential	1905	40	1400
76	1071CB	Pieter Cornelisz Hooftstraat 76 1071CB	52,3603008	4,8805406	Residential	1905	60	2100
80	1071CB	Pieter Cornelisz Hooftstraat 80 1071CB	52,3603	4,880509	Residential	1905	20	700
82	1071CB	Pieter Cornelisz Hooftstraat 82 1071CB	52,360275	4,880422	Residential	1905	55	1500
84	1071CB	Pieter Cornelisz Hooftstraat 84 1071CB	52,360266	4,880358	Residential	1905	40	1400
86	1071CB	Pieter Cornelisz Hooftstraat 86 1071CB	52,3603168	4,8802274	Residential	1875	72,5	1700
88	1071CB	Pieter Cornelisz Hooftstraat 88 1071CB	52,3601968	4,8801581	Residential	1875	70	2000
90	1071CC	Pieter Cornelisz Hooftstraat 90 1071CC	52,3602414	4,8800536	Residential	1875	40	1400
92	1071CC	Pieter Cornelisz Hooftstraat 92 1071CC	52,3601731	4,8800177	Residential	1875	35	800
100	1071CC	Pieter Cornelisz Hooftstraat 100 1071CC	52,3601321	4,8796713	Residential	1875	35	800
102	1071CC	Pieter Cornelisz Hooftstraat 102 1071CC	52,3601039	4,8795921	Residential	1875	20	800
104	1071CC	Pieter Cornelisz Hooftstraat 104 1071CC	52,3600754	4,8795316	Residential	1875	40	1500

106	1071CC	Pieter Cornelisz Hooftstraat 106 1071CC	52,360022	4,879461	Residential	1875	55	1500
108	1071CD	Pieter Cornelisz Hooftstraat 108 1071CD	52,3600523	4,8793331	Residential	1875	55	1500
110	1071CD	Pieter Cornelisz Hooftstraat 110 1071CD	52,3600239	4,8792632	Residential	1875	55	1500
112	1071CD	Pieter Cornelisz Hooftstraat 112 1071CD	52,359949	4,879209	Residential	1875	117,5	3100
114	1071CD	Pieter Cornelisz Hooftstraat 114 1071CD	52,3599802	4,879061	Residential	1875	60	2200
120	1071CD	Pieter Cornelisz Hooftstraat 120 1071CD	52,359853	4,878855	Residential	1876	110	3200
122	1071CD	Pieter Cornelisz Hooftstraat 122 1071CD	52,3598993	4,8787486	Residential	1876	40	1400
124	1071CD	Pieter Cornelisz Hooftstraat 124 1071CD	52,3598818	4,8786677	Residential	1876	20	700
126	1071CD	Pieter Cornelisz Hooftstraat 126 1071CD	52,3598643	4,8785867	Residential	1877	55	1500
128	1071CE	Pieter Cornelisz Hooftstraat 128 1071CE	52,3598076	4,8785207	Residential	1877	40	1400
130	1071CE	Pieter Cornelisz Hooftstraat 130 1071CE	52,3598837	4,8783698	Residential	1877	40	1400
134	1071CE	Pieter Cornelisz Hooftstraat 134 1071CE	52,359787	4,8782701	Residential	1877	75	2200
136	1071CE	Pieter Cornelisz Hooftstraat 136 1071CE	52,3598116	4,8780978	Residential	1875	40	1400
138	1071CE	Pieter Cornelisz Hooftstraat 138 1071CE	52,3596464	4,8780727	Residential	1875	60	2100
140	1071CE	Pieter Cornelisz Hooftstraat 140 1071CE	52,359675	4,8779855	Residential	1875	70	2000

142	1071CE	Pieter Cornelisz Hooftstraat 142 1071CE	52,3596669	4,8778796	Residential	1875	60	2100
59	1071XB	Ruysdaelstraat 59 1071XB	52,3534847	4,8812204	Residential	1923	100	4000
