Stimulation of urban mining hub realisation in the Netherlands

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Delft University of Technology

Construction Management and Engineering

2024

Delft University of Technology

2024

Stimulation of urban mining hub realisation in the Netherlands

by

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to obtain degree of

Master of Science
in Construction Management and Engineering

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BRINK

I. ACKNOWLEDGEMENTS

This research has been conducted as part of the completion of the master's program Construction Management Engineering at the Delft University of Technology. From October until June, I have been studying the current theoretical and practical insights on urban mining hub realisation in the Netherlands, leading to a step-by-step framework providing the necessary steps and strategies for stimulation of hub development. This thesis is written for all stakeholders involved in construction projects, organisations initiating hub realisation, and anyone interested in and wanting to learn more about the developmental aspects of urban mining hubs.

Before moving over to the report, I would like to thank everyone who has been involved or contributed to the graduation process. At first, I would like to express my gratitude to all members of my graduation committee. In particular, I want to thank Hans and Denise for the time, effort, and energy they have given me throughout the entire process. Besides all your valuable expertise, your supportive attitude and our many laughs during the meetings have made the graduation process an exciting time. Additionally, I would like to thank everyone who participated in this research during the interviews and the experts evaluation. Thank you for your involvement, honest answers, and interesting discussions. Also, I want to express my gratitude to Brink Groep and all colleagues for the collaboration and valuable contributions to the graduation process.

Furthermore, I would like to thank my family and friends, and particularly my boyfriend Bart, who was always available for questions, to hear my story, or to provide a positive pep talk. A grateful acknowledgment to my brother Rocco, whom I could always reach out to for questions, sparring sessions, and good advice, helping me think beyond the boundaries of my own thoughts. Also, I would like to express deep appreciations to my parents, Myriam and Ronald, for all the support and encouragements during both my bachelor's and master's studies. I am looking forward to what the future will bring.

Enjoy reading!

Delft, 2024
Amber van der Mark

II. SUMMARY

The Dutch government aims to achieve a fully circular built environment by 2050, shifting from a linear economy towards a circular economy. To realise this objective, the Transition Agenda outlines a comprehensive strategy including sustainable initiatives like the establishment of construction hubs. These hubs can be divided into circular construction hubs (focused on closed-loop material chains and maximising material life spans) and non-circular construction hubs (focussing on efficient transportation by minimising transportation movements). Only a small fraction of the construction and demolition waste generated by the Dutch construction sector is currently reused in new construction projects. Increasing this fraction is essential for establishing a circular built environment. As timelines of demolition and construction projects are often not aligned, circular construction hubs can play a pivotal role in facilitating material reuse and storage. This study focuses on how the realisation of urban mining hubs in the Netherlands can be stimulated. Based on the theoretical and practical research findings, urban mining hubs are defined as *physical, regional, and collaborative centres that facilitate the sorting, storing, processing, and efficient transportation of reusable and upcyclable building materials and products, extracted from anthropogenic stocks, to construction projects.*

The primary objective of this research is to provide an answer to the main research question, which is formulated as: *How can the realisation of urban mining hubs in the Netherlands be stimulated?* To address the main research question, theoretical data is collected through a systematic literature review supplemented with practical data obtained through semi-structured interviews with key stakeholders in the construction industry, including architects, construction and demolition contractors, engineering consultancy firms, and public organisations (in the role of client and construction owner). By analysing and comparing the current theoretical and practical insights on urban mining hub realisation in the Netherlands, an actionable framework has been developed. The step-by-step framework is assessed through an experts evaluation, resulting in the final framework.

The theoretical research findings outlined, besides the definition of urban mining hubs and the involved stakeholders, the undefined role of hubs within the urban mining process. Urban mining consists of four phases: inventorying potential materials, collection during circular demolition, storage (potentially in a hub), and reuse in new projects. The role of a hub in transitioning secondary materials from the collection to the reuse phase remains unclear. Additionally, the theoretical findings presented both the advantages and disadvantages of urban mining hubs and the urban mining process. Environmental benefits focus on conserving valuable resources and minimising emissions, along with financial advantages by minimising material costs, waste generation and transportation movements. Moreover, this process contributes to social advantages by creating employment opportunities. Despite these benefits, barriers such as insufficient material supply and demand, inventory uncertainties, and insufficient legislation hinder material reuse and hub development. From the practical findings, the correlation between material reuse and the necessity for hubs became apparent: an increase in material reuse corresponds to a greater demand for hubs. Furthermore, the practical findings align and supplement the theoretical findings, identifying three main barriers to hub realisation: practical, financial, and legal. These barriers include challenges in material integration with new projects, perceptions of cost-effectiveness, and existing regulations often leading to a preference for primary materials. Stakeholders acknowledged that adopting a mindset focused on circularity can help overcoming these challenges. While theoretical research emphasised the potential of urban mining hubs, practical findings reveal varied perspectives on their necessity and role, advocating for a network of hubs with diverse functions, with material reuse and efficient transportation as its primary goals. Key features

include assured demand storage, transparent inventory management, and logistical and processing capabilities. Active participation from all organisations within the construction sector is deemed crucial for hub effectiveness.

The findings from the literature review, semi-structured interviews and the experts evaluation have led to a step-by-step framework aiming to simulate urban mining hubs realisation in the Netherlands. The theoretical and practical findings and their comparison form the fundament of the framework. The framework outlines three phases, each defining different steps per stakeholders to stimulate urban mining hub realisation in the Netherlands. The first phase, *initiation* phase, kickstarts a learning process on material reuse and hub development, aiming to stimulate material reuse in projects. The necessary steps per stakeholder primarily rest with the stakeholders themselves and should focus on prioritising innovation and educational advancement within their business models, shifting from a purely profit-oriented mindset to a circular one. Progressing the transition will demand voluntary efforts from private organisations, while other measures can be incentivised or mandated through revised regulations or CO_2-budgets in projects. Public organisations play a crucial role in kickstarting this process by developing concrete circularity strategies, enabling private organisations to align and take necessary actions. Secondly, the *optimisation* phase addresses the gap between secondary material supply and construction demands, requiring an increase in supply, with construction and demolition contractors playing a central role. Architects and engineering consultancy firms must actively seek available secondary materials and integrate them into designs, creating a stable market for secondary materials. Both public organisations and hub initiating organisations have an investigative role in this phase, aiming to optimise the balance between supply and demand and foster material reuse across all phases of the construction cycle. By expanding the supply and diversity of secondary materials and stimulating the demand, the implementation of hubs becomes more needed. In the third phase, the *expansion* phase, the construction sector increasingly adopts and embraces circular practices. To advance the expansion of hub implementation, stakeholders must undertake two pivotal actions. Firstly, it is essential that stakeholders sustain structured and systematic collaboration. Circular purchasing from hubs and stimulating material reuse by requesting it in projects remains important. Active involvement of stakeholders with the hubs ensures consistent supply and stable demand. The second critical action builds on this collaboration, stressing the importance of effective information management throughout the various construction phases involving all relevant parties. After progressing through this third phase, the focus should be on evaluating the impact of a network of diverse hubs and reassessing the individual actions and participation of stakeholders. The network's success and overcoming the *chicken-and-egg problem* depend on stakeholders' commitment to circularity and effective collaboration throughout all three phases.

As urban mining hubs are a relatively novel concept, the scarcity of scientific studies on those hubs and their practices can be considered as a limitation. Also, the limited number of research participants and the incomplete stakeholder representation constrain the findings. Future research should include manufacturers and project developers to enhance understanding of the construction industry's dynamics. Investigating stakeholders individually will yield more stakeholder-specific steps. Moreover, stakeholder recommendations focus on additional research into current calculation methods and norms, tax systems, and Extended Manufacturers Responsibility, as well as the development of a pilot hub. Standardising circular demolition is also recommended to ensure that materials are consistently collected from every project, preventing the waste of valuable resources. The actionable framework of this research can serve as a discussion document to clarify each stakeholder's roles and responsibilities. It is recommended to use this framework to initiate and guide discussions in new projects, among clients and involved stakeholders, and during (internal) strategy formulation sessions.

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1. INTRODUCTION

This chapter will explain the purpose and context of this research and the overall structure of this report. Section 1.1, the problem statement, will discuss the relevance of this research. In Section 1.2, an elaboration will be made on the objective of this study, phrasing the main question and sub-questions. Section 1.3 will outline the scope and relevance of this research, followed by the description of the report's structure in Section 1.4.

1.1. Problem statement

It is well known that the construction industry has a significant impact on the environment. The activities within this sector, like material extraction, manufacturing of construction products and the construction of buildings generate around twenty-five million tonnes of construction and demolition waste a year (Yu, Murat Yazan, Bhochhibhoya, & Volker, 2021). As resources are running out and the impact on the environment needs to be minimised, the construction industry should prioritise durable design, sustainable maintenance, and engage in practices such as reuse, remanufacturing, refurbishing, recycling, and upcycling (Afshari & Górecki, 2019). From the nationwide program Netherlands Circular 2050, the Transition Agenda outlines the strategy for achieving a circular construction economy (Rijksoverheid, 2018). A circular economy (CE) is a business model centred on sustainable development and particularly for the construction sector, on emphasising the reduction of raw material consumption, maximising the lifespan and the recovery of materials (Kirchherr, Reike, & Hekkert, 2017). In 2050, the built environment must be fully circular and to achieve this, sustainable measures need to be taken. A suitable measure within the circular construction economy are circular construction hubs (Rijksoverheid, 2018).

Although the concept of circular construction hubs in the Dutch circular economy has been proposed often in both public policy and private strategies and some initial steps have been taken by companies, this novel concept is not well studied or defined in scientific literature studies (Adams, Osmani, Thorpe, & Thornback, 2017; Tsui, Furlan, Wandl, & Timmeren, 2023). Most research consider improvements in construction and demolition waste generation, which focuses on downcycling (Adams, Osmani, Thorpe, & Thornback, 2017). In addition, significant research gaps exist on the collaboration of stakeholders in innovations in the circular economy in the fragmented construction sector (Gasparri, Arasteh, Kuru, Stracchi, & Brambilla, 2023). Therefore, this research aims to investigate the necessary steps per key stakeholder within the construction sector to stimulate the practical realisation of urban mining hubs in the Netherlands.

1.2. Research objective

The aim of this master's thesis is to offer a comprehensive understanding of both the current theoretical and practical insights into urban mining hub realisation in the Netherlands, and the steps towards their practical realisation. A framework will be developed to integrate these findings into a step-by-step plan incorporating all involved stakeholders to stimulate the realisation of urban mining hubs in the Netherlands. This framework will outline distinct phases and provide clear, actionable steps per stakeholder group across these phases. This development framework can serve as a discussion document for all involved stakeholders and initiating hub developers to clearly understand what steps need to be taken to stimulate urban mining hub realisation in the Netherlands.

1.2.1. Main research question

This research aims to gain a deeper understanding of the steps necessary for the stimulation of urban mining hubs development in the Netherlands. Therefore, the main research question is formulated as follows:

How can the realisation of urban mining hubs in the Netherlands be stimulated?

1.2.2. Sub research questions

In order to address the main research question, sub questions are formed. The first sub question aims to map out the current theoretical insights into urban mining hub development in the Netherlands. This involves conducting a thorough literature review to define and characterise urban mining hubs within the context of the circular economy, laying a solid foundation for the research's scope and the remainder of this research. Secondly, sub question 2 will delve into the current practical insights regarding the realisation of urban mining hubs, through interviews with key stakeholders in the construction industry. Sub question 3 will concentrate on identifying the initial steps crucial for hub realisation in the Netherlands, comparing the theoretical and practical findings to outline where they align, complement, or contradict each other. This comparison will inform the formulation of the initial steps and the development framework aimed at stimulating the realisation of urban mining hubs. Finally, sub question 4 will evaluate the development framework through an experts meeting, facilitating necessary adjustments or additions to the framework.

The sub questions of this research are formulated as follows:

1. What are current theoretical insights on the realisation of urban mining hubs in the Netherlands?
2. What are current practical insights on the realisation of urban mining hubs in the Netherlands?
3. What are the first steps to kick-start the realisation of urban mining hubs in the Netherlands?
4. How do experts evaluate these defined first steps?

1.3. Research scope and relevance

This research will investigate the development of circular construction hubs in the Netherlands as an initiative in the transition towards a circular economy. The focus of this research is specifically on urban mining hubs. The study does not delve into the specific (physical) characteristics of these hubs, but focuses on identifying strategic steps required per stakeholder to stimulate the realisation of urban mining hubs in the Netherlands. The research was initiated in response to a query from Brink Group in Rotterdam. Brink Groep aims to integrate circular construction within its own organisation, services, and projects for various private and public stakeholders. Furthermore, they play an active role in Cirkelstad: a platform developed by and for private and public parties striving for a circular and inclusive construction sector. As Brink Groep acknowledges the importance of construction hubs to close material chains within the construction sector, location analyses are currently being conducted for the province to determine the locations for hubs. However, a significant question remains regarding the initial strategic to drive the development of hubs. Brink Group has the ambition to play a role in this process. As it is essential to thoroughly understand the requirements for the stimulation, this research aims to bridge and compare theoretical and practical findings regarding urban mining hubs in the Netherlands. The goal is to investigate the current status of hub development, understanding and identifying the current barriers preventing hubs from being realised, and determining developmental steps per stakeholder. Due to the complexity of circular construction, the ambition is to develop a visualisation providing insights into the

required steps per involved stakeholder. This visualisation can help Brink Groep (and other organisations) to initiate and guide discussions in new projects, among clients and involved stakeholders, and (internal) strategy formulation sessions.

1.4. Report structure

The structure of this report is as follows: In Chapter 2, the research methodology will be detailed, elaborating on the strategies for gathering, analysing, and evaluating the research data. In Chapter 3, a systematic review for the literature review will be conducted, exploring the current theoretical findings and leading to an answer to sub question 1. The results of the semi-structured interviews will be presented and analysed through thematic analysis in Chapter 4, exploring the current practical findings and addressing sub question 2. Chapter 5 will describe the comparison between theoretical and practical findings along with the step-by-step framework towards urban mining hub realisation, addressing sub question 3. Subsequently, Chapter 6 will discuss the experts evaluation and address sub question 4. Following this, Chapter 7 will provide the discussion, leading to the conclusion in Chapter 8, which will answer the main research question. Chapter 9 will offer the (self)-reflection on the graduation process. Appendix A will outline the distinct organisation-specific questions formulated for the semi-structured interviews.

2. RESEARCH METHODOLOGY

This chapter will discuss the research methodology of this thesis consisting of data gathering, analysis, and evaluation. In the first step, two methodologies for data gathering were employed. Firstly, a systematic review as detailed by Wright, Brand, Richard, Dunn, and Spindler (2007) and Templier and Pare (2015) was utilised to obtain theoretical findings. Subsequently, semi-structured interviews were conducted to collect practical data from key stakeholders in the construction industry. The framework by Kallio et al. (2016) served as the basis of the semi-structured interviews. Secondly, the practical data was analysed using thematic analysis, following the six-phase framework of Braun and Clarke (2006). The third step of the research methodology involved evaluating the research deliverable through an experts meeting.

Section 2.1 will present two strategies for data gathering, beginning with an explanation of the literature review approach, followed by the semi-structured interview method. Subsequently, Section 2.2 will elaborate on the data analysis strategy: thematic analysis. Section 2.3 will provide clarification of the experts evaluation method utilised to evaluate the research deliverable. Finally, Section 2.4 will outline details on the software used for this thesis, while Section 2.5 will describe the research deliverable: the step-by-step framework for stimulating urban mining hub realisation.

2.1. Data gathering

For this research, data was collected through a literature review and interviews. This section will describe how relevant (scientific) research was gathered and analysed through a systematic review in Section 2.1.1, followed by the approach for conducting semi-structured interviews in Section 2.1.2. Systematic review of current literature studies was used to build a comprehensive picture of current perspectives on urban mining hub (development) and provided the basis for semi-structured interviews (Kallio, Pietilä, Johnson, & Kangasniemi, 2016). Semi-structured interviews were conducted with key stakeholders to further explore the practical side of the development of urban mining hubs and to identify problems, motivations, and limitations. In addition, to conduct semi-structured interviews properly, a certain level of knowledge about the research topic was required.

2.1.1. Systematic review

For the first part of data gathering, the systematic review method as detailed by Wright, Brand, Richard, Dunn and Spindler (2007) and Templier and Pare (2015) was utilised. Studies included in this research were screened by title and abstract and had to (a) be published in primary journals or practical sources in case scientific research was limited and (b) be published in Dutch, German or English. Studies were excluded when (a) similar results or information was already obtained in other articles, (b) the scope was irrelevant or too small to be applicable to this research study, and (c) full text was not available. A deliberate decision was made to not utilise too many exclusion criteria considering the novelty of the phenomenon and to prevent the exclusion of potentially valuable articles in advance.