61	1071XB	Ruysdaelstraat 61 1071XB	52,3534614	4,881101	Residential	1923	80	3200
63	1071XB	Ruysdaelstraat 63 1071XB	52,3534681	4,8809953	Residential	1923	80	3200
65	1071XB	Ruysdaelstraat 65 1071XB	52,3534296	4,8809374	Residential	1923	40	1600
71	1071XB	Ruysdaelstraat 71 1071XB	52,3532953	4,8802534	Residential	1905	120	4800
73	1071XB	Ruysdaelstraat 73 1071XB	52,3532413	4,8799941	Residential	1983	360	11500
75	1071XB	Ruysdaelstraat 75 1071XB	52,3532386	4,8799813	Residential	2018	360	9100
77	1071XB	Ruysdaelstraat 77 1071XB	52,353222	4,8799014	Residential	2018	165	4500
79	1071XB	Ruysdaelstraat 79 1071XB	52,3532064	4,8798268	Residential	2018	100	3500
81	1071XC	Ruysdaelstraat 81 1071XC	52,3531918	4,8797564	Residential	2018	120	4200
83	1071XC	Ruysdaelstraat 83 1071XC	52,353179	4,8796949	Residential	2018	120	4200
85	1071XC	Ruysdaelstraat 85 1071XC	52,3531534	4,8795722	Residential	2018	245	5700
87	1071XC	Ruysdaelstraat 87 1071XC	52,3531415	4,879515	Residential	2018	207,5	3800
89	1071XC	Ruysdaelstraat 89 1071XC	52,3531259	4,8794404	Residential	2018	155	5800
91	1071XC	Ruysdaelstraat 91 1071XC	52,3531094	4,8793609	Residential	1905	80	2800
93	1071XC	Ruysdaelstraat 93 1071XC	52,3531184	4,8793303	Residential	1905	95	3300
95	1071XC	Ruysdaelstraat 95 1071XC	52,3530751	4,879198	Residential	1905	80	2800
97	1071XC	Ruysdaelstraat 97 1071XC	52,3530564	4,8791119	Residential	1905	125	3600
99	1071XC	Ruysdaelstraat 99 1071XC	52,3530405	4,8790392	Residential	1906	95	2900
88	1071XH	Ruysdaelstraat 88 1071XH	52,3536669	4,8808844	Residential	1922	105	2400
90	1071XH	Ruysdaelstraat 90 1071XH	52,3536797	4,8808733	Residential	1922	75	2400
92	1071XH	Ruysdaelstraat 92 1071XH	52,3536174	4,8807113	Residential	1909	225	7300
96	1071XH	Ruysdaelstraat 96 1071XH	52,3535924	4,8806177	Residential	1906	60	2200
100	1071XH	Ruysdaelstraat 100 1071XH	52,3535672	4,8804849	Residential	1906	60	2100
102	1071XH	Ruysdaelstraat 102 1071XH	52,3535525	4,8804097	Residential	1906	90	2800
104	1071XH	Ruysdaelstraat 104 1071XH	52,3535387	4,8803388	Residential	1905	40	1600
106	1071XH	Ruysdaelstraat 106 1071XH	52,3535241	4,8802636	Residential	1905	40	1600

108	1071XH	Ruysdaelstraat 108 1071XH	52,3535033	4,8801618	Residential	1907	130	3900
110	1071XH	Ruysdaelstraat 110 1071XH	52,353482	4,8799882	Residential	1907	80	2800
112	1071XH	Ruysdaelstraat 112 1071XH	52,3534488	4,8799029	Residential	1907	60	2100
114	1071XJ	Ruysdaelstraat 114 1071XJ	52,3534338	4,8798278	Residential	1905	110	3200
116	1071XJ	Ruysdaelstraat 116 1071XJ	52,3534173	4,8797487	Residential	1905	125	3800
118	1071XJ	Ruysdaelstraat 118 1071XJ	52,3533999	4,8796654	Residential	1907	90	2500
120	1071XJ	Ruysdaelstraat 120 1071XJ	52,3533816	4,8795774	Residential	1907	80	2800
122	1071XJ	Ruysdaelstraat 122 1071XJ	52,3533472	4,8794778	Residential	1907	75	2200