To find relevant references, the following search engines were used: ResearchGate, Google Scholar, ScienceDirect, supplemented by practical references from Google. Additionally, references of articles used in this research were also examined.

The following key words and combinations of search terms were chosen and employed due to their relevance to the research question. To conduct research on the current state and development of urban mining hubs, clarity on the definition of an urban mining hub was essential. Thus, terms like *circular construction hubs* or *circular material hubs* were selected.

Secondly, to comprehend the broader context of urban mining hubs, including their relationship with the circular economy and involved stakeholders, terms such as *circular economy relevance/initiatives/strategy/stakeholders* were employed. Building upon this, to dive deeper into the functioning of a hub and the (individual) steps of the urban mining process terms as *functioning/steps of circular construction hubs* were utilised. Moreover, examining the benefits, limitations, potential, and relevance of urban mining hubs through terms like *urban mining hubs benefits/limitations/potential/relevance* brought clarity to the motivations and necessary steps various stakeholders must undertake to stimulate the development of urban mining hubs.

For an overview of the search terms, see below:

1. Circular construction hubs or circular material hubs;
2. Circular economy relevance, initiatives, strategy, stakeholders;
3. Urban mining hubs, benefits, limitations, potential, relevance;
4. Functioning, steps of circular construction hubs.

2.1.2. Semi-structured interviews

To obtain practical insights on the development of urban mining hubs in the Netherlands, semi-structured interviews were conducted with key stakeholders in the construction industry. Interviews are recommended for qualitative research topics which are relatively unexplored (Jain, 2021; Swedberg, 2020). Surveys did not appear suitable for this topic as the research involves a novel concept with many unknown aspects (Jain, 2021). The aim was to obtain as many perspectives from stakeholders as possible without prefilling them through surveys. Semi-structured interviews provide ample space for both the interviewer and the interviewee to delve more extensively into a question or answer (Galletta & Cross, 2013) and offer more personalised exchange of information, as compared to surveys (Jain, 2021). Furthermore, this method enables the possibility to improvise follow-up questions based on the interviewee's responses for increased clarification (Kallio, Pietilä, Johnson, & Kangasniemi, 2016; Rubin & Rubin, 2012). This was desirable to achieve a comprehensive overview of the prospects of urban mining hubs in the Netherlands.

Utilising semi-structured interviews demands an understanding of the research topic as that provides the conceptual basis for the interview questions (Kelly, 2010; Wengraf, 2001). As it is also important that the interviewees are related to the research topic, based on their theoretical relevance, the to be interviewed stakeholders were derived from the literature review (DiCicco-Bloom & Crabtree, 2006; Weis & Willems, 2017). As the quality of data is the measurement of its value, the sample size of interviewees should not be too large; risks of cluttering and unnecessary information will otherwise arise (Guest, Bunce, & Johnson, 2006; Marshall, Cardon, Poddar, & Fontenot, 2013; Mason, 2010; Sandelowski, 1995). Given the limited timespan for this master's research, two participants per stakeholder group were interviewed.

An interview guide was formulated following the framework created by Kallio et al. (2016) (see Figure 1), encompassing questions based on the themes and knowledge gaps resulting from the literature review (Kallio, Pietilä, Johnson, & Kangasniemi, 2016; Taylor, 2005). Utilising a semi-structured interview guide increases the credibility, confirmability, and dependability and therefore overall trustworthiness of qualitative research (Kallio, Pietilä, Johnson, & Kangasniemi, 2016).

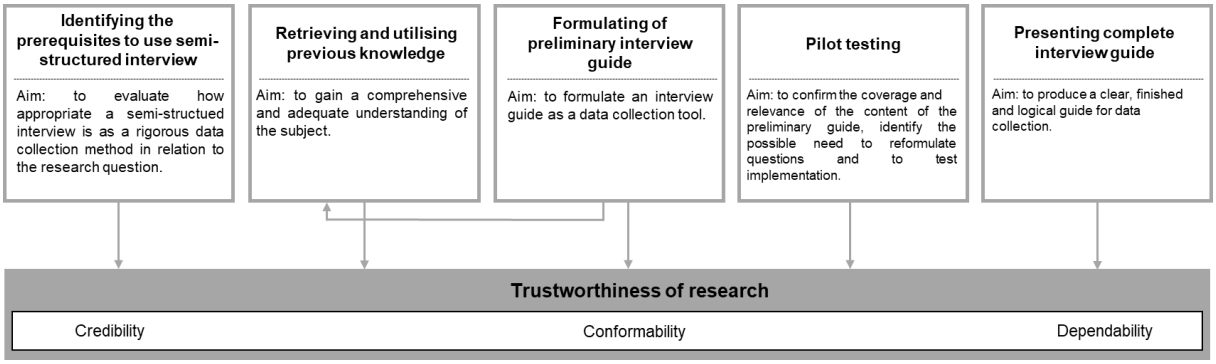

Figure 1. Framework of Kallio et al. (2016) for the development of a qualitative semi-structured interview guide.

Prior to the process of conducting semi-structured interviews, a data management plan (DMP) was established. This plan outlined how data was collected, managed, and stored during the research, and eventually shared after the research. Since this study involves human research subjects, approval from the Human Research Ethics Committee was also required. For this approval, a risk assessment strategy was conducted and submitted. Both steps had to be completed before potential participants were involved in the research. Moreover, a consent form was prepared for gaining consent from each participant to record the interview and to analyse and incorporate the results into the report. The interviews were mainly conducted in person during the months of December 2023 and January 2024.

2.2. Data analysis

The results of the semi-structured interviews were analysed through the thematic analysis method. Thematic analysis is a qualitative research method and according to Clarke and Braun (2016) thematic analysis can be used to identify patterns within and across data in relation to participants' lived experience, views and perspectives, and behaviour and practices. This method can be used in large (more than 60 interviews) and small (1-2 interviews) data sets making it applicable for different types of research (Clarke & Braun, 2016).

The thematic analysis process consists of a systematic iterative procedure to generate codes and themes from data sets. Codes represent small topics capturing interesting features relevant for the research question. In contrast, themes capture the overarching patterns constructed from codes. Thematic analysis not only summarises data sets but also identify and interprets key features in order to enable answering the research questions (Maguire & Delahunt, 2017). Braun and Clarke (2006) distinguish theoretical (top-down) and inductive (bottom-up) thematic analysis. Given exploratory nature of this research, inductive thematic analysis with open coding was used.

Braun and Clarke (2006) provide a clear and useful six-phase framework to conduct thematic analysis (Maguire & Delahunt, 2017). This framework was used for this research and is depicted in Table 1.

Table 1. Thematic analysis framework including phases and procedures (Braun & Clarke, 2006).

	PHASE	PROCEDURE
1.	Become familiar with the data	Transcribe data from audio files, reading and re-reading the interviews and develop initial codes.
2.	Generate initial codes	Analyse interviews in random order utilising open coding. If new codes are created during the analysis process, previous interviews will be revisited with the new codes, as part of the iterative process. Marking interesting quotes per codes across the different data sets.
3.	Search for themes	Revise and combine codes and assemble potential themes. Themes are characterised by its significance.
4.	Review themes	Review, modify and develop initial themes and generate a thematic map.
5.	Define themes	Revise themes by generating clear names identifying the essence of the theme.
6.	Produce report	Analyse final themes and coding and develop the report.

2.3. Data evaluation

As described previously, in this research a variety of steps were taken to ensure the quality and validity of the research and its outcomes. The in-depth description, explanation and justification of the methodology and extensive documentation to this research (including the interview guide and thematic analysis documentation) contributed to the transparency and intersubjectively verifiability of this research (Kitto, Chesters, & Grbich, 2008; Weis & Willems, 2017). Furthermore, utilising an interview guide developed following the framework as described in Section 2.1.2 increased the credibility, confirmability, and dependability and therefore overall trustworthiness of qualitative research (Kallio, Pietilä, Johnson, & Kangasniemi, 2016).

In addition, an experts evaluation was conducted to assess and evaluate the research findings on the first steps to kick-start urban mining hubs development in the Netherlands. Experts evaluations are utilised diversely, particularly for evaluating novel models or factors (Szwed, 2016; Mohd Idros, Mohamed, & Jenal, 2020). From an academic viewpoint, knowledge from experts is considered a valuable source of information (Veen, Stoel, Zondervan-Zwijnenburg, & van de Schoot, 2017). The evaluation of research outcomes entails engaging experts to verify the results on accuracy and comprehensiveness. The research outcomes should be aligned with the research objectives (de Jongh, Larney, Mare, van Vuuren, & Verster, 2017). There is no specific description on how experts evaluation techniques should be applied, fitting well with the novelty of this research topic. Literature studies suggest varying minimum numbers of involved experts, ranging from two to three compared to a minimum requirement of three experts (Clemen & Winkler, 1999; Hora, 2004; Olson, 2010; Szwed, 2016). In this experts evaluation, four experts were engaged to evaluate the research deliverable.

2.4. Software

In conducting this research, different software was used. The interview audio files were recorded using either a voice recording application or Microsoft Teams and were transcribed in Microsoft Word and manually adjusted if needed. After familiarisation with the data sets, the

initial codes were developed. This was initially being done manually, but eventually, this process was replicated in ATLAS.ti24. This manner served as a double assurance that no data would be lost. Utilising the software of ATLAS.ti24 during the coding phase offered advantages of easy adjustment and rearrangement of quotes, codes, and themes. The final organisation of the themes took place in Microsoft Excel. The step of producing a report and oral presentations occurred using, respectively, Microsoft Word and Microsoft PowerPoint.

2.5. Research deliverable

This research aimed to provide a comprehensively understanding of both the current theoretical and practical insights into urban mining hubs and their developmental steps by integrating all components of the research methodology. The objective was to create a step-by-step plan accessible to all stakeholders, presented in an actionable framework, stimulation urban mining hub realisation in the Netherlands. This framework outlined distinct phases, with defined steps for each stakeholder throughout these phases.

3. EXPLORING THEORY

This chapter will explore and analyse relevant literature research on the subject of circular construction hubs, addressing sub question 1, which is formulated as: *What are current theoretical insights on the realisation of urban mining hubs in the Netherlands?* In Section 3.1, an elaboration is made on the relevance of construction hubs in a circular economy. Section 3.2 will investigate the diverse definitions and types of construction hubs. Section 3.3 will provide an overview of the functioning of urban mining (hubs), followed by the stakeholder identification in Section 3.4. Section 3.5 and Section 3.6 will respectively outline the advantages and disadvantages of urban mining hubs and the answer to the first sub question will be presented in Section 3.7.

3.1. Relevance of circular construction hubs

In the Netherlands, consciousness of environmental issues is growing. Shifting towards a circular economy has never been so prominently placed on the societal agenda (Geissdoerfer, Savaget, Bocken, & Hultink, 2017). From 2023 and onwards, all public procurement will request tenders to be fully circular, except for situations in which this is not (fully) feasible yet. The aim is to achieve fifty percent of the final target by 2030 and attain a fully circular built environment by 2050 (Rijksoverheid, 2018). The public and political debate of circular economy aims to create connections between different territories, e.g., links between production and consumption activities (Bourdin, Galliano, & Gonçalves, 2022). Rijksoverheid (2018) describes circular construction as follows:

> "Circular construction entails developing, utilising, and reusing buildings, areas, and infrastructure without needlessly depleting natural resources, contaminating the living environment, or harming ecosystems. It involves building in an economically responsible manner that enhances the well-being of both humans and animals, both now and in the future" (p. 10).

The recommendations of the Social and Economic Council, the nationwide initiative *The Netherlands Circular in 2050* and the Resource Agreement provided crucial frameworks for the Transition Agenda Circular Construction Economy. The Transition Agenda outlines the strategy to realise a circular construction economy (Rijksoverheid, 2018). Circular economy (CE) is a business model that is aimed at sustainable development and focuses in the construction sector on reducing raw material use, optimising the lifespan of products and materials, and recovering materials and materials (Kirchherr, Reike, & Hekkert, 2017). This type is contradictory to a linear economy, which is dominant to date and often referred to as the 'take, make, dispose'-model. In this model materials are used for construction and disposed at the end of their life cycle (Benachio, do Carmo Duarte Freitas, & Fernando Tavares, 2020). In Figure 2, the difference between the linear and circular economy is shown.

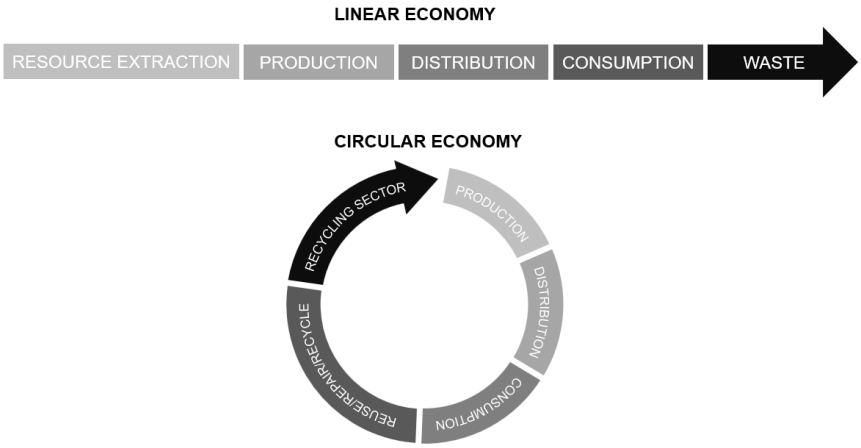

Figure 2. Overview of two different economy model types: linear economy (top) and circular economy (bottom) (Unterfrauner, Voigt, Schrammel, & Menichinelli, 2017).

The concept of the circular economy aims for a significantly reduced and more efficient utilisation of resources (Hanemaaijer, et al., 2023). In a circular economy, the use of finite resources is minimised by prolonging the lifespan of materials or reusing materials, maintaining their value for a longer duration (Schuit, Hoorn, Sorel, & Rood, 2023). The construction sector in the Netherlands generates around twenty-five million tonnes of construction and demolition waste a year, of which ninety-five percent of the materials is downcycled, signifying a loss of material value (Yu, Murat Yazan, Bhochhibhoya, & Volker, 2021). Only a small portion of building sector materials (less than three percent) is reused in new building construction (Schut, Crielaard, & Mesman, 2015), shown in Figure 3. Because materials from demolition projects often cannot be immediately reused in new construction projects, storage facilities are necessary where these materials are (temporarily) kept before transportation to new projects. These storage facilities are referred to as construction hubs and can assist in the pursuit of a circular economy (Loeber & Snoek, 2020; Rijksoverheid, 2018).

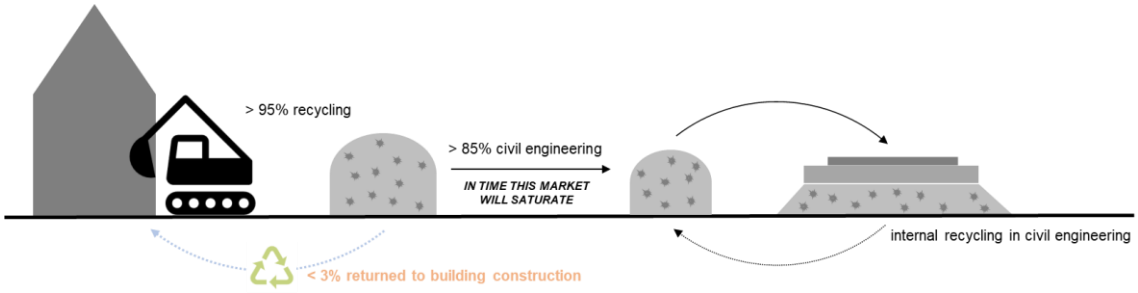

Figure 3. Material flows and quantities from demolition projects (Schut, Crielaard, & Mesman, 2015).

3.2. Definitions of construction hubs

In literature studies, numerous definitions have been provided for distinct types of construction hubs. Košir, Brunova and van Eijk (2021) describes a hub as an entry point (such as centres, platforms, or networks) at national and regional levels for developing and facilitating connections and collaboration among different stakeholders, aiming to stimulate the transition towards a circular economy. The primary distinction among the diverse types of hubs lies in whether they are circular or non-circular. Circular hubs function as logistical points for the storage, processing, and distribution of secondary construction materials. On the other hand, non-circular hubs focus on primary materials (Yang, et al., 2023).

Due to the limited implementation of urban mining hubs to date, the definition of urban mining hubs has much overlap with the definitions of other types of hubs. The key differentiator is that an urban mining hub supports the process urban mining (Tsui, Furlan, Wandl, & Timmeren, 2023), while other types of hubs mainly focus on new produced or virgin mined materials. As shown in Figure 4, virgin mining consists of extraction materials from geological deposits, while urban mining involves the extraction of materials from anthropogenic stocks (Espinoza, Rostek, Loibl, & Stijepic, 2020).

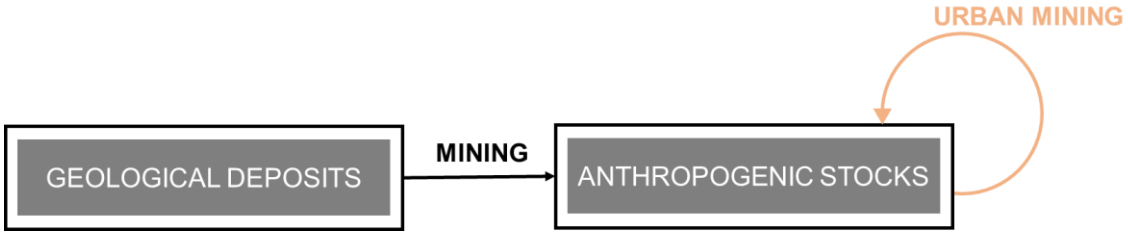

Figure 4. Origin of materials in mining and urban mining (Espinoza, Rostek, Loibl, & Stijepic, 2020).

Aldebij and Dombi (2021) define the process of urban mining as the exploitation of anthropogenic resources to replace and complement the extraction of unrenewable natural resources. According to Blok (2021), urban mining is the process of recovering and reusing a city's materials. In the context of this study, the definition of urban mining emerges from the aforementioned descriptions and is formulated as follows: urban mining is the process of extracting and reusing materials from anthropogenic stocks (cities and urban environments) to replace and complement the extraction of (unrenewable) natural resources.

Section 3.2.1. will provide definitions of distinct types of circular construction hubs, followed by the definitions of different types of non-circular construction hubs in Section 3.2.2.

3.2.1. Circular construction hubs

The first type, urban mining hubs, sort and collect building materials and products from demolition projects that do not need processing before redistribution, like bricks and doors. These hubs typically focus on constructions like residences, offices, and governmental building (Tsui, Furlan, Wandl, & Timmeren, 2023). Residences and office spaces are appealing as they often utilise standardised materials and demand renovations regularly. Governmental buildings benefit from the circular public procurement strategies, enabling more centralised coordination in their construction and demolition processes (Tsui, Furlan, Wandl, & Timmeren, 2023). Furthermore, there are circular building material hubs, which collect, sorts and process non-bulk waste into secondary materials. These materials can be transported to the building sites or back to suppliers (Nieuwhoff, 2022). It is important to note that these hubs distinguish from urban mining hubs in that they process waste into secondary materials, while urban mining hubs concentrate on materials that do not need processing before reuse.

In addition, industry hubs or circular raw material hubs manage bulk construction materials such as asphalt, concrete, sand, gravel, and topsoil and therefore, require extensive space. They often operate at a large scale (provincial or even national level) and are mostly located in existing ports or industrial parks (Tsui, Furlan, Wandl, & Timmeren, 2023; Nieuwhoff, 2022). According to Van Merrënboer, Bastein, Rondaij, and Rabbie (2022), a logistic analysis has determined that there is limited synergy to be gained from a combination of urban mining hubs and industry hubs, which collect, sort, and process both bulk and non-bulk construction and demolition waste. Consequently, aligning the logistical processes of these two streams and, therefore, integrating a raw material hub with an urban mining hub may not yield significant benefits (van Merriënboer, Bastein, Rondaij, & Rabbie, 2022).

Another type of construction hubs are local material banks, mostly focussing on the business-to-consumer market. These hubs work with smaller residue flows, often ignored by larger companies, for small scale private housing renovations, governmental or university buildings or furniture (Tsui, Furlan, Wandl, & Timmeren, 2023).

The last distinct type, craft centres also focus on smaller residue and are mostly located closed to residential areas. The materials, often wood from public buildings, are collected and sold within the same city. Customers of craft centres are private individuals, who use these materials for small-scale projects or follow workshops in these centres (Tsui, Furlan, Wandl, & Timmeren, 2023). Additionally, Werner, Albers, Verschuuren, and Dierdorp (2020) describe a circular craft centre as a local collaborative initiative where a combination of existing (or new) strategies are combined to achieve high-quality product and material reuse, aiming for the maximal preservation of value in a product, raw material, or component. By encouraging collaboration among entities like a recycling centre, a thrift store, and a repair workshop, products and raw materials are kept in use for longer duration.

3.2.2. Non-circular construction hubs

The non-circular construction hubs primarily concentrate on logistics systems within construction projects, leading to significant similarities with the operations of distribution centres. A distribution centre is defined as an important node in a supply network that executes essential functions supporting the material movement: storing goods (temporarily or for an extended period), processing products, breaking down vehicle loads, and assembling shipments (Higginson & Bookbinder, 2005). The non-circular construction hubs often serve similar purposes and are developed due to transportation complexity, in terms of accessibility, time and space, within urban construction projects (Loeber & Snoek, 2020).

Regarding non-circular construction hubs, one type is construction logistics hubs or mandatory building material hubs. These hubs are large-scale facilities where various contractors, suppliers and transporters cooperate to improve the transportation and logistics efficiency within a construction project. Both construction materials and equipment for per construction project are organised through these hubs. Construction flows, such as concrete, are transported directly to the construction site as their point-to-point delivery system is already very efficient. This type of hubs aims, among other objectives, to better organise construction logistics and reduce the influx of construction traffic into the city. Given that these hubs serve a broader network of distribution, accessibility for a wider range of organisations becomes crucial. Therefore, these hubs are often strategically positioned in areas with diverse transportation access options (dos Santos Vieira & Luna, 2016; van Rijn, Rondaij, van Merriënboer, Kin, & Quak, 2020). The smaller scaled version of construction logistics hubs is referred to as construction site hubs, situated on the construction site used for the temporary storage of materials (Nieuwhoff, 2022).

Additionally, within construction logistics hubs, consideration can be given to hubs that leverage various forms of transportation. Multimodal material hubs are locations that, depending on the construction phase, type of transport flow, and construction site, employ alternative modalities alongside roads whenever feasible for transporting construction flows. (van Rijn, Rondaij, van Merriënboer, Kin, & Quak, 2020; Nieuwhoff, 2022).

In Figure 5, the distribution of the different type of hubs are shown. The x-axis represents circularity and the y-as the operating level of the hubs. As this thesis focuses on the circular and non-processing hubs, which operates on a regional level, the urban mining hubs are the applicable type of hubs for this research.

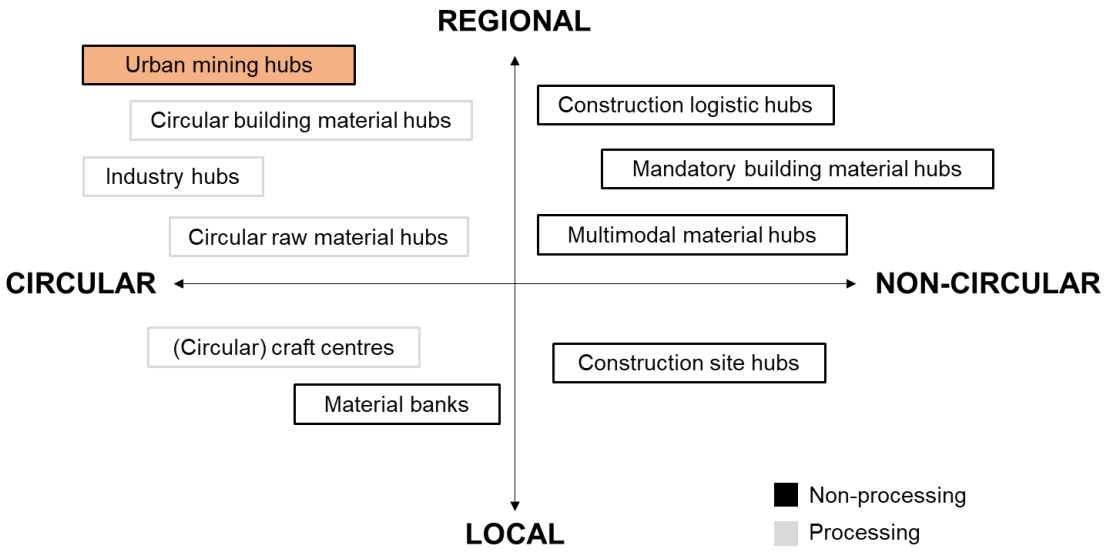

Figure 5. Division of hubs based on level of circularity and operating scale.

3.3. Functioning of urban mining (hubs)

To determine the necessary steps to stimulate urban mining hub realisation in the Netherlands, it is crucial to understand the distinct phases of urban mining, the hub's role within this context, and the involvement of stakeholders at each step. The urban mining process can be categorised into four phases. The initial phase involves inventorying building materials from anthropogenic stock, which will be detailed in Section 3.3.1. The second phase focuses on the collection of these materials, which will be discussed in Section 3.3.2. Section 3.3.3 will describe the third phase, which considers the sorting and storing of the extracted materials in an urban mining hub. In Section 3.3.4, the final phase will outline the (re)distribution of these materials to new destinations (Guldager Jensen, et al., 2019; Tsui, Furlan, Wandl, & Timmeren, 2023).

3.3.1. Phase 1: Inventorying

Towards the end of a building's life cycle or during its service life as a construction is changing in function, full or partial demolition (maintenance, adaptation, replacement) becomes necessary. Formerly, demolition projects were treated as waste management issues, involving disposal (often in landfills) and, at best, recycling, typically through downcycling. However, adopting the cradle-to-cradle perspective suggests that viable materials should consistently circulate (Braungart & McDonough, 2008). After it has been decided by the client or the owner of the construction to conduct circular demolition, the first step involves creating an inventory of all materials within the construction(s) of the demolition project. In the context of urban mining, the focus lies on construction materials and products that are suitable for upcycling or direct reuse. Upcycling involves the process of converting a material or product to increase its quality in their second life (Sung, 2015). Direct reuseable materials do not just pertain to the basic construction materials like steel used in buildings. It also includes wooden beams, glass, copper pipes, aluminium facades, roof tiles, bricks, and doors. Even iron railings from balconies, sanitary facilities, stairs, and window frames are also valuable for urban mining (Blok, 2021).

Developing an inventory requires understanding the quantity and quality of materials and components that can be acquired from a particular structure on or near a site. This process includes assessing the quality and value of these items. For organisations interested in the use of secondary materials knowing the availability of specific materials or components is crucial (Guldager Jensen, et al., 2019). Various strategies exist for inventorying available

materials in anthropogenic stocks. One approach involves assessing the availability of secondary resources in cities and countries by mapping their locations using geographical information. This process utilises data such as cadastre information (governmental recording of real estate properties) or Geographic Information System (GIS) datasets. GIS datasets are very useful for obtaining information of buildings, such as geometry, year of construction and function (Yang, Hu, Zhang, & Steubing, 2022; Tsui, Furlan, Wandl, & Timmeren, 2023). In addition, Material Flow Analysis (MFA) represents another inventorying strategy, providing a systematic assessment of material flows and stocks within a system defined in space and time (Aldebei & Dombi, 2021).

3.3.2. Phase 2: Collecting

Gathering the valuable secondary materials describes the process of salvaging materials and products from construction. Instead of demolishing a building entirely, the reusable materials are carefully removed and separated. Although fully demolition seemed less expensive as it is less labour-intensive and time consuming, it is now seen in cases that harvesting a building instead of demolishing it is financially more interesting because of the re-sell value of harvested materials (Guldager Jensen, et al., 2019). Bides the salvaging of materials and product, a certain level of demolition will be required. The specific method used for demolishing the building can vary based on factors such as the type of construction, height, and proximity to neighbouring structures (Moulton-Patterson, et al., 2002). Arora, Raspall, Fearnley and Silva (2021) define three different material recovery processes. The first process, deconstruction, consists of a carefully planned and highly controlled process producing a varied assortment of components and materials for reuse. Secondly, demolition, the opposite of deconstruction, is a less selective process in which a building is dismantled and compacted, offering potential for recycling but often resulting in waste disposal in landfills. Finally, destruction entails the complete demolition of buildings with minimal or no resource recovery, for example by using explosives. The most effective approach for demolition projects focussing on urban mining involves a combination of the three methods (Arora, Raspall, Fearnley, & Silva, 2021).

After acquiring materials from a demolition project, there are three general streams for managing the collected materials (Guldager Jensen, et al., 2019). One option involves directly reselling the materials and products to a party or returning them to their original supplier, who then recycles or repurposes the products. Another alternative is to send the materials to (local) marketplaces specialising in building materials. These marketplaces purchase the materials and resell them (online). The third option entails temporarily storing the materials at a specific location before resale and/or reuse, a choice often preferred as it minimises additional transportation costs and time.

3.3.3. Phase 3: Sorting and storing

During this stage, the hub becomes highly significant. The materials and goods acquired from demolition projects are sorted and stored within the hub, which may include processes such as cleaning sanitary items. Since the exact functions and facilities of this hub are yet to be determined, this research focuses on identifying the necessary steps for various key stakeholders to stimulate hub development in the Netherlands. According to Shan (2023), all types of circular construction hubs, including urban mining hubs, are linked with the emergence of closed-loop supply chains and will therefore provide more functions in comparison with traditional construction hubs. In addition, it is clear that the hub must be a part of the physical infrastructure for circular construction, facilitating the utilisation of materials from existing buildings in the construction of new ones (Interreg North-West Europe, 2023).

3.3.4. Phase 4: Distribution and reuse

Several authors argue that circular economy initiatives, such as urban mining hubs and logistics management, are closely interconnected, particularly because logistics often

represents a key bottleneck in transitioning the traditional construction industry toward a circular economy (Charef, Morel, & Rakhshan, 2021; Mojumder & Singh, 2021). According to Van den Berghe and Verhagen (2021), the hub involves not only transporting materials harvested from construction and demolition projects to the hub but also delivering materials from the hub to construction sites. In contrast, the specific role of the hub in redistributing secondary materials and products remains uncertain according to (Ding, Wang, & Chan, 2023). This contrast underscores the importance of studying how and to what extent the hub will be involved and responsible for redistributing its stored materials and products.

3.4. Stakeholder identification

Considering the aforementioned phases within urban mining, the key stakeholders of this research can be identified. Significant overlap can be seen with the stakeholders within the traditional building and demolition projects, in which architects, (public) clients, engineering consultancy firms, and construction and demolition contractors play an influential role.

After the initiative for demolition, coming from public organisation or private organisations and individuals, demolition contractors and consultants get involved in phase 1. The latter party is often hired by public organisations in cases of procurement procedures to make the material inventory and to provide advice on harvesting opportunities (Guldager Jensen, et al., 2019). In phase 2, demolition contractors are mainly responsible for the deconstruction of a construction. They can collaborate in this with harvest and material experts (Guldager Jensen, et al., 2019). In phase 3, the hub comes in. The specific functions and facilities within the hub are currently unclear. In addition, there is no consensus on which organisation or partnership should be the owner or managing party of urban mining hubs. Furthermore, concerning phase 4, the distribution function of the hub and its role in overseeing the reuse of stored materials are undetermined. In traditional or integrated construction contracts, architects, engineering consultants, (public) clients and (sub)contractors collaborate to establish a reliable construction (Chao-Duivis, Bruggeman, Koning, & Ubink, 2018). Even though it now concerns secondary materials, the aforementioned stakeholders are taken into account here as well. Some stakeholders will participate in multiple phases. Figure 6 gives an overview per phase which stakeholders are involved.