124	1071XJ	Ruysdaelstraat 124 1071XJ	52,3533704	4,8794111	Residential	1907	80	2800
126	1071XJ	Ruysdaelstraat 126 1071XJ	52,3533055	4,8792323	Residential	1907	80	2800
1	1075KJ	Pieter Lastmankade 1 1075KJ	52,3507563	4,8642995	Residential	1925	20	700
2	1075KJ	Pieter Lastmankade 2 1075KJ	52,3507869	4,8641812	Residential	1925	80	2800
3	1075KJ	Pieter Lastmankade 3 1075KJ	52,3507058	4,8641138	Residential	1925	40	1400
4	1075KJ	Pieter Lastmankade 4 1075KJ	52,3506757	4,8640032	Residential	1925	60	2100
5	1075KJ	Pieter Lastmankade 5 1075KJ	52,3507096	4,8638323	Residential	1925	40	1400
6	1075KJ	Pieter Lastmankade 6 1075KJ	52,350635	4,8638503	Residential	1925	40	1600
7	1075KJ	Pieter Lastmankade 7 1075KJ	52,3506994	4,8635828	Residential	1926	40	1600
8	1075KJ	Pieter Lastmankade 8 1075KJ	52,3506746	4,8635889	Residential	1926	40	1400
29	1075KK	Pieter Lastmankade 29 1075KK	52,3506196	4,8630742	Residential	1925	140	3200
30	1075KK	Pieter Lastmankade 30 1075KK	52,3505475	4,8627785	Residential	1924	547,5	13100
31	1075KK	Pieter Lastmankade 31 1075KK	52,3504485	4,8625758	Residential	1922	80	2800
32	1075KK	Pieter Lastmankade 32 1075KK	52,3503124	4,8626121	Residential	1922	80	2800
33	1075KK	Pieter Lastmankade 33 1075KK	52,3504456	4,8623424	Residential	1922	125	3700
34	1075KK	Pieter Lastmankade 34 1075KK	52,3504146	4,8621973	Residential	1922	140	4000
35	1075KL	Pieter Lastmankade 35 1075KL	52,3502257	4,862287	Residential	1922	95	3100
36	1075KL	Pieter Lastmankade 36 1075KL	52,3501693	4,8620744	Residential	1922	110	3000
37	1075KL	Pieter Lastmankade 37 1075KL	52,3502199	4,8619188	Residential	1922	140	3200
38	1075KL	Pieter Lastmankade 38 1075KL	52,3500976	4,8618039	Residential	1922	185	3200
39	1075KL	Pieter Lastmankade 39 1075KL	52,3500796	4,8617352	Residential	1922	185	3200

40	1075KM	Pieter Lastmankade 40 1075KM	52,3500791	4,8610493	Residential	1921	110	3000
41	1075KM	Pieter Lastmankade 41 1075KM	52,3499194	4,8611258	Residential	1921	80	2800
42	1075KM	Pieter Lastmankade 42 1075KM	52,3498877	4,8610473	Residential	1921	80	2800
43	1075KM	Pieter Lastmankade 43 1075KM	52,3497731	4,8606772	Residential	1921	20	700
44	1075KM	Pieter Lastmankade 44 1075KM	52,3496647	4,8607469	Residential	1921	55	1500
45	1075KM	Pieter Lastmankade 45 1075KM	52,3496812	4,8606092	Residential	1926	55	1500
46	1075KM	Pieter Lastmankade 46 1075KM	52,3495755	4,860478342	Residential	1926	35	800
47	1075KM	Pieter Lastmankade 47 1075KM	52,3496442	4,8605847	Residential	1926	35	800
48	1075KM	Pieter Lastmankade 48 1075KM	52,3496248	4,8605554	Residential	1926	35	800
49	1075KM	Pieter Lastmankade 49 1075KM	52,349593	4,8604942	Residential	1926	35	800
50	1075KN	Pieter Lastmankade 50 1075KN	52,3496249	4,8605494	Residential	1926	20	700
51	1075KN	Pieter Lastmankade 51 1075KN	52,3496107	4,860547	Residential	1926	20	700
52	1075KN	Pieter Lastmankade 52 1075KN	52,3496017	4,8605325	Residential	1926	20	700
53	1075KN	Pieter Lastmankade 53 1075KN	52,3495926	4,8605179	Residential	1926	20	700
54	1075KN	Pieter Lastmankade 54 1075KN	52,3495836	4,8605033	Residential	1926	20	700
55	1075KN	Pieter Lastmankade 55 1075KN	52,3495715	4,8604892	Residential	1926	35	800
56	1075KN	Pieter Lastmankade 56 1075KN	52,3495566	4,860489	Residential	1926	35	800
57	1075KN	Pieter Lastmankade 57 1075KN	52,3495475	4,8604744	Residential	1926	35	800
58	1075KN	Pieter Lastmankade 58 1075KN	52,3494481	4,8603583	Residential	1926	35	800
59	1075KN	Pieter Lastmankade 59 1075KN	52,3494391	4,8603436	Residential	1926	35	800
60	1075KN	Pieter Lastmankade 60 1075KN	52,34943	4,8603289	Residential	1926	35	800
61	1075KN	Pieter Lastmankade 61 1075KN	52,349421	4,8603145	Residential	1926	20	700
62	1075KN	Pieter Lastmankade 62 1075KN	52,3494119	4,8602999	Residential	1926	57,5	800
63	1075KN	Pieter Lastmankade 63 1075KN	52,34929	4,8601086	Residential	1926	20	700
64	1075KN	Pieter Lastmankade 64 1075KN	52,3492296	4,860103	Residential	1926	20	700
65	1075KN	Pieter Lastmankade 65 1075KN	52,3492404	4,8601258	Residential	1926	20	700
66	1075KN	Pieter Lastmankade 66 1075KN	52,3492313	4,8601112	Residential	1926	35	800
67	1075KN	Pieter Lastmankade 67 1075KN	52,3491494	4,8600497	Residential	1926	20	700
68	1075KN	Pieter Lastmankade 68 1075KN	52,3491226	4,8599819	Residential	1926	20	1400

69	1075KN	Pieter Lastmankade 69 1075KN	52,3491432	4,8601541	Residential	1926	20	1400
70	1075KN	Pieter Lastmankade 70 1075KN	52,3490108	4,8598916	Residential	1922	20	700
150	1075KT	Pieter Lastmankade 150 1075KT	52,3487809	4,8596363	Residential	1922	20	700
151	1075KT	Pieter Lastmankade 151 1075KT	52,3487771	4,8596157	Residential	1922	20	700
152	1075KT	Pieter Lastmankade 152 1075KT	52,3487609	4,8596108	Residential	1922	20	700
153	1075KT	Pieter Lastmankade 153 1075KT	52,3487294	4,859574	Residential	1922	20	700
154	1075KT	Pieter Lastmankade 154 1075KT	52,3487131	4,8595508	Residential	1922	20	700
155	1075KT	Pieter Lastmankade 155 1075KT	52,3486729	4,8595022	Residential	1922	20	700
156	1075KT	Pieter Lastmankade 156 1075KT	52,3486493	4,859465	Residential	1922	20	700
157	1075KT	Pieter Lastmankade 157 1075KT	52,3486311	4,8594306	Residential	1922	20	700
158	1075KT	Pieter Lastmankade 158 1075KT	52,3486064	4,859412	Residential	1922	20	700
159	1075KT	Pieter Lastmankade 159 1075KT	52,3485694	4,8593732	Residential	1922	20	700
160	1075KT	Pieter Lastmankade 160 1075KT	52,3485461	4,8593541	Residential	1922	20	700
161	1075KT	Pieter Lastmankade 161 1075KT	52,3485352	4,8593273	Residential	1922	20	700