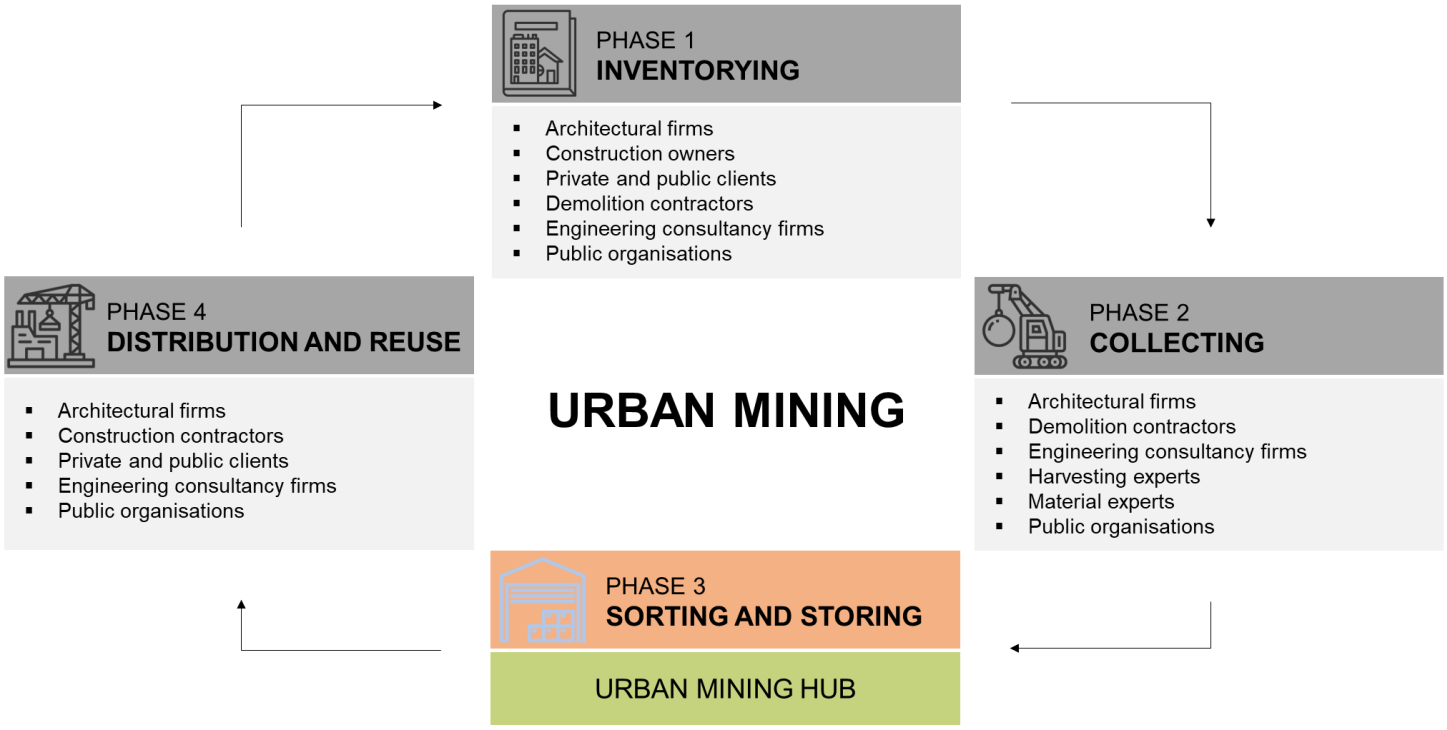

Figure 6. Visual overview of stakeholders per phase in urban mining process (Chao-Duivis, Bruggeman, Koning, & Ubink, 2018; Guldager Jensen, et al., 2019).

3.5. Advantages of urban mining (hubs)

This section will discuss the advantages of the process of urban mining and the implementation of urban mining hubs. The benefits of urban mining hubs can be categorised into two main categories. The first category, environmental advantages, will be outlined in Section 3.5.1, followed by the elaboration on the financial advantages, serving as the second category, in Section 3.5.2.

3.5.1. Environmental advantages

Urban mining hubs offer several key benefits, mainly focussing on preventing depletion of natural resources, reducing emissions, and conserving valuable resources. The overarching aim is to minimise the environmental impact. Urban mining effectively diminishes the need for extensive exploitation of natural resources, facilitating environmental recovery which eventually positively affects local ecosystems. Additionally, urban mining helps limit the demand for resource processing. Anthropogenic storage sites contain substantial quantities of valuable substances that are often no longer economically viable to extract from domestic geological reserves. In many cases, these anthropogenic stockpiles, particularly for raw materials like metal ores, surpass the quantities found in their respective countries' geological reserves. Moreover, as construction projects continue to proliferate, these anthropogenic material storage areas continue to expand (Umwelt Bundesamt, 2022).

Furthermore, urban mining plays a crucial role in minimising solid waste generation. By developing a detailed inventory of construction’s elements, all valuable materials can be systematically extracted, reducing waste, and promoting resource efficiency (Zeng, et al., 2022).

3.5.2. Financial advantages

Due to population growth, rapid urbanisation, economic and industrial expansion, and increasing incomes, there is a growing demand for housing, infrastructure, and materials. Because the geological resources are not only limited but also unevenly distributed, most countries rely on imports for several types of raw materials. By optimising the use of secondary raw materials and managing resource stocks domestically, there is a reduced need for primary raw materials from abroad (Umwelt Bundesamt, 2022). This also reduces countries' dependence on issues related to primary mining, price fluctuations, material scarcity, availability, and access. Recent experiences have shown that countries dependent on mineral imports are increasingly vulnerable to serious risks from commodity price spikes, monopolistic and strategic behaviour by exporters, and supply disruptions due to instability and conflicts in exporting countries (Arora, Paterok, Banerjee, & Saluja, 2017).

Furthermore, it is well known that the mining industry has made positive contributions to economies of many resource-rich countries, for example in Africa. However, this was accompanied by adverse effects to society and to the environment, as described above. The negative social impacts include the reclamation of large areas of land, various human rights violations such as child labour and the financing of terrorist activities. By utilising the existing anthropogenic resource stocks in today's urban areas, these negative effects can be drastically reduced (van der Merwe, Cabernard, & Günther, 2023).

In addition, there are even more financial benefits to urban mining. The utilisation of secondary raw materials and domestic processing benefits the construction industry through savings in material and transportation costs. Evidence of material cost reduction can be found in the research study by Zeng et al. (2022), in which a comparison was made between the costs and benefits of virgin mining and urban mining. Another financial advantage, particularly beneficial for contractors and transporters, is that urban mines are often located precisely where raw materials are most needed. Additionally, the recycling industry serves as a promising driver of innovation and a source of employment opportunities (Umwelt Bundesamt, 2022).

3.6. Disadvantages of urban mining (hubs)

The drawbacks, including the current limitations and uncertainties, of urban mining (hubs) are outlined in this section. In Section 3.6.1, the barrier of insufficient supply will be addressed, followed by Section 3.6.2 discussing the uncertainties regarding inventory and collection of secondary materials. Section 3.6.3 will focus on the complexity of ensuring quality of secondary materials, while Section 3.6.4 will elaborate on the existing development barriers hindering hub realisation.

3.6.1. Disbalance of supply and demand

The main limitation of urban mining is its inability to meet the current demand for raw materials. The output of urban mining is equal to the quantities and composition of waste from the existing stock, a factor which is independent of the present raw material demand. In contrast to virgin mining, urban mining will not increase the amount of (raw) materials in the anthropogenic stock. Both challenges create a gap between supply and demand. Consequently, it remains necessary to explore and identify (sustainable) materials for new construction projects that can address this shortage (Espinoza, Rostek, Loibl, & Stijepic, 2020). Additionally, it is a challenge that the (design) processes for new constructions have not yet been structured to effectively incorporate the use of second-hand materials. For instance, architects often lack the time to collaboratively scout secondary materials with demolition contractors and integrate these materials into new projects (Loeber & Snoek, 2020).

3.6.2. Inventorying and collecting difficulties

Regarding the inventory of materials and products, many studies are conducted on the assumed material recovery (benefits) that can come from the deconstruction of buildings. However, practical realities often differ from these assumptions and materials inventories. Despite the contemporary focus on Design for Deconstruction, the buildings at the end-of-life today are not designed by this approach. Consequently, there is still much uncertainty in making inventories and estimating material recovery benefits (Arora, Raspall, Fearnley, & Silva, 2021).

Additionally, there remains a gap in detailed studies focused on the building components level, where costs, skills, and feasibility of circular demolition are assessed to support decision-making in urban mining. This lack of examination between traditional and circular demolition can lead to uncertainty when opting for urban mining (Arora, Raspall, Fearnley, & Silva, 2021). Moreover, the absence of advanced technologies or a highly mechanised process increases the likelihood of opting for demolition over deconstruction, with the potential for material recovery. Additionally, challenges such as high labour costs, personnel shortages, and strict construction project schedules pose significant obstacles for precise deconstruction exercises (Arora, Raspall, Fearnley, & Silva, 2021).

Furthermore, gaining approval from the community near demolition sites is crucial for the successful implementation of urban mining. As urban mining processes take longer than traditional demolition and may lead to pollution or other adverse effects, societal barriers need to be taken into account (Espinoza, Rostek, Loibl, & Stijepic, 2020).

3.6.3. Undetermined (failure) responsibility and quality

To establish urban mining practices, collaboration between a diverse variety of stakeholders is necessary. Customers in the construction market play a crucial role in utilising the components extracted from urban mining. For these customers, a significant challenge regarding the problem of reusing materials lies in the uncertainty which organisation is responsible for possible failures or quality issues of urban mined materials. Providing secondary materials with a quality certification is feasible, however it is proved to be an expensive and time-consuming process, which is disproportionate to the current amount of secondary material. In addition, the measurements and standards of urban mined materials often differ from those applied to new materials, rendering their reuse impossible (Arora, Raspall, Fearnley, & Silva, 2021; Loeber & Snoek, 2020). Furthermore, resources in the urban mines are sometimes available in higher concentrations but that is not always the case. The pricing of urban mined materials is depending on the availability of the materials and may not always be economically advantageous. Consequently, organisations may find it less appealing to incorporate these materials into their practices (Espinoza, Rostek, Loibl, & Stijepic, 2020). In general, recycling processes tend to have a reduced carbon footprint compared to virgin mining processes. However, in some examples, the recovery of certain types of metals can lead to significant expenses due to technical challenges, diminished economic viability, and increased environmental burdens (Espinoza, Rostek, Loibl, & Stijepic, 2020)

3.6.4. Development uncertainties and barriers

The development of urban mining hubs can be perceived as a high-risk investment. The long-term benefits and profits of a hub are unknown and become apparent only after the hub is used for a longer duration and for multiple projects. Additionally, efficiency and cost in comparison with traditional construction are only visible in the long term (van Luik, de Wilde, & Blokzijl, 2023).

Due to the limited supply, costs for customers can be very high. The expenses depend on dismantling, storage duration, and transport, which can consequently lead to an increase in the selling price (Metropoolregio Amsterdam, n.d.; Loeber & Snoek, 2020).

Additionally, the construction of the hub itself can also pose a disadvantage. In a circular economy, space is required for business activities like repair, recycling, storage, and necessary transportation infrastructure. The intensive construction sector in the Netherlands demands specific industrial areas with a designated high environmental category due to the potential nuisances they may cause. Challenges arise from the limited space available in the Netherlands for such hubs, the nitrogen decision of the Council of State, the limited consideration in policies for the shortage of suitable space, and the objection from municipalities and residents related to landscape pollution (Claessens, 2021; Rood & Evenhuis, 2023; Witlox, 2019). These factors collectively contribute to a complex drawback.

In terms of legal obstacles, Kumar, Sezersan, Gonzalez and Al-Shboul (2019) assert that the current system is well-suited for linear economies but fall short in enabling Circular Economy strategies. Additionally, a significant barrier to the development of these strategies arises from the inadequate enforcement of legislation and a lack of policy support. Loeber and Snoek (2020) confirm this and provide three examples where current legislation hinders the reuse of materials. At first, Het Bouwbesluit refers to (NEN-)standards applicable to new materials, thereby excluding second-hand materials that may no longer meet conditions related to energy efficiency. Secondly, waste management regulations stipulate that once a material is considered as waste, one has the responsibility that it is properly disposed at a waste processing facility. Lastly, the Conformité Européene marking (CE marking) mandates that construction products must comply with legal conditions for safety, health, and environmental protection (European Commission, n.d.). Much of the secondary materials currently harvested comes from a period when the CE marking did not exist, making secondary materials even more expensive besides all harvesting and processing costs.

3.7. Answer to sub question 1

The first data gathering step in this research was to conduct a literature study based on the systematic review method detailed by Wright, Brand, Richard, Dunn, and Spindler (2007) and Templier and Pare (2015). The process of finding and analysing research in literature resulted in a variety of references. Most research focused on specific aspects of hubs in general, such as types of construction hubs and most efficient locations. There was a scarcity of available scientific research on the comprehensive role of hubs within the entire process. Therefore, the role of hubs within the urban mining process remained undefined. Regarding the utilised research and the fact that this topic concerns a novel concept, most articles used were published between 2017-2023. In case of general understanding and information of related subjects some older articles were utilised. Often referenced journals are Journal of Cleaner production and Resources, Conservation and Recycling. Furthermore, articles are used from Circular Economy and Sustainability, as well as from Journal of Management Science and Engineering. Due to a lack of scientific research, as it concerns a novel topic, practical sources were also included.

This chapter addressed the first sub question, which was formulated as: *What are current theoretical insights on the realisation of urban mining hubs in the Netherlands?* This question is important to establish a clear understanding and framework of the concepts for the remainder of this research. Various research studies revealed that the Dutch government is prioritising sustainability across various sectors, including the construction industry. The aim is to transition towards a circular economy. Within this economic model, which stands in contrast to the linear economy, the focus is on developing, utilising, and reusing buildings, spaces, and infrastructure without unnecessarily depleting natural resources, polluting the

environment, or harming ecosystems. It involves constructing in a financially responsible manner that enhances the well-being of both humans and animals, both now and in the future (Benachio, do Carmo Duarte Freitas, & Fernando Tavares, 2020; Kirchherr, Reike, & Hekkert, 2017; Rijksoverheid, 2018; Schuit, Hoorn, Sorel, & Rood, 2023). To achieve this economic shift, the Transition Agenda of Rijksoverheid outlines a strategy, including various measures to stimulate sustainability. Among these measures are circular construction hubs (Rijksoverheid, 2018). Various research studies categorise construction hubs into circular construction hubs (focused on closed-loop material chains and maximising material life spans) and non-circular construction hubs (mostly focussing on effective logistics and minimising congestion in densely populated areas). This research centres on circular construction hubs with a focus on materials and products that do not require processing before reuse. Nowadays, only three to four percent of the twenty-five million tons of waste produced annually by the construction sector is reused in new building construction. Because materials from demolition projects often cannot be immediately reused in new construction projects due to the misalignment in project schedules, these circular hubs will become essential (Loeber & Snoek, 2020; Schut, Crielaard, & Mesman, 2015; Yu, Murat Yazan, Bhochhibhoya, & Volker, 2021).

In the literature study, different definitions of circular construction hubs were mentioned. Based on all aforementioned definitions of the distinct types of hubs, the answer to the first sub question of this research and the definition of urban mining hubs used in this thesis is:

A physical[1], regional[2], and collaborative[3] centre which sorts, stores and transports[4] directly reusable and upcyclable building materials and products, extracted from anthropogenic stocks, to construction projects.

1. Physical, as it needs to bridge the time gap between demolition and new construction. Space is required to temporarily store materials for reuse (Rood & Evenhuis, 2023).
2. Regional, to generate sufficient volume of reusable materials and products for the current demands of the construction sector, reducing the complexity in matching secondary materials and new projects and to minimise transportation movements and distances. In addition, when these hubs operate on a regional scale, this creates a potential that these hubs can eventually be clustered with concrete plants or waste processors or integrated with construction logistics hubs (Tsui, Furlan, Wandl, & Timmeren, 2023).
3. Collaborative, as numerous stakeholders are involved in various phases of urban mining and different disciplines are needed for development of urban mining hubs (Chao-Duivis, Bruggeman, Koning, & Ubink, 2018; Guldager Jensen, et al., 2019). Circular economy demands collaboration between private and public organisations (Rood & Evenhuis, 2023). The key stakeholders obtained from the literature review are architects, construction and demolition contractors, engineering consultancy firms, and public organisations.
4. After completing the inventory and collection steps in the overarching process of urban mining, the hub will have a facilitating role (Tsui, Furlan, Wandl, & Timmeren, 2023). It sorts, stores, and transports the materials from demolition projects to new locations.

Urban mining hubs in the circular economy and the process of urban mining offer various (dis)advantages to stakeholders. Besides environmental benefits, urban mining is financially rewarding, reducing primary material usage, waste generation, and minimising transportation movements. However, challenges persist, including the inability to meet the current material demand, uncertainties in material inventories, and inadequate legislation to support material reuse.

Summary of answer to sub question 1:
Various research studies indicated that the Dutch government is prioritising circularity to transition towards a circular economy. This economic model contrasts with the linear economy by focusing on reusing buildings and infrastructure to minimise resource depletion, pollution, and ecosystem damage. The government's Transition Agenda, describing a strategy towards a circular economy, includes implementation of circularity measures such as establishing circular construction hubs, which aim to create closed-loop material chains and maximise material lifespans (Rijksoverheid, 2018; Tsui, Furlan, Wandl, & Timmeren, 2023). Based on the literate findings, urban mining hubs in the Netherlands are defined as physical, regional, and collaborative centres that sort, store, and transport reusable building materials. These hubs require physical space to store materials, operate regionally to match supply and demand while minimising transportation, and involve collaboration among various stakeholders of the construction industry. The literature findings indicated that urban mining hubs offer environmental and financial benefits by reducing primary material usage, waste generation and transportation movements. However, challenges were also highlighted conserving the alignment of secondary material supply with the current demand, uncertainties in material inventory scans, and inadequate legislation to support material reuse.