162	1075KT	Pieter Lastmankade 162 1075KT	52,3485194	4,8593164	Residential	1922	57,5	800
163	1075KT	Pieter Lastmankade 163 1075KT	52,348481	4,859272	Residential	1922	57,5	800
164	1075KT	Pieter Lastmankade 164 1075KT	52,3484592	4,8592421	Residential	1922	20	700
165	1075KT	Pieter Lastmankade 165 1075KT	52,3484387	4,8592165	Residential	1922	35	800
166	1075KT	Pieter Lastmankade 166 1075KT	52,3484122	4,8591926	Residential	1922	20	700
167	1075KT	Pieter Lastmankade 167 1075KT	52,3483798	4,8591535	Residential	1922	35	800
168	1075KT	Pieter Lastmankade 168 1075KT	52,3483607	4,8591353	Residential	1922	20	700
169	1075KT	Pieter Lastmankade 169 1075KT	52,3483317	4,8591175	Residential	1922	20	700
170	1075KT	Pieter Lastmankade 170 1075KT	52,3483136	4,8591	Residential	1922	20	700
171	1075KT	Pieter Lastmankade 171 1075KT	52,3483069	4,8590909	Residential	1922	57,5	800
172	1075KT	Pieter Lastmankade 172 1075KT	52,348082	4,8588154	Residential	1921	20	700
173	1075KT	Pieter Lastmankade 173 1075KT	52,3480981	4,8588013	Residential	1921	35	800
174	1075KT	Pieter Lastmankade 174 1075KT	52,3480878	4,8588236	Residential	1921	20	700
175	1075KT	Pieter Lastmankade 175 1075KT	52,3480887	4,8588216	Residential	1921	57,5	800
176	1075KT	Pieter Lastmankade 176 1075KT	52,3480386	4,8587672	Residential	1921	20	700

177	1075KT	Pieter Lastmankade 177 1075KT	52,3480454	4,8587526	Residential	1921	35	800
178	1075KT	Pieter Lastmankade 178 1075KT	52,3480358	4,8587548	Residential	1921	20	700
179	1075KT	Pieter Lastmankade 179 1075KT	52,3480411	4,8587617	Residential	1921	57,5	800
180	1075KT	Pieter Lastmankade 180 1075KT	52,3480068	4,8587346	Residential	1921	20	700
181	1075KT	Pieter Lastmankade 181 1075KT	52,3479712	4,8586902	Residential	1921	20	700
182	1075KT	Pieter Lastmankade 182 1075KT	52,3480246	4,8587196	Residential	1921	20	700
183	1075KT	Pieter Lastmankade 183 1075KT	52,348007	4,8587305	Residential	1921	20	700
184	1075KT	Pieter Lastmankade 184 1075KT	52,3479381	4,8586618	Residential	1921	57,5	1000
185	1075KT	Pieter Lastmankade 185 1075KT	52,3479564	4,8586417	Residential	1921	57,5	1000
186	1075KT	Pieter Lastmankade 186 1075KT	52,3479429	4,8586262	Residential	1921	35	1000
187	1075KT	Pieter Lastmankade 187 1075KT	52,347939	4,8586614	Residential	1921	57,5	1000
188	1075KT	Pieter Lastmankade 188 1075KT	52,3478773	4,8585857	Residential	1921	20	700
189	1075KT	Pieter Lastmankade 189 1075KT	52,347878	4,8585854	Residential	1921	20	700
190	1075KT	Pieter Lastmankade 190 1075KT	52,3478746	4,8585272	Residential	1921	20	700
191	1075KT	Pieter Lastmankade 191 1075KT	52,3478763	4,8585855	Residential	1921	20	700
192	1075KT	Pieter Lastmankade 192 1075KT	52,3478673	4,8585298	Residential	1921	20	700
193	1075KT	Pieter Lastmankade 193 1075KT	52,3478882	4,8584944	Residential	1921	20	700