The theoretical findings of this chapter defined the relevance and definition of urban mining hubs while underscoring the uncertain role of hub within the process of urban mining. Furthermore, the literature review identified the main stakeholders involved in the process of urban mining and the development of the associated hubs. The subsequent chapter delves into the practical aspects of urban mining hub development by conducting semi-structured interviews. The interview questions will be shaped by incorporating the insights from the literature review regarding the definition of urban mining hubs and the process of urban mining. Moreover, the stakeholders identified in this chapter will participate in the interviews.

4. EXPLORING PRACTICE

This chapter will focus on the method for gathering practical data by conducting semi-structured interviews and aims to address sub question 2: *What are current practical insights on the realisation of urban mining hubs in the Netherlands?* In Section 4.1, the participants of the interviews will be discussed. The semi-structured interview guide will be clarified in Section 4.2. The third Section, 4.3, will provide the results obtained from the semi-structured interviews. In Section 4.4, the process of thematic analysis will be discussed. This chapter will end by addressing the second sub question of this research in Section 4.5.

4.1. Participants of semi-structured interviews

In the literature review, Section 3.4, the main stakeholders involved in the urban mining process were identified. The organisations involved in this research were selected in consultation with the graduation committee and were invited both through personal initiative and from the networks of the supervisors and Brink Groep. By personal effort, ABT, Adex Groep, and Superuse were approached. The graduation committee supported in inviting Paul de Ruiter Architecten, BAM, and Dura Vermeer. Additionally, Brink Groep assisted in contacting Province of Zuid-Holland, Rijksvastgoedbedrijf, Meijs Ingenieurs & Uitvoering, and VERAS sloopaannemers. Employees from the organisations have been selected based on two criteria: the participant must (1) be actively engaged in circular construction and (2) possess a minimum of three years of work experience within circularity. Due to the novelty of circular construction hubs, no specific requirements have been imposed on the participants' profiles to avoid the exclusion of relevant individuals. Some stakeholder functions can be performed by several organisations, such as, for example, material scouts who can also work within engineering consultancy firms. The way the participants are now divided along the different stakeholders allows for the possibility of interviewing two organisations per stakeholder. This is indicated in Table 2, which also describes the job title of the participant and its organisation, along with the corresponding interview date.

The majority of interviews were held in-person to create a more relaxed atmosphere and to stimulate in-depth answers. However, due to participants' busy working schedules, two interviews were conducted online. Since online interviews can lead to potential communication and interpretation challenges, extra attention was paid to a neutral and non-judgmental attitude during the interview (e.g., focussing on body language and tone of voice).

Table 2. Information of interview participants and interview dates.

STAKEHOLDER	COMPANY	REFERENCE	JOB TITLE	INTERVIEW DATE
Public organisation	Province Zuid-Holland	Public1	Transition manager circular construction	11 January, 2024
	Rijksvastgoedbedrijf	Public2	Circularity intermediary	20 December, 2023
Architectural firm	Paul de Ruiter Architecten	Arch1	Chief Executive Officer	19 January, 2024
	Superuse	Arch2	Material scout	8 December, 2023
Engineering consultancy firm	ABT	Cons1	Engineering consultant and building physics specialist	15 December, 2023
	Meijs Ingenieurs & Uitvoering	Cons2	Chief Executive Officer	12 December, 2023

Construction contractor	BAM	Contr1	Business improvement manager	19 December, 2023
	Dura Vermeer	Contr2	Circular manager	14 December, 2023
Demolition contractor	Adex Groep	Demo1	Chief Commercial Officer	6 December, 2023
	VERAS sloopaannemers	Demo2	Industry management consultant	12 December, 2023

As representatives of public organisations, interviews were conducted with the Rijksvastgoedbedrijf and the province of South Holland. Public organisations are important stakeholders because they serve as role models and encourage sustainability ambitions. Additionally, research indicated that constructions developed through public procurement are attractive for urban mining (Tsui, Furlan, Wandl, & Timmeren, 2023). Given its extensive and diverse real estate portfolio and the fact that the Rijksvastgoedbedrijf often acts as a client in construction projects, it becomes evident that the Rijksvastgoedbedrijf is a crucial stakeholder.

Secondly, the province Zuid-Holland formulates policies with the goal of maintaining the well-being, safety, and cleanliness of South Holland. To achieve this, the province actively encourages collaboration among entrepreneurs, researchers, residents, and public organisations. Furthermore, the province is actively seeking novel circular construction materials and construction methods, including initiatives which promotes the usage of bio-based and secondary materials, encouraging demountable design, or implementing innovative logistics solutions such as construction hubs. The province aims to fulfil the roles of commissioner, connector, and catalyst, which makes the province of South Holland an important participant for this research (Provincie Zuid-Holland, n.d.)

In addition, the stakeholder identification in Section 3.4 showed that architects play a pivotal role in various phases of urban mining. Not only in designing structures with secondary materials, but also in inventorying valuable materials and products in demolition projects. The architectural firm Paul de Ruiter Architecten focuses primarily on material and construction waste reduction, the use of circular and biobased materials, and the longevity and disassembly of structures. Their vision highlights innovative sustainable architecture with a positive impact on user well-being, the environment, and biodiversity. According to this firm, circular and biobased materials hold higher value due to their minimal impact on the environment (Paul de Ruiter Architects, 2024).

Superuse, the second architectural firm involved in this research, is a company that employs various strategies to create sustainable architecture using reclaimed materials. One of these strategies involves circular materials, where Superuse utilises a decision tree to determine the hierarchy of material choices. The best choice is to prevent the utilisation of building components and materials, prioritising the use of reusable, renewable, and ultimately recycled materials, with the use of conventional materials considered as most unfavourable option (Superuse, n.d.).

Both architectural firms make use of circular materials and aim to apply this on much larger scale, making them important stakeholders for the identification of the current barriers impeding the development of urban mining hubs.

Moreover, consultancy firms have various roles in multiple phases, as illustrated in Figure 6. They can be hired for material inventories (first phase), provide support as harvest and material experts (second phase), or assist in the design, development, and renewal of construction projects (fourth phase). Firstly, ABT, an engineering consultancy firm, focuses on the reuse of existing buildings through renovation or transformation, ensuring their future

viability. Their vision is that buildings should be developed to be adaptive, detachable, and climate positive. Additionally, in the design process, ABT explicitly considers the use of biobased and circular materials, making them a suitable interviewee to point out the benefits and limits of urban mining (hubs) (Adviseurs in bouwtechniek, n.d.)

Meijs Ingenieurs & Uitvoering is an engineering firm that focuses not only on sustainable design but also on circular demolition projects. For demolition projects, they perform material potential scans and conduct research on material value. In this capacity, they function as specialists in harvesting and materials, making them a noteworthy stakeholder in this research (Meijs Ingenieurs & Uitvoering, n.d.).

In the context of urban mining's construction and demolition phases, the contracting and demolition sectors hold significant importance. Interviews were undertaken with employees from various construction and demolition contractors to gain insights into their perspectives and experiences.

Regarding construction contractors, mainly active in the fourth phase of Figure 6, both BAM and Dura Vermeer were interviewed. BAM aims to deliver circular products through maximum resource efficiency and waste elimination. They have initiated the *Samen Versnellen* program in collaboration with Dura Vermeer and various public and private partners, aiming to develop a common language and standard for circular construction, area development, and infrastructure. A notable outcome is the creation of *Het Nieuwe Normaal*, a framework with indicators and validation methods for circular construction. Additionally, Dura Vermeer operates its own circular construction hub, the Urban Miner, for the reuse and application of resources and materials (BAM, 2023; Dura Vermeer, 2021). With this motivation, knowledge, and experience, these organisations are of great significance in this study.

About the demolition contractors, active in first and second phase of Figure 6, interviews with Adex Groep and VERAS Sloopaannemers were held. Adex Groep is a demolition contractor, specialised in various demolition methods, including circular demolition. The organisation is currently focused on materials for reuse and started their own circular hub (Adex Groep, 2024).

VERAS Sloopaannemers is the industry association for demolition contractors and asbestos removal companies. VERAS Sloopaannemers has been chosen because it has a thorough understanding of the issues related to circularity and circular demolition among its members, including smaller and larger demolition contractors. The association is well aware that its members can make a significant contribution to a fully circular construction economy. Therefore, it aims to inform and inspire demolition contractors, clients, and other stakeholders in the field of circular demolition (VERAS Sloopaannemers, n.d.).

Both organisations operate within the demolition sector, with ADEX Groep being more execution oriented and VERAS Sloopaannemers advocating for the interests of its members within the demolition sector. Both organisations are valuable contributors to this research due to their interests and ambition.

4.2. Semi-structured interview guide

The structure of the interviews is composed of two parts. In the first part, the research topic is briefly addressed to provide clarification without guiding the interview. Furthermore, the interviewees' consent to record and process the interview was obtained through a consent form developed based on the Data Management Plan. This is a prerequisite for obtaining permission to record the interview, as well as for processing the transcription of the interview and the interviewee's information. In the second part, the interview was conducted, which consisted of three sets of questions.

The first set of questions includes general questions about the organisation's motivation to focus on the circularity and the processing or use of secondary materials. Question 1.1 and

1.2 served as a check to verify if the participant and the organisation is actively engaged in circular construction. Additionally, the benefits and current obstacles regarding material reuse and hubs were discussed. In some interviews, conversations were held about projects where sustainable construction methods were already applied or where secondary materials were already being implemented. The questions in this part are formulated as follows:

1.1 Could you provide some information about the function you perform for the organisations and the associated tasks you have?
1.2 In what ways is your organisation currently focused on the use of secondary construction materials and sustainable construction methods in projects, and what are the motivations behind this?
1.3 What are the advantages for your organisation in utilising secondary construction materials and/or circular construction hubs?
1.4 What are the barriers and drawbacks for your organisation in utilising secondary construction materials and/or circular construction hubs?

In the second part, questions are asked with a more stakeholder-specific character. As highlighted in Section 4.1, interviews are conducted with five distinct stakeholders. In Appendix A, the questions detailed for each organisation are shown in Table 18 until Table 22.

The third set of questions is specifically centred on urban mining hubs. Serving as a guideline, these questions, along with potential follow-ups, aim to gather information about collaborations between various organisations, and the physical characteristics of the urban mining hubs. The questions from this third part are formulated as follows:

3.1 What is required to reduce the aforementioned drawbacks and make the overall process of urban mining less interrupted?
3.2 What functions should an urban mining hub facilitate?
3.3 Which physical characteristics should an urban mining hub have?
3.4 What role will your organisation play in urban mining hubs?
3.5 Who will be the managing organisation of the hub?

Since the interviews are semi-structured, follow-up questions were asked based on the diverse responses.

4.3. Results from semi-structured interviews

This section addresses the results obtained from the semi-structured interviews exploring the practical side of urban mining hub realisation. The results are categorised into three sections. The first section, 4.3.1, will outline the barriers identified during the interviews, which are crucial for understanding the obstacles that have impeded the development of urban mining hubs in the Netherlands thus far. Addressing these barriers provides insights into the challenges that a hub should address. The second section, 4.3.2, will examine the stakeholders' expectations in the development of urban mining hubs, which is important for several reasons. Firstly, it allows for the identification of potential collaboration opportunities. Given that hubs are a collaborative centre, this is crucial for fostering more efficient hub development. Secondly, mapping out the expectations per stakeholder enables alignment with their individual needs and highlights potential conflicts. Finally, this also leads to understanding the specific requirements of each stakeholder, including available resources such as funding and retraining programs. The final section, 4.3.3, will map out the visions of the stakeholders regarding urban mining hubs. During the interviews, questions were posed about the prospects of hubs, the potential collaboration opportunities, the management of a hub, and the different functions and material focuses, all of which will be reflected in the third section.

4.3.1. Identified barriers preventing hub development

Research studies have shown the significant role of urban mining hubs in a circular economy, including the associated benefits and potential. To explore the practical side of urban mining hubs and the reason, in the eyes of stakeholders, why these hubs have not yet been developed, semi-structured interviews with key stakeholders were conducted. It became evident during the interviews that material reuse and the necessity for urban mining hubs are closely linked. Currently, the development of urban mining hubs is premature due to the limited demand for secondary materials and the absence of need to store those materials without a guaranteed market. Several barriers in practical, financial, and legal terms attributed to the limited material reuse and the lack of hub development in the Netherlands.

Practical barriers

The limited demand for secondary materials and reuse can be attributed to several practical barriers. One of the main barriers preventing reuse and urban mining hub development concerns the complexity in matching secondary materials with new construction projects. It is often unknown what exact materials can be extracted from a structure. There are uncertainties in material inventory or material potential scans, as it is not clear beforehand what is present in construction, the condition of the materials and the quality (considering the conditions under which it has been stored). Additionally, the origin and proper technical and aesthetic specifications of the material are often lacking. Contr1 illustrates this by stating: *Where it goes wrong with urban mining, circularity and cradle to cradle is that it is quite complex. Because you actually need to start by looking at existing buildings: hmm, what is in there? And often we have no idea* (Contr1, 19 December 2023).

In addition, it is noted by interviewees that there is insufficient supply and diversity of secondary materials, minimising material reuse and the need for urban mining hubs. According to various participants, materials from demolition sites mainly consist of unique items or have a wide variety in quality and dimension. Therefore, they are unable to align with the current demand of construction materials. Additionally, the current supply does not meet the existing demand, as reflected by Cons1: *Where can I currently purchase materials for an 80,000 m² office building? I want to use circular or reused materials to construct internal walls that are 3 meters high, meeting my specifications and the requirements I desire for my internal walls. I cannot find that* (Cons1, 15 December 2023). Even when suitable materials are available, several factors lower the demand for secondary materials and lead to a preference for traditional construction methods. These factors include the absence of (affordable) storage spaces, the lack of alignment between demolition and construction schedules, and the high material reservation costs.

Furthermore, this barrier is also enhanced by uncertainty regarding the quality of secondary products and the absence or unknown nature of liability. Questions and remarks have arisen, including Public1 questioning: W*hom should I approach to obtain a guarantee?* (Public1, 11 January 2024) and Arch1 mentioning that the advantage of new products is that *when you buy something new, you know for sure it has the quality you want* (Arch1, 19 January 2024). The complexity in quality and guarantees is also related to the fact that there is still much unfamiliarity with the process of circular construction and demolition and the use of secondary materials. The lack of standardisation in these processes leads to increased costs, making it difficult and undesirable to prioritise sustainability in projects.

Financial barriers

In addition to practical barriers, financial obstacles also emerged during the interviews, leading to a limited demand for secondary materials and hampering hub development. Currently, traditional construction and demolition methods are cheaper than circular alternatives according to many stakeholders. The same applies to primary and secondary materials.

Especially the fact that more labour is required for extracting and processing the material results in a high cost. Public1 confirms this and states: *Reused materials are already more expensive due to the labour costs involved, so extracting, processing, cleaning, repainting, and reinstalling them under architecture are quite labour-intensive tasks. Buying something new is often cheaper* (Public1, 11 January 2024). Therefore, circular steps and measures are often omitted in projects, as Contr2 illustrates: *any additional measures you might take are currently often cost increasing. Circularity is thus still cost increasing, more expensive, so if the client does not ask for it, it does not come into the project* (Contr2, 14 December 2023). However, a critical point from private and public stakeholders is that the difference in costs between traditional and circular demolition can be minimised or even positive when the residual value of projects and materials is considered (Cons2, 12 December 2023-a; Public 1, 11 January 2024; Arch1, 19 January 2024).

Legal barriers

The third type of barriers identified during the interviews is the legal barriers. Interviewees indicate that current regulations (e.g., Bouwbesluit and construction norms) are reducing the demand for secondary materials and decreasing the need for urban mining hubs. Different private stakeholders mentioned that meeting the building regulations with secondary materials is challenging. Moreover, different construction and demolition contractors and architects also point out the problem of construction norms, secondary materials, and design decisions. The current standards for materials are very strict, often requiring secondary materials to undergo extensive upgrading, which, as previously mentioned, increases costs. Additionally, meeting the correct standards may require much more secondary materials compared to using primary materials, for example for isolation. However, this is not always taken into account in the design phase, leading to a lack of available space in the construction. Furthermore, public clients also face challenges with regulations obstructing their individual progress towards circularity. In the procurement procedures, Public2 would like to have a higher level of sustainability, but this is impeded by the public procurement law: *We cannot ask questions to the market that are not yet possible. Because we have to ask in a way that multiple parties can bid, so even if we know that there is one party that can apply 100% recycled inner walls. We cannot ask that because there is only one party* (Public2, 20 December 2023).

Additionally, the current tax system does not incentivise material reuse because of the taxes on labour and materials. This leads to an increase in costs when reusing materials, as supported by Cons1: *you have to handle something twice when reusing materials, you have to do two operations. Circular materials are currently being paid for at excessively high prices* (Cons1, 15 December 2023).

Finally, participants from private parties believe that the lack of a sustainability vision and budget from the public organisations has led to the lack of development of hubs. Arch1 summarises this as follows: *the frustrating thing about our government is that they are very unpredictable and swing from left to right. So, they should actually say: this is the roadmap, then you can anticipate it. And then you also get a bit of a stimulating effect because then people start to innovate. Then you do not have to change everything all at once. The whole industry can align with it. This is why parties do not want to invest because they do not know where they stand* (Arch1, 19 January 2024). Public organisations admit that this is a problem, but Public2 attribute it to *a political decision, a political will, a political wind* (Public2, 20 December 2023).

4.3.2. Stakeholders' expectations for engaging in urban mining hub realisation

Initiatives and steps within circularity, such as the development of hubs, are often perceived by the interviewees as challenging and complex. Because urban mining hubs are a collaborative initiative, the interviewees agreed that collaboration between stakeholders is required to make urban mining hubs a reality. Cons1 confirms this: *the entire construction*

industry, from architects to engineering firms to contractors should be involved (Cons1, 15 December 2023). Regarding this collaboration, the stakeholders expressed expectations to other organisations involved urban mining hubs development, which are described in this section. Especially according to various stakeholders, the sense of urgency for change towards circularity is still too small for many companies to take the first step. Demo1 believes *that there is a need for individuals who are willing to look beyond this and dare to take action, driven by intrinsic motivation to solve things a little better* (Demo1, 6 December 2023).

The expectations towards the individual stakeholders aim to define steps necessary for circularity in general before hub development can be facilitated. Consequently, the answer may seem less related to the expectations stakeholders have regarding urban mining hubs but is in essence very relevant as enhancements in circularity can eventually lead to hub development.

Towards all stakeholders

Regarding the stakeholders' business operations, all organisations agreed that business models and operations should be focused more on circularity to be able to realise the transitions towards a circular economy. While sustainability is becoming increasingly important within some organisations, other organisations are still lagging behind. A few interviewed organisations have a very clear circularity vision and aim for a high level of ambition, primarily because they are intrinsically motivated, as seen with Arch1, who stated: *I wanted buildings to produce energy instead of consuming it. That why I started my company in sustainability in 1990* (Arch1, 19 January 2024). Other organisations also prioritise sustainability more and more but for different reasons. For example, because *it is good for the business and future-oriented* (Demo2, 12 December 2023-b) or because the *business cannot and do not want to be left behind* (Contr1, 19 December 2023).

Narrowing down from overall business models to project execution, the interviewees unanimously agreed that circularity should be prioritised in the demolition, design, and execution of projects. This means that from the start of the project, all stakeholders collaborating in projects should critically examine circularity during each of the project phases enabling circularity in the project. Table 3 presents relevant quotes from the semi-structured interviews in which various private organisations express the need for more circular decision-making processes.

Table 3. Expectations expressed towards all stakeholders.

Statement	Prioritise circularity in decision making processes throughout all project phases.		
STATED BY	**QUOTES**	**TOWARDS**	**AIM**
Arch1	*It is simply about constructing a building with as little material as possible. So, following the Trias Energetica principle: first try to save energy, use sustainable energy, and finally, use fossil fuels as efficiently and cleanly as possible. And the same goes for materials: use as little material as possible, then use sustainable materials, and finally, use primary materials as efficiently as possible.*	All stakeholders	Effectively utilise all types of materials.
Cons1	*Look, at some point, everyone needs to try to reuse materials. We should first apply existing materials before we are allowed to use new ones; that way, the support for this approach will increase significantly.*	All stakeholders	Prioritise the reuse of materials.
Contr1	*Decisions should not only be based on financial considerations.*	All stakeholders	Base decisions not solely on financial factors but also consider environmental impacts.

An essential initial step to facilitate prioritising sustainability in projects, according to various participants, begins with timely disclosure of (potential) demolition projects. Both demolition contractors express the need for organisations to announce their potential demolition plans earlier. Demo1 states: *Developers need to indicate in advance when a building will be demolished, so that we, as demolition contractors, can promptly search for a new application* (Demo1, 6 December 2023). Demo2 also confirms this by stating*: From the perspective of the demolisher, it would be ideal to have ample time for demolition and if you grant an architect access to such a building and explain what will be available, what will be dismantled, and that it will be available in 6 months, then they can incorporate it into a new building, probably without interim storage* (Demo2, 12 December 2023-b).

Towards architectural firms

The interviewed stakeholders expect architects to undergo a change in mindset and (design) approaches to design and work with sustainability and circularity as the primary starting point. Both public and private stakeholders emphasise the importance of architects considering available materials, whether secondary or locally sourced during the design phase. The quotes from private and public stakeholders in Table 4 provide evidence of this need.

Table 4. Expectations expressed towards architects.

Statement	Shift in mindset and design approaches/decisions (exploring limited design options by considering what is available secondarily or locally)		
STATED BY	**QUOTES**	**TOWARDS**	**AIM**
Public2	*I really think the time has passed where an architect can come up with a concept for a building and then just design everything they want and source it from anywhere in the world so it can be built.*	Architects	Consider what is available secondarily or locally.
Contr1	*Architects have an important role to play in this and should be more open-minded, seeing it less as a limitation of their creativity, as it is often perceived.*	Architects	Shift in mindset.
Demo2	*What we would like to see is that architects initially consider what is available and then start designing based on that.*	Architects	Revise design approaches.

Towards public and private clients

In the results of the interviews, there is seen a clear difference in sustainability ambitions between private and public clients. Organisations would prefer to see higher circularity ambitions among developers and other private organisations. The interviewees unanimously agree that public clients aim for the highest level of ambition regarding sustainability in their projects. Stakeholders believe that the drive to strive for circularity in projects mostly depends on the ambition level of the client and would like to see circularity being important from the beginning of the assignment. The quotes from different stakeholders in Table 5 present the difference in ambition between public and private parties, highlighting the need for higher circularity ambitions in projects from private organisations, and expressing the need for more measurable circularity goals in projects.

Table 5. Expectations expressed towards public and private clients.

Statement	Elevate circularity ambitions within projects and clearly outline these ambitions in project requirements.		
STATED BY	**QUOTES**	**TOWARDS**	**AIM**
Contr1	*There are also truly old-fashioned clients, often private equity companies with high returns, such as McDonald's, garden and shopping centers, etc., who just say, build it. And often, the design is super fancy, difficult, with all sorts of strange shapes. Then try to pursue technical application or sustainability ambitions.*	Private clients	Heighten circularity ambitions within projects.
Cons1	*The importance of circularity still varies from project to project. You see Rijksvastgoedbedrijf, which has a very high level of ambition, but a private client prefers not to do this.*	Private clients	Heighten circularity ambitions within projects.
Contr2	*What you definitely notice is that circularity or CO_2 reduction is still not an objective in every project. So, when it is not included in project inquiries, you notice that the drive is less. We mainly work on projects demand driven. When we have to secure a project, we closely examine what the requirements are and how we can score as well as possible.*	Public and private clients	Clearly articulate circularity ambitions in the project requirements.

Towards construction and demolition contractors

Expectations expressed by various stakeholders towards construction contractors focus on the need for innovation and educational development within the construction industry. The interviewed stakeholders required contractors to allocate more resources towards research and development focusing on new construction methods aimed at circularity and demountable construction. Additionally, they expect contractors to invest in retraining their personnel, ensuring they possess the knowledge and skills necessary for implementing circular practices effectively. Table 6 shows quotes from the semi-structured interviews supporting the desired changes from various private and public stakeholders towards construction and demolition contractors.

Table 6. Expectations expressed towards construction and demolition contractors.

Statement	Transition from a purely profit-oriented mindset to a circular one and implement necessary measures to accomplish this shift.		
STATED BY	**QUOTES**	**TOWARDS**	**AIM**
Arch1	*The contractor industry is a rather sluggish and outdated entity. There is little innovation, and it is very traditional. I think they invest too little in research despite their profit margins being so small.*	Construction contractors	Improve business operations and project execution methods through innovation.
Public2	*Contractors who cut corners and just pour and stick everything together should not do that anymore; it is scandalous. They need to take responsibility and say we are not going to attach things together like that anymore. Construction contractors have a lot to improve.*	Construction contractors	Take responsibility for implementing circular project execution.
Cons1	*Half of the installing companies in the Netherlands are not there yet, as they all need to be retrained.*	Construction and demolition contractors	Provide personnel with retraining to facilitate circular project execution.
Public2	*It is indeed more of a call or a desire for them to do much more, perhaps even before it yields any financial returns. And maybe also refuse projects, when it is not a circular one.*	Demolition contractors	Take an extra step to encourage circular demolition.

Towards demolition contractors, only Public2 expressed the desire for them to take an additional step (Public2, 20 December 2023). Other interviewees did not mention any expectations towards demolition contractors.

Towards manufacturers

One stakeholder often mentioned during the interviews but not included as a key stakeholder in this study is the manufacturers. All involved participants would like to see original or alternative manufacturers being responsible for taking back materials and products. According to the stakeholders, they possess the right expertise and experience, enabling them to retain material value in the most efficient manner during processing. They can also provide all types of quality assurances and guarantees to resolve the barrier related to uncertainty in liability for secondar material. In Table 7, quotes from private and public organisations are shown that prove these expectations.

Table 7. Expectations expressed towards manufacturers.

Statement	Reclaim materials and products, process them while preserving their original value (facilitating as direct reuse as possible), and reintroduce them to the market with the necessary quality assurance and guarantees.		
STATED BY	**QUOTES**	**TOWARDS**	**AIM**
Demo1	*I see a particularly important role for manufacturers, that they actually assert much more of a claim on the products they sell today. And with some sort of take-back guarantee or statement because they ultimately hold the knowledge and expertise. Where they can also provide all forms of quality, guarantees, and stickers in the end. (...) You only truly achieve scale when you have the manufacturer at the table.*	Manufacturers	Reclaim materials to resolve uncertainties regarding liability for secondary materials.
Public2	*Ideally, I want all manufacturers always take back materials and products. In that way, the supply circles are kept as small as possible. This ensures good recycling and reuse as directly as possible if feasible.*	Manufacturers	Reclaim materials to facilitate as direct reuse as possible.
Cons1	*I believe that many materials and products coming from demolition sites can go to a processing party that turns them into very good circular products. Because they are the specialists. A specialist in their own field can always improve because they have the precise knowledge, logistics, supply chain management, and production facilities for their specialisation. And the most important aspect, they can produce on large scale and ensure quality, so they can provide a guarantee on that.*	Manufacturers	Reclaim materials to resolve uncertainties regarding liability for secondary materials and provide sufficient supply.

Towards public organisations

The interviews paint a clear picture of important steps expected from the public organisations to stimulate circular initiatives, such as urban mining hubs. According to the interviewees, there is a need for more guidance from public organisations. Contr1 articulated this, stating that: *certain market influence or government intervention is necessary* (Contr1, 19 December 2023). Cons1 suggests that: *there is not enough guidance from the government to force people to be more sustainable* (Cons1, 15 December 2023). To create market movement,

stakeholders expressed three main expectations to stimulate material reuse and urban mining hub development.

Firstly, various stakeholders believe that there should be stricter regulations for circularity in projects through adapted legislations. Three different options were provided during the interviews to achieve this:

1. CO_2-budgets in projects;
2. Stricter Environmental Performance Standards (MPG-values) that projects must adhere to;
3. Revision of the current Building Decree to align more with circularity objectives.

Table 8 provides a list of quotes obtained from the interviews to confirm these options given by different interview participants.

Table 8. Expectations expressed towards public organisations regarding the revision and implementation of (new) regulations.

Statement	Revise and implement regulations to encourage the transition towards a circular economy.		
STATED BY	**QUOTES**	**TOWARDS**	**AIM**
Arch1	*You need some sort of incentive. If you save carbon dioxide with a product, it should be valued rather than undervalued. Then you can compare wood from China and the Netherlands, and wood from the Netherlands should become cheaper. And that is also better for the Dutch economy.*	Rijksvastgoedbedrijf, provinces, municipalities (and clients)	Incorporate CO_2-budgets into projects.
Demo1	*I think that will only happen if it is stimulated, and that can be done by adding an MPG to the Bouwbesluit or adding a CO_2-tax at the end. (...) Regulations need to become stricter. From then on, it becomes increasingly interesting to use second-hand material.*	Ministry of Economic Affairs and Climate Policy and Ministry of the Interior and Kingdom Relations (and clients)	Introduce stricter MPG values or implement CO_2-taxes in projects.
Demo2	*I first think the ministry should take the lead with the entire Bouwbesluit. The Bouwbesluit, as it stands now, is simply not circular at all, so I think that is just a first step.*	Ministry of the Interior and Kingdom Relations	Revise the Bouwbesluit to better align it with circular ambitions.

Secondly, private parties have expressed the need for financial incentives in the form of subsidies from public organisations. Table 9 clarifies this expectation with several quotes from private organisations.

Table 9. Expectations expressed towards public organisations regarding the provision of essential resources.

Statement	Provide the essential resources, allocate suitable locations, and offer financial incentives (subsidies) to encourage material reuse and urban mining hub realisation.		
STATED BY	**QUOTES**	**TOWARDS**	**AIM**
Cons1	*It helps to financially stimulate those ambitions because often that is the reason not to do it. Such as a CO_2-tax or some subsidy to compensate for the extra cost compared to new. That certainly helps to get the market moving.*	Ministry of Finance and Tax and Customs Administration	Offer subsidies to incentivise material reuse.
Arch1	*If subsidies were provided for this or a beneficial economic model could be applied, these materials would become more appealing to use.*	The Netherlands Enterprise Agency, ministries, provinces and municipalities	Offer subsidies to incentivise material reuse.
Contr1	*For such a circular hub, the internal barrier is often too high. So, I think that requires subsidies from the Netherlands Enterprise Agency or whatever.*	The Netherlands Enterprise Agency, Ministry of the Interior and Kingdom Relations, provinces, and municipalities	Offer subsidies to stimulate hub development.
Arch2	*I think the municipality would be a good choice to facilitate that space, that storage space.*	Municipalities and provinces	Provide space and location to stimulate hub development.

Although private parties have a need for subsidies, there are critical comments from public organisations regarding this matter. Public2 acknowledges that subsidies can stimulate circular initiatives but believes that this is more of a task for the Ministry of the Interior and Kingdom Relations, the province, and the municipality, when *they think something is a good idea* (Public2, 20 December 2023). Public1 believes that the options to stimulate market movement (Table 9) should be explored first to make secondary products more attractive. According to Provincie Zuid-Holland, this is important because: *if we continue to subsidise things, it will never become dominant, it will never grow bigger, so we have to process the actual environmental impact, the true price of that door made from primary material compared to the avoided emissions from transport, CO_2, and forest clearing for the second-hand door. If that is visible, then it almost happens automatically* (Public1, 11 January 2024).

Thirdly, there is a shared desire among both private and public stakeholders for public organisations to explore the implementation of Extended Manufacturer Responsibility within the construction sector. This would entail holding manufacturers accountable for reclaiming products and materials, a measure perceived as advantageous by many stakeholders, as outlined previously (in section *Towards manufacturers*).

4.3.3. Potential and characteristics of urban mining hubs

Different visions on urban mining hubs have been revealed through interviews with the key stakeholders. Furthermore, the findings delve into the functions that hubs should support and identify the materials considered most suitable for storage. Moreover, the results provide insight into the collaboration between the different stakeholders required for development of those hubs.

Visions regarding hubs

From the interviews, it emerged that stakeholders have diverse ideas regarding the development and potential of hubs. They unanimously agree, however, that a hub only has potential if there is clear demand beforehand. This means that only materials and products should be stored that are assured to be reused or have a very high probability of being utilised in new projects. One of the reasons why urban mining hubs have not been implemented on a large scale is mainly due to the risk associated with demand. Contr2 expresses this as: *That is the flaw when there is no demand, to what extent are you then willing to arrange transportation, storage, and ultimately incur costs to match beams* (Contr2, 14 December 2023). Demo2 also confirms this by stating: *The biggest disadvantage actually comes afterward, which is that you cannot get rid of your materials. So, you put a lot of time and effort into demolition, but ultimately end up with materials. I think that is a nightmare for every demolisher* (Demo2, 12 December 2023-b).

Additionally, Arch2 agrees that materials without certainty in reuse should not just be stored. They see a lot of potential in urban mining hubs because they enable alignment of project schedules: *So far, the biggest challenge is to make a match that somewhat aligns with planning. And there, an urban mining hub, a physical hub, could help because suddenly the gap between material requests and their application is bridged* (Arch2, 8 December 2023). However, Cons2 believes *that the majority of good solutions skip the hub, and by that, I mean the following: I think that a lot of items coming from a demolition go to a processing party that turns them into a very good circular product* (Cons2, 12 December 2023-a).