194	1075KT	Pieter Lastmankade 194 1075KT	52,3478629	4,858517	Residential	1921	20	700
195	1075KT	Pieter Lastmankade 195 1075KT	52,3478659	4,858529	Residential	1921	20	700
196	1075KT	Pieter Lastmankade 196 1075KT	52,3478448	4,8584132	Residential	1921	20	700
197	1075KT	Pieter Lastmankade 197 1075KT	52,3478605	4,8583923	Residential	1921	20	700
198	1075KT	Pieter Lastmankade 198 1075KT	52,3478552	4,858329	Residential	1921	20	700
199	1075KT	Pieter Lastmankade 199 1075KT	52,3478519	4,8584073	Residential	1921	20	700
200	1075KT	Pieter Lastmankade 200 1075KT	52,3478348	4,8583537	Residential	1921	57,5	800
201	1075KT	Pieter Lastmankade 201 1075KT	52,347826	4,8583424	Residential	1921	57,5	800
202	1075KT	Pieter Lastmankade 202 1075KT	52,3478452	4,8583415	Residential	1921	20	700
203	1075KT	Pieter Lastmankade 203 1075KT	52,3478505	4,8583359	Residential	1921	20	700
204	1075KT	Pieter Lastmankade 204 1075KT	52,3478218	4,8582318	Residential	1921	20	700
205	1075KT	Pieter Lastmankade 205 1075KT	52,3478123	4,8582133	Residential	1921	20	700

206	1075KT	Pieter Lastmankade 206 1075KT	52,3478836	4,8582241	Residential	1921	20	700
207	1075KT	Pieter Lastmankade 207 1075KT	52,347819	4,8582258	Residential	1921	20	700
3	1075LA	Karperweg 3 1075LA	52,348597	4,8569486	Residential	1929	60	2100
5	1075LA	Karperweg 5 1075LA	52,3485899	4,8568042	Residential	1929	117,5	2900
7	1075LA	Karperweg 7 1075LA	52,3485899	4,8568042	Residential	1929	97,5	2200
9	1075LA	Karperweg 9 1075LA	52,3485899	4,8568042	Residential	1929	137,5	3800
11	1075LA	Karperweg 11 1075LA	52,3485899	4,8568042	Residential	1929	95	3000
40	1075LC	Karperweg 40 1075LC	52,3477513	4,8542028	Residential	1926	20	700
15	1075LB	Karperweg 15 1075LB	52,3481542	4,8560613	Residential	1938	35	800
17	1075LB	Karperweg 17 1075LB	52,3483233	4,856042	Residential	1938	35	800
37	1075LB	Karperweg 37 1075LB	52,3475774	4,8543795	Residential	1939	35	800
43	1075LB	Karperweg 43 1075LB	52,3471909	4,8540449	Residential	1935	20	700
45	1075LB	Karperweg 45 1075LB	52,3472458	4,8538291	Residential	1935	57,5	800
47	1075LB	Karperweg 47 1075LB	52,347333	4,8536763	Residential	1935	20	700
1	1077RC	Titianstraat 1 1077RC	52,3496018	4,8707622	Residential	1929	57,5	340
3	1077RC	Titianstraat 3 1077RC	52,3496076	4,8706577	Residential	1929	57,5	440
5	1077RC	Titianstraat 5 1077RC	52,3496007	4,870498	Residential	1929	57,5	440
7	1077RC	Titianstraat 7 1077RC	52,3496002	4,8703806	Residential	1929	35	427,5
9	1077RC	Titianstraat 9 1077RC	52,3496087	4,8702778	Residential	1929	57,5	440
11	1077RC	Titianstraat 11 1077RC	52,3495992	4,8701605	Residential	1929	57,5	440
13	1077RC	Titianstraat 13 1077RC	52,3496275	4,8700918	Residential	1929	57,5	440
15	1077RD	Titianstraat 15 1077RD	52,3495167	4,8694338	Residential	1928	127,5	995