Moreover, Contr2 envisions a network of interconnected hubs to facilitate local material sourcing, as illustrated by: *I do not have the illusion that all materials will go to one storage location in the region. I think multiple storage points will be created. I believe, in principle, that where materials become available, it is preferable to store them nearby because if you have to travel far, it adds a lot of costs and CO_2-emissions. I think it is efficient to look for local storage if possible* (Contr2, 14 December 2023).

Both Arch2 and Contr1 believe that the development of urban mining hubs should start small with experienced individuals before scaling up (Arch2, 8 December 2023; Contr1, 19 December 2023).

Finally, Cons2 and Demo2 also see potential in hubs acquiring a bulk function to transport materials more efficiently to manufacturers. A specific material will be collected and temporarily stored before being transported in bulk to manufacturers (Cons2, 12 December 2023-a). Demo2 describes this as: *Then you are actually talking about a hub with specific materials (...), then you can really collect them to bulk and then drive to a manufacturer with full containers. I see added value in that* (Demo2, 12 December 2023-b).

Functions facilitated by hubs

The three main functions identified by stakeholders that must be carried out by the urban mining hub focus on transparent inventory, a logistical function and a processing function.

Firstly, according to stakeholders, it is crucial that the inventory of the hub is clearly visible (online), detailing what is available, including all types of material specifications. Arch2

elaborates on this, stating: *A comprehensive system should underpin this so that supply is well-maintained online in a database. I believe there should also be a link to the physical hub, a digital counterpart, like a website. Where you should essentially find all the information or as much as possible* (Arch2, 8 December 2023). Public2 also emphasises: *There must be a robust digital system in place so you know what is available, who it belongs to, and where it can go* (Public2, 20 December 2023).

Secondly, it can be concluded from the results that stakeholders consider a logistical function as a valuable addition to an urban mining hub. A logistic function is not being mentioned in the definition of urban mining hubs for this research. Stakeholders see great potential in a combination of a circular and a logistical construction hub, whereby the hub focuses on secondary materials and is strategically located, minimising the transport movements to construction sites. Cons2 states: *We discussed that logistical aspect. That is a problem I believe they can play a significant role in and add value to. (...) That these logistical hubs and circular hubs, which are currently in somewhat parallel worlds, will become one world* (Cons2, 12 December 2023-a). Public1 also believes that adding a logistical function to a circular hub adds value, as illustrated by: *we have said, the idea of a hub or hubs with certain specialisations located in strategic locations to facilitate construction logistics offers many benefits. Simply fewer transport movements, thus less emissions and better availability of materials and products that would otherwise end up in landfills* (Public1, 11 January 2024).

Thirdly, stakeholders desire a processing facility within the hub. Cons2 defines this with: *I also think that in processing, cleaning, and such, they can make a significant contribution* (Cons2, 12 December 2023-a). Arch2 also considers a processing place in a hub or collaboration with a processor as an enhancement and confirms this with: *And if, for example, there is a workshop that can shorten or lengthen those frames a bit. (...) Especially if it is in collaboration with a processor, they can customise and nail it, et cetera* (Arch2, 8 December 2023). Demo2 also sees value in this and sees an opportunity for people with distance to the labour market: *I think that also creates added value* (Demo2, 12 December 2023-b).

Materials suitable for hubs

Regarding the materials suitable for storage, the stakeholders unanimously agree that only materials with (almost) certain demand should be stored. Demo2 illustrates this by: *Storage only increases costs. From the outset, there should be a distinction between what you want to store and what you do not. Not everything from demolition should be stored with the mindset of figuring out later what to do with it, but rather a specific assessment to see if the product can be reused later.* They emphasise that *the intrinsic price of the material is particularly relevant* (Demo2, 12 December 2023-b): the higher the original value of the material, the more likely it is suitable for storage in a hub. Materials with already a destination for reuse could also be stored in the hub. Arch2 defines materials with nearly guaranteed demand as: *the most common items in stock at the hub. Such as common steel structural elements, common wood elements, typical sanitary items, doors, and windows* (Arch2, 8 December 2023). Furthermore, the hubs could potentially serve in storing their own house material collection. Cons2 sees potential for the hub particularly in small items: *like doorknobs, a sink, faucet, those kinds of small things: store them in the hub* (Cons2, 12 December 2023-a). Public2 agrees and also considers commonly used materials: *easy things like bricks, etc* (Public2, 20 December 2023). Additionally, Demo1 sees potential in leftover new materials. They refer to this as: *On a construction site, there is a huge amount of leftover material that is technically new but no longer needed at the site and ends up in the dumpster. If you could capture those material flows, you have already found a significant resource* (Demo1, 6 December 2023).

Collaboration in hub development

During the interviews, results were also obtained regarding collaboration between the involved organisations for the development of urban mining hubs. From these results, it can be concluded that participants would like to see various types of organisations within the construction sector involved in this process. Contr1 believes that this is something for *Bouwend Nederland, the covenant* (Contr1, 19 December 2023), which was also stated by Cons1 (Cons1, 15 December 2023). Public1 confirms this and would also like to see various disciplines involved in the development of urban mining hubs, as evidenced by: *What is interesting for us is if a circular hub is truly circular, open, transparent, and accessible. That is a requirement for such a hub to function, so we keep conveying this to market parties* (Public1, 11 January 2024).

Regarding whom should manage an urban mining hub, the answers were generally consistent. Only Contr1 envisions that initially, a public organisation should manage the hub (Contr1, 19 December 2023). Other stakeholders suggest that this should be led by a (new) commercial organisation. Demo1 does not mind which organisation it is, but states that it should be done by *commercial parties that have a sharp focus on financial feasibility* (Demo1, 6 December 2023). Arch2 also believes a hub should be a managed by a commercial organisation and adds some additional conditions for that party: *What I think is important is that whoever sells it and owns it has knowledge about the material, its origin, has experience with it, can provide advice, and feels responsible for its quality. And that can be either the demolisher who rents a part of the hub to deposit their material or a new company that buys the materials from the demolishers. Either way, as long as the seller is also the owner of the material. The involvement is then greater, and it just works smoothly* (Arch2, 8 December 2023). Public1 agrees with this and also thinks it is smart to leave it to a third party, *who can play a role in representing that general interest* (Public1, 11 January 2024). Contr2 sees potential in a network of urban mining hubs accessible to *Bouwend Nederland*, managed by multiple different owners (Contr2, 14 December 2023).

According to Demo1, Contr1, and Arch2, public organisations primarily play a role in facilitating storage space (Demo1, 6 December 2023; Arch 2, 8 December 2023; Contr1, 19 December 2023). They all believe that the remainder of the process should be managed by private organisations. Both Public 1 and Public2 also see a facilitating role for public organisations in this regard. Public1 states: *As a public organisation or province, I think we have a facilitating role. Making sure that if companies decide they want a hub, we support that as much as possible, issuing permits, regulations, making it as easy as possible for them* (Public1, 11 January 2024). Public2 positive attitude towards hubs and their willingness to collaborate, is evident form their statement: *We are pro-hub, so we will use it when the time has come* (Public2, 20 December 2023).

4.4. Analysis of practical findings

The analysis of the results from the semi-structured interviews is conducted based on the six-phase thematic analysis framework defined by Braun and Clarke (2006). During the transcription process, a first set of codes was developed. Based on these initial codes, the interviews were marked. As thematic analysis is an iterative process, new codes emerged from interviews later on. Figure 7 illustrates this process, in which quotes from the interview transcriptions can be submerged in codes. A collection of codes culminates in a subtheme, compromising a broader topic. Ultimately, multiple sub themes converge to form the main themes.

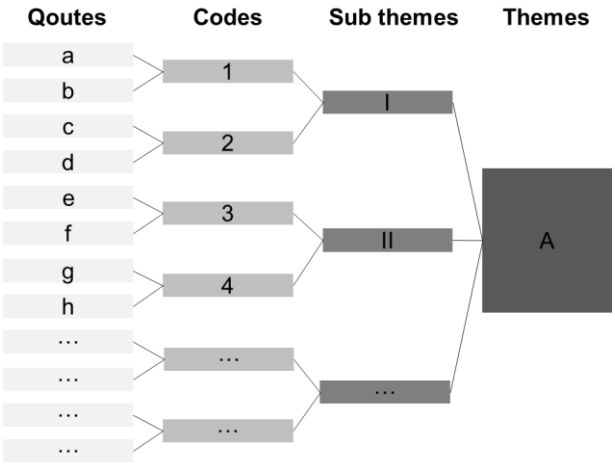

Figure 7. Systematic visualisation of the thematic analysis process from quotes to main themes.

After completing all interviews for the first time (round 1), the interviews were reanalysed with the newly acquired codes. Table 10 illustrates the difference in quotes between round 1 and round 2.

Table 10. Overview of adjustments during the iterative process of thematic analysis.

	START PROCES		DURING PROCES	END OF PROCES
	Interview marking		Revise codes and create initial themes	Final result
	Round 1	*Round 2*		
Quotes	607	650	614	612
Codes	39	39	31	26
Subthemes	0	0	9	9
Themes	7	7	3	3

Next, various codes were either retained, merged, or eliminated. Codes were merged when there was significant overlap between different codes and the associated quotes fitted well under one overarching code. These codes were renamed when necessary. Additionally, codes with insufficient support, defined as fewer than ten supporting quotes, were removed. In total twelve codes were merged to six codes and seven codes have been removed, resulting in a reduction from thirty-nine initial codes to twenty-six well-supported codes. Subsequently, from the revised codes, subthemes were derived, each consisting of codes with a shared overarching topic. This step was conducted again with the sub themes, which eventually led to the main themes. The final outcome of the thematic analysis is presented in the tables below, which include the codes and their frequency as supported by quotes, the subthemes, and the overarching themes. Each of the three main themes forms a separate table, with Table 11 focusing on the current barriers, Table 12 on initial steps to encourage hub development and Table 13 centred on the stakeholders' perspectives of urban mining hubs.

Table 11. Framework of theme 1: Current barriers and limitations hindering circular construction, demolition, and reuse of materials.

	CODES		SUB THEMES
	Description	*Frequency*	
1.	Complexity in matching secondary materials and new projects	25	Practical barriers
2.	Limited supply, insufficient diversity in secondary materials and too many unique items	11	
3.	Unfamiliarity and lack of standardised processes regarding circular construction and demolition and secondary materials	17	
4.	Uncertainties in material inventories scans	11	
5.	Lack of clarity in quality, guarantee of secondary materials and the associated liability	28	
6.	Circular construction and secondary materials more expensive than traditional construction and primary materials	30	Financial barriers
7.	Current standards and norms hindering material reuse	18	Legal barriers
8.	Lack of sustainability vision and policy from the public organisations.	19	

Table 12. Framework of theme 2: Initial steps and strategies to stimulate material reuse and implementation of hubs.

	CODES		SUBTHEMES
	Description	*Frequency*	
9.	Providing insight and standardising the characteristics of the supply	18	Practical steps for stimulating and facilitating material reuse and storage
10.	Considering residual value of projects and materials	12	
11.	Prioritising sustainability in demolition, design, and execution phase of projects	34	
12.	Earlier announcement of demolition nominations	14	
13.	Prioritising sustainability in core business policy and decision-making processes	28	Changes within company and project management to stimulate circular initiatives
14.	Varity in sustainability ambitions among clients	32	
15.	Acceptance and change in mindset regarding secondary materials required	44	
16.	Need for financial incentives	21	Legal steps to stimulate material reuse and development of hubs
17.	Implementing stimulating legislation by public organisations	40	
18.	Involving manufactures in reclaim materials and products	29	Expectations of stakeholders among themselves and towards others regarding circularity
19.	Contractors need to renew and invest more in sustainable construction (methods)	20	
20.	Approaches and expectations of stakeholders of secondary materials and circularity initiatives	38	

Table 13. Framework of theme 3: Visions from stakeholders regarding the potential and characteristics of urban mining hubs.

	CODES		SUBTHEMES
	Description	*Frequency*	
21.	Strategies for hubs	51	Potential of urban mining hubs
22.	Risks in the demand of stored secondary materials in hubs	17	
23.	Types of materials suitable for hubs	16	
24.	Collaboration of stakeholders in hubs	18	Involved stakeholders and their roles in the development of hubs
25.	Managing organisation of hubs	11	
26.	Facilitating role of public organisations in organisation of hubs	10	

4.5. Answer to sub question 2

Conducting semi-structured interviews with the various key stakeholder (see Table 2) aimed to address the second sub research question, which was formulated as follows: *What are current practical insights on the realisation of urban mining hubs in the Netherlands?*

From the interview results, it can be concluded that urban mining hubs hold potential, but the practical implementation remains unrealised. Currently, there are several barriers preventing the realisation of those hubs. According to stakeholders, the realisation of hubs is promising, but this potential can only be achieved when all stakeholders take responsibility for their own actions and undertake necessary steps.

Regarding the barriers preventing the realisation of urban mining hubs, four obstacles were identified. Firstly, a significant challenge lies in the complexity of aligning secondary materials with new construction projects. This complexity arises, among other factors, due to uncertainties in material inventory scans, insufficient supply, and ambiguity surrounding the quality of secondary products and potential liabilities. Secondly, many stakeholders perceive traditional construction and demolition methods as more cost-effective compared to circular alternatives. This perception is mainly influenced by the higher labour requirements for extracting and processing materials, leading to increased costs. Therefore, it is crucial to consider the residual value of materials, even in the context of new project development, as these materials retain value beyond their initial use and should be regarded as investments. Thirdly, existing regulations are reducing the demand for secondary materials and diminishing the need for urban mining hubs. Finally, the lack of a sustainability vision and budget allocation from the public organisations has impeded the development of such hubs.

This latter barrier was often referred to when diving deeper into the expectations the different stakeholders have of each other for the development of urban mining hubs. The various stakeholders had a clear understanding of the steps the other stakeholders need to take to enable urban mining hubs. All stakeholders are expected to prioritise circularity their own business models and the executions of projects, moving from a fully profit-focused mindset towards circular mindset. Contractors are required to invest more in research and development for new construction methods aimed at circularity and demountable construction, as well as retraining of employees on circular construction practices. From architects, stakeholders expect a new mindset and design approach, where they will design using available secondary materials, emphasising sustainability and circularity as their primary focus. A stakeholder towards whom no expectations (only a single desire) have been expressed is the demolition contractors. Manufacturers were frequently mentioned by interviewees, although they were not identified as key stakeholders in the literature study. Stakeholders expressed a desire for manufacturers to take responsibility for reclaiming materials and products, process them while preserving their original value as much as possible and reintroduce to the market with quality assurances and warranties. As mentioned, interviewees underscored the need for increased guidance from public organisation, including stricter sustainability regulations in projects through adjusted legislation, financial incentives, and the implementation of Extended Manufacturer Responsibility legislation (*Uitgebreide Producentenwetgeving)* in the construction sector. A noticeable difference in circularity ambitions exists between private and public entities. The interviewed stakeholders are advocating for higher circularity standards among developers and other private organisations, as those ambitions are often lacking.

Regarding the concept of urban mining hubs, the interview results revealed various perspectives from stakeholders. A fundamental principle guiding the operation and potential of hubs in general is the storage of materials only with assured demand. According to various interviewees, a network of diverse types of hubs holds the most potential. Within this network, hubs will vary in scale and material focus. Key features of an urban mining hub include transparent insight in the hubs' inventory (potentially through a website of platform), logistical and processing capabilities, and the ability to facilitate material reservations. Active participation of all organisations within the construction sector is essential for the effective functioning of such hubs. The managerial organisation overseeing the hub's operations should ideally be a commercial entity, ensuring the financial feasibility. Public organisations (operating on regional or local level) are expected to play a facilitating role in land allocation and offering support and guidance to ensure the seamless operation of the hub network.

Summary of answer to sub question 2:

The current practical results highlighted the advantages and potential of urban mining hubs in the Netherlands but indicated that practical implementation remains unrealised due to practical, financial, and legal barriers. Interviewees expressed expectations towards all involved stakeholders and emphasised the need for collective responsibility and actions to overcome these barriers. They believe that prioritising circularity in business models and project execution is crucial. Furthermore, private organisations called for increased guidance from public organisations to incentivise material reuse and hub development. Furthermore, the interview findings emphasised the potential of hubs in the Netherlands that store materials with assured demand, incorporate logistical and processing capacities, maintain a clear digital inventory, and operate within a network of diverse hubs.

The above-described practical findings will be taken into account in the next chapter, where a comparison will be made between the practical insights and the theoretical insights from Chapter 3 on the realisation of urban mining hubs.

5. COMPARING THEORY AND PRACTICE

This chapter will compare the theoretical findings from Chapter 3 with the practical findings from Chapter 4, merging in a framework outlining essential steps for fostering urban mining hub realisation. The objective of this chapter is to address sub question 3, which is formulated as: *What are the first steps to kick-start the realisation of urban mining hubs in the Netherlands?* Section 5.1 will delve into the comparison of the theoretical and practical research findings. In Section 5.2, the formulation of an actionable framework will be explored, ultimately leading to a visualisation. The last section, 5.3, will provide the answer to third sub question.