17	1077RD	Titianstraat 17 1077RD	52,3495097	4,8692436	Residential	1928	105	982,5
19	1077RD	Titianstraat 19 1077RD	52,349545	4,8688478	Residential	1928	150	1007,5
23	1077RE	Titianstraat 23 1077RE	52,3494961	4,8688763	Residential	1928	112,5	985
25	1077RE	Titianstraat 25 1077RE	52,349489	4,8686861	Residential	1928	90	922,5
27	1077RE	Titianstraat 27 1077RE	52,3495561	4,8685172	Residential	1928	127,5	995
29	1077RG	Titianstraat 29 1077RG	52,3495211	4,8679433	Residential	1928	127,5	1195
31	1077RG	Titianstraat 31 1077RG	52,3495152	4,867767	Residential	1928	172,5	1220

33	1077RG	Titianstraat 33 1077RG	52,3495109	4,8676383	Residential	1928	92,5	867,5
35	1077RG	Titianstraat 35 1077RG	52,3495069	4,8675213	Residential	1928	115	880
18	1077RH	Titianstraat 18 1077RH	52,3498179	4,8695711	Residential	1927	185	1335
20	1077RH	Titianstraat 20 1077RH	52,3498108	4,8693802	Residential	1927	77,5	657,5
22	1077RH	Titianstraat 22 1077RH	52,3498063	4,8692601	Residential	1928	77,5	757,5
26	1077RH	Titianstraat 26 1077RH	52,3498095	4,8688148	Residential	1928	70	655
28	1077RH	Titianstraat 28 1077RH	52,3497836	4,8686449	Residential	1928	92,5	667,5
30	1077RJ	Titianstraat 30 1077RJ	52,3497821	4,8686563	Residential	1928	115	880
32	1077RJ	Titianstraat 32 1077RJ	52,3497755	4,8684262	Residential	1928	70	855
34	1077RJ	Titianstraat 34 1077RJ	52,3497722	4,8683385	Residential	1928	115	880
36	1077RJ	Titianstraat 36 1077RJ	52,3496204	4,8682399	Residential	1928	115	880
38	1077RK	Titianstraat 38 1077RK	52,3496156	4,8681045	Residential	1928	172,5	1220
40	1077RK	Titianstraat 40 1077RK	52,3497704	4,8679286	Residential	1928	92,5	667,5
42	1077RK	Titianstraat 42 1077RK	52,3497073	4,8678062	Residential	1928	92,5	767,5
44	1077RK	Titianstraat 44 1077RK	52,3497545	4,8677652	Residential	1928	115	880
46	1077RL	Titianstraat 46 1077RL	52,3497505	4,8676469	Residential	1928	92,5	667,5
48	1077RL	Titianstraat 48 1077RL	52,3497471	4,8675445	Residential	1927	92,5	667,5
50	1077RL	Titianstraat 50 1077RL	52,3497423	4,8674023	Residential	1927	70	855
52	1077RL	Titianstraat 52 1077RL	52,3497141	4,8673264	Residential	1927	115	880

Appendix B

Street	Postcode	Full Address	Material	Function	Quantity kg	Length m	Installation date	Expected availability
Pieter Cornelisz Hooftstraat	1070 BL	Pieter Cornelisz Hooftstraat 1071 BL	Aluminum	Power cable	1158,3	500	2012	2042-2052
Pieter Cornelisz Hooftstraat	1071 BM	Pieter Cornelisz Hooftstraat 1071 BM	Aluminum	Power cable			2012	2042-2052
Pieter Cornelisz Hooftstraat	1071 BN	Pieter Cornelisz Hooftstraat 1071 BN	Aluminum	Power cable			2012	2042-2052
Pieter Cornelisz Hooftstraat	1071 BP	Pieter Cornelisz Hooftstraat 1071 BP	Aluminum	Power cable			2012	2042-2052
Pieter Cornelisz Hooftstraat	1071 BR	Pieter Cornelisz Hooftstraat 1071 BR	Aluminum	Power cable			2012	2042-2052
Pieter Cornelisz Hooftstraat	1071 BS	Pieter Cornelisz Hooftstraat 1071 BS	Aluminum	Power cable			2012	2042-2052
Pieter Cornelisz Hooftstraat	1071 BZ	Pieter Cornelisz Hooftstraat 1071 BZ	Aluminum	Power cable			2012	2042-2052
Pieter Cornelisz Hooftstraat	1071 CA	Pieter Cornelisz Hooftstraat 1071 CA	Aluminum	Power cable			2012	2042-2052
Pieter Cornelisz Hooftstraat	1071 CB	Pieter Cornelisz Hooftstraat 1071 CB	Aluminum	Power cable			2012	2042-2052
Pieter Cornelisz Hooftstraat	1071 CC	Pieter Cornelisz Hooftstraat 1071 CC	Aluminum	Power cable			2012	2042-2052
Pieter Cornelisz Hooftstraat	1071 CD	Pieter Cornelisz Hooftstraat 1071 CD	Aluminum	Power cable			2012	2042-2052
Pieter Cornelisz Hooftstraat	1071 CE	Pieter Cornelisz Hooftstraat 1071 CE	Aluminum	Power cable			2012	2042-2052
Ruysdaelstraat	1071 XB	Ruysdaelstraat 1071 XB	Aluminum	Power cable	1105,45	190	2012	2042-2052

Ruysdaelstraat	1071 XC	Ruysdaelstraat 1071 XC	Aluminum	Power cable			2012	2042-2053
Ruysdaelstraat	1071 XH	Ruysdaelstraat 1071 XH	Aluminum	Power cable			2012	2042-2054
Ruysdaelstraat	1071 XJ	Ruysdaelstraat 1071 XJ	Aluminum	Power cable			2012	2042-2055
Pieter Lastmankade	1075 KJ	Pieter Lastmankade 1075 KJ	Aluminum	Power cable			2003	2033-2043
Pieter Lastmankade	1075 KK	Pieter Lastmankade 1075 KK	Aluminum	Power cable			2003	2033-2043
Pieter Lastmankade	1075 KL	Pieter Lastmankade 1075 KL	Aluminum	Power cable	5635,37	630	2003	2033-2043
Pieter Lastmankade	1075 KM	Pieter Lastmankade 1075 KM	Aluminum	Power cable			2003	2033-2043
Pieter Lastmankade	1075 KN	Pieter Lastmankade 1075 KN	Aluminum	Power cable			2003	2033-2043
Pieter Lastmankade	1075 KT	Pieter Lastmankade 1075 KT	Aluminum	Power cable			2003	2033-2043
Karperweg	1075 LA	Karperweg 1075 LA	Aluminum	Power cable			2003	2033-2043
Karperweg	1075 LC	Karperweg 1075 LC	Aluminum	Power cable	48736,8	310	2003	2033-2044
Karperweg	1075 LB	Karperweg 1075 LB	Aluminum	Power cable			2003	2033-2045
Titianstraat	1077 RC	Titianstraat 1077 RC	Aluminum	Power cable			2012	2042-2052
Titianstraat	1077 RD	Titianstraat 1077 RD	Aluminum	Power cable			2012	2042-2052
Titianstraat	1077 RE	Titianstraat 1077 RE	Aluminum	Power cable			2012	2042-2052
Titianstraat	1077 RG	Titianstraat 1077 RG	Aluminum	Power cable	898,6	260	2012	2042-2052
Titianstraat	1077 RH	Titianstraat 1077 RH	Aluminum	Power cable			2012	2042-2052
Titianstraat	1077 RJ	Titianstraat 1077 RJ	Aluminum	Power cable			2012	2042-2052
Titianstraat	1077 RK	Titianstraat 1077 RK	Aluminum	Power cable			2012	2042-2052
Titianstraat	1077 RL	Titianstraat 1077 RL	Aluminum	Power cable			2012	2042-2052
Pr.Irenestraat		Pr.Irenestraat 1077	Aluminum	Power cable	11380,5	650	2012	2042-2052