5.1. Comparing theoretical and practical findings

This section will describe the similarities, contradictions, and additions between the theoretical results from Chapter 3 and practical results of Chapter 4. The structure of this section is based on the structure of Chapter 3, in which firstly, the relevance of hubs will be discussed, followed by the definition and role of urban mining hubs. Afterwards, the analysis of the stakeholder identification will be provided, as well as an elaboration on the (dis)advantages of urban mining hubs.

5.1.1. Relevance of urban mining hubs

The literature review, including the Transition Agenda, indicated that urban mining hubs have significant potential and offer advantages as an initiative in the circular economy (Rijksoverheid, 2018; Zeng, et al., 2022; van der Merwe, Cabernard, & Günther, 2023; Tsui, Furlan, Wandl, & Timmeren, 2023). However, while theoretical research highlighted their promise, practical findings (semi-structured interviews) revealed a variety of perspectives concerning their role and necessity. Furthermore, it became evident that the relationship between material reuse and the demand for hubs is pivotal: an increase in material reuse corresponds to a greater demand for hubs, which at this moment leads to the practical implementation of hubs remaining unrealised.

The results of the interviews indicated a spectrum of views regarding the relevance of urban mining hubs. Some stakeholders underscored the pivotal role these hubs can play in facilitating material reuse within the circular economy. However, they emphasised certain preconditions, such as the necessity to store only materials with assured market demand and the necessity of an online platform presenting the material inventory (including product specifications) of the hub. Additionally, they advocate for several prerequisites to increase material reuse and ensure the effective operation of such hubs, including the integration of CO_2-budgets into projects. Conversely, other interviewees envision alternative solutions that mitigate the necessity of urban mining hubs, such as the enforcement of Extended Manufacturers Responsibility legislation. Overall, there is no unanimous consensus among stakeholders regarding the relevance of urban mining hubs. The interviews depict a less optimistic perspective on the viability of urban mining hubs than the perspective obtained from the theoretical findings.

5.1.2. Definition of urban mining hubs

Prior to the interviews, the scope of the research was briefly discussed, including the presentation of the definition of urban mining hubs. To reiterate, the definition of urban mining hubs in this research is obtained from the literature review and is formulated as: *a physical[1], regional[2], and collaborative[3] centre which sorts, stores and transports[4] directly reusable and*

upcyclable building materials and products, extracted from anthropogenic stocks, to construction projects. During the interviews, it became apparent that the definition does not fully meet the needs of the involved stakeholders envisioning an urban mining hub.

1. The characteristic that a hub must be a physical centre has been confirmed by the interviewees. The literature review indicated that even when suitable secondary materials are found for new projects, the absence of (affordable) storage spaces prevent reuse (Rood & Evenhuis, 2023). The interviewees also indicated that a physical hub could play a crucial role in aligning project schedules of demolition and construction projects. There is a considerable amount of time between the design phases and the actual execution of new construction projects. During the design phase, consideration should already be given to available materials so that they can be incorporated into the design. Storage is needed for subsequent phases in the construction process to store these secondary materials from demolition projects before the project execution begins. This process of material reuse can only be facilitated through a physical space.
2. Based on the literature review, it was noted that urban mining hubs operate at the regional level (Tsui, Furlan, Wandl, & Timmeren, 2023). The interview results confirmed this. Additionally, it can be concluded from the interview results that stakeholders see the most potential in a network of hubs operating at the regional level, with hubs varying in size and material focus.
3. As the literature review suggested, the results of the interviews also concluded that urban mining hubs are a collaborative initiative (Chao-Duivis, Bruggeman, Koning, & Ubink, 2018; Guldager Jensen, et al., 2019; Rood & Evenhuis, 2023). The interviewees unanimously agreed that for material reuse and the development of hubs, all organisations engaged in the construction industry must be involved.
4. Focusing on functions, the literature review stated that urban mining hubs sort, store, and transport secondary materials (Tsui, Furlan, Wandl, & Timmeren, 2023). From the practical results, it appeared that the functions that a hub should facilitate are missing two essential components. Firstly, the interviewees indicated that a hub should also facilitate a logistical function and a processing function. Participants expressed potential in a combination of a circular and a logistical hub: a hub strategically positioned, for example, on the outskirts of densely populated areas, to reduce and minimise transport movements and with a focus on secondary materials. Secondly, it was discovered that many participants desire a hub to possess internal processing capabilities or to establish a strong connection with a processing organisation, enabling (deep)-cleaning, refurbishing, and/or customising the stored materials. By implementing a processing function or by connecting with a processing organisation, the focus of the hub can shift from solely directly reusable materials to a broad range of construction materials.

Taking into account the aforementioned additions from the practical results, the definition of urban mining hubs is revised. After comparing both findings, the revised definition of an urban mining hub is formulated as: *a physical, regional, and collaborative centre that facilitates the sorting, storing**, **processing, and efficient transportation** of **~~directly~~** reusable and upcyclable building materials and products, extracted from anthropogenic stocks, to construction projects.*

5.1.3. Role of urban mining hubs

In the literature review, the specific role of an urban mining hub in the overall process of urban mining is incompletely defined. It has been established from the theoretical and practical results that the hub can play a role in sorting, storing, processing, and efficiently transporting materials to new construction sites. The interviewees claimed that the hub should function within a network of interconnected hubs and should focus on materials with guaranteed demand. Distinct stakeholders defined materials with guaranteed demand as (1) materials already sold to new projects and require temporarily storage, (2) common (small) materials needed in every project, such as wood elements, doors, window frames, and sanity items, and (3) new materials leftover from construction sites.

Moreover, an essential precondition for successful organisation of a hub is the need for the hub to maintain a transparent inventory, possibly through an app or website. By making it visible and describing the conditions of the products, material reuse is facilitated for stakeholders.

Another role for the hubs emerged from the interview results, focusing on Extended Manufacturers Responsibility legislation. Implementing this legislation is seen as a comprehensive solution. By implementation this legislation in the construction sector, hubs could serve a different function than urban mining hubs, providing storage for materials and products reclaimed by manufacturers.

5.1.4. Stakeholder identification

The literature review identified ten different stakeholder groups and functions involved in the urban mining process. These included architectural firms, construction contractors, engineering consultancy firms, construction owners, demolition contractors, harvesting experts, material experts, and public organisations. These identified stakeholders led to the selection of interview participants. The practical results confirmed and supplemented the identified stakeholders with manufacturers. Additionally, the practical results provide insights into which stakeholders can exert the most influence on achieving urban mining hubs.

One stakeholder that emerged as crucial from the interviews but was not mentioned in the literature study is manufacturers. Stakeholders expressed a desire for manufacturers to take responsibility for reclaiming materials and products, processing them while preserving their original value as much as possible, and reintroducing them to the market with quality assurances and warranties. This would enable direct reuse with minimal loss of original material value and address issues related to liability and quality. Furthermore, both private and public stakeholders argued that manufacturers have the expertise and knowledge to process secondary materials and produce them on a large scale, thus solving the problem of insufficient supply. The take-back of materials and products by manufacturers is seen as a key solution in a circular economy and could even minimise the need for urban mining hubs.

The practical findings also highlighted the influence of different construction stakeholders. It became apparent that clients, architects, and engineering consultancy firms play crucial roles in boosting the demand for secondary materials. This demand increases when secondary materials are mandated in project assignments and when demountable construction is incorporated in designs, obliging contractors to adopt these practices. From the start of a new construction project, clients have most influence and should therefore set clear (and elevated) circularity requirements in their assignments. From the practical results, it became evident that private parties (in public procurement processes) strictly adhere to the project requirements and are reluctant to take any additional steps regarding circularity and sustainability. This is often still cost increasing, reducing the likelihood of winning a tender. It is crucial for both

clients and contractors to consider environmental impact in design considerations, not solely the financial considerations.

According to interviewees, construction contractors have limited influence on the stimulation of urban mining hub realisation. This is because they are primarily execution-oriented and carry out what is required in the assignment. However, it is expected that construction contractors will take significant steps towards circularity (by adjusting their business operations) and take more responsibility for their own activities. Furthermore, they currently play an important role in future renovation and demolition projects. By implementing circular building methods, such as demountable or modular construction, circular demolition is facilitated during the end-of-life phase of a construction. Demolition contractors are already taking important steps towards a circular economy, according to interviewees. Their influence is particularly significant on the supply side by providing secondary materials from projects.

5.1.5. Advantages and barriers of urban mining hubs

Regarding the advantages, both the theoretical and practical results highlighted the benefits of urban mining hubs. The practical results confirmed the environmental benefits of material reuse and the implementation of hubs described in the literature review. Most financial benefits obtained from the literature analysis were also mentioned in the practical results, except for the cost-saving benefits on secondary materials compared to primary materials. Most stakeholders discussed that currently the traditional construction and demolition methods are less expensive than circular variants. The financial considerations are often leading in the decision-making processes, resulting in traditional methods being preferred. Only Arch1 and Cons2 argued that circular demolition can be cheaper than traditional demolition when considering the residual value of the materials of the construction. Consensus among all stakeholders has been reached on the fact that circular materials are more expensive than primary materials. Besides the fact that it takes a lot of labour to harvest the materials from constructions, further processing is needed to enable application of the secondary materials in new constructions. The labour required for this process increases the costs of secondary materials, usually leading to a preference for primary materials in projects.

Regarding the disadvantages and barriers mentioned in the literature review, a variety of barriers were discussed during the interviews. Practical, financial, and legal obstacles contributing to minimal material reuse and consequently a reduced demand for urban mining hubs. The interviews identified more development barriers than the literature review. Therefore, Table 14, Table 15, and Table 16 will describe respectively the practical, financial, and legal barriers identified in both the theoretical and practical results. Additionally, the tables indicate the solutions mentioned during the interviews and which stakeholder is responsible for or involved in the solution.

Table 14. Elaboration on the practical barriers identified in theoretical and practical results including suggested solutions.

	BARRIERS	ATTRIBUTED TO	OBTAINED FROM		SOLUTIONS GIVING BY INTERVIEWEES	INVOLVED OR RESPONSIBLE STAKEHOLDER(S)
	Practical barriers					
1.	**Complexity in matching secondary materials**					
1.1.		Uncertainties in material potential scans and missing technical and quality specifications of harvested materials.	**Theory:** - Arora, Raspall, Fearnley, & Silva (2021)	**Practice:** - Arch1 - Cons1 - Contr1 - Contr2	A. Standardising material passports of constructions (content remains transparent at the end of its lifespan). B. Further research into potential scanners using AI or 3D scanners.	Clients and construction owners All stakeholders
1.2.		Insufficient supply and diversity (inability to meet current demand).	**Theory:** - Espinoza, Rostek, Loibl, & Stijepic (2020)	**Practice:** - Cons1 - Cons2 - Contr1 - Contr2 - Public2	A.1. Implementing circular demolition as standard procedure. A.2. Followed by presenting harvested materials on a digital marketplace accessible to stakeholders. B. Enforcing higher circularity standards in projects and contracts (encouraging material reuse). C. Manufacturers reclaiming materials (ability to generate large volumes).	Demolition contractors, construction owners, Ministry of the Interior and Kingdom Relations, Ministry of Infrastructure and Water Management and regional/local governmental authorities. Clients Manufacturers

1.3.		Uncertainty regarding quality, guarantees, and liability for secondary materials.	**Theory:** - Arora, Raspall, Fearnley, & Silva (2021) - Espinoza, Rostek, Loibl, & Stijepic (2020) - Loeber & Snoek (2020)	**Practice:** - Arch1 - Arch2 - Cons1 - Cons2 - Contr1 - Contr2 - Demo2 - Public 1	A. Manufacturers reclaiming materials (applying quality assurances and guarantees on reintroduced materials). B. Developing new calculation methods to determine the quality of second-hand materials and establishing a common language to uniformly share these specifications (in terms of quality and circularity), thus making material reuse more attractive.	Manufacturers Collaboration between all stakeholders
2.	**Lack of physical space for hub development**		**Theory:** - Claessens (2021) - Rood & Evenhuis (2023) - Witlox (2019)	**Practice:** - Arch1 - Arch2 - Contr1 - Demo1 - Public1 - Public2	A. Prioritising circularity in business operations (making space available on organisations' sites). B. Facilitating and allocating location and space.	All private stakeholders Municipalities or provinces

Table 15. Elaboration on the financial barriers identified in theoretical and practical results including suggested solutions.

	BARRIERS	ATTRIBUTED TO	OBTAINED FROM		SOLUTIONS GIVEN BY INTERVIEWEES	INVOVLED OR RESPONSIBLE STAKEHOLDERS
	Financial barriers					
3.	**Circular construction and demolition methods are more expensive than traditional ones**		**Theory:** - van Luik, de Wilde, & Blokzijl (2023) - Metropoolregio Amsterdam (n.d.) - Loeber & Snoek (2020)	**Practice:** - Arch1 - Cons1 - Cons2 - Contr1 - Contr2 - Demo1 - Demo2 - Public 1	A. Critically evaluating the residual value of materials and projects and incorporating this into the design phases of new projects so that material value is seen as an investment that can be recouped at the end of a construction's lifespan. B. Investigating whether tax shifting has a positive effect on material reuse (reducing taxes on labour or secondary materials and/or increasing taxes on primary materials).	All stakeholders Ministry of Finance

Table 16. Elaboration on the legal barriers identified in theoretical and practical results including suggested solutions.

	BARRIERS	ATTRIBUTED TO	OBTAINED FROM		SOLUTIONS GIVEN BY INTERVIEWEES	INVOVLED OR RESPONSIBLE STAKEHOLDERS
	Legal barriers					
4.	**Current regulations obstructing material reuse and hub development**					
4.1.		Regulations (e.g., Bouwbesluit and construction standards) fail to align with circularity ambitions.	**Theory:** - Kumar, Sezersan, Gonzalez & Al-Shboul (2019) - Loeber & Snoek (2020)	**Practice:** - Arch1 - Cons1 - Contr1 - Demo1 - Demo2 - Public 1 - Public 2	A. Critically revising Bouwbesluit and construction standards/norms, so that the current regulations no longer hinder but enable and possibly even facilitate the use of secondary materials. B. Critically examining which materials need to meet specific criteria (example: not all materials in a construction need to meet specific fire safety requirements).	Ministry of Interior and Kingdom Relations (in collaboration regulatory bodies and Dutch Standardisation Institute (NEN)) All stakeholders
4.2.		Insufficient tax system not stimulating material reuse.	**Theory:** -	**Practice:** - Cons1 - Cons2 - Demo2 - Public1	Investigating whether tax shifting has a positive effect on material reuse (reducing taxes on labour or secondary materials and/or increasing taxes on primary materials).	Ministry of Finance

5.	**Lack of circularity strategy from public organisations**	**Theory:** -	**Practice:** - Arch1 - Cons1 - Contr2 - Demo2 - Public1	Developing a multi-year plan with actionable steps, clarified milestones, and potential sanctions.	Public organisations (in collaboration with industry stakeholders and experts)

The tables depict that most barriers are supported by both theoretical and practical evidence. The practical results further elaborate on the barrier concerning current regulations obstructing material reuse and hub development, stating the insufficient tax system as a factor hindering material reuse (see Table 16). Additionally, the practical findings add that due to the lack of a circularity strategy from public organisations (and fluctuations in circular ambitions), they are uncertain and hesitant to make significant investments towards a more circular business model (see Table 16).

The comparison of results provides a comprehensive view of the current state of hub realisation. This comparison will be integrated into the development of a step-by-step framework in Section 5.2, distinguishing various phases to achieve hub realisation. Within each phase, stakeholders will be responsible for simultaneously executing actions to address the identified barriers and enhance the potential for hub development.

5.2. Framework development

The aim of this research is to outline actionable steps stakeholders need to take to stimulate the realisation of urban mining hubs in the Netherlands and visualise this in a framework. During the interviews, the *chicken-and-egg* problem regarding hub realisation was often referenced. Based on this, it became clear that various phases exist in which both private and public stakeholders must take simultaneous action. The objective of transitioning from the current state (with limited material reuse and without a large implementation of hubs) to a desired future state (with standardisation of material reuse and hubs) shares similarities with change management. Change management is a systematic process in which organisations or systems overcome challenges to shift from a current state (existing methods and practices), through a transition, to a new desired future state. Change management focuses on addressing the needs and actions of stakeholders affected by the change (Hughes, Dwivedi, Simintiras, & Rana, 2016; Hamdo, 2021). The development of the framework was influenced and inspired by two change management models: *Lewin's 3-stages model for change management* and *Prosci's 3-phases process for change management* (Lewin, 1951; Hiatt & Creasey, 2003). Both models show strong similarities with each other and are depicted in Figure 8. Lewin's model has been used as an inspiration and defines three stages, of which in the first stage, *Unfreeze*, urgency must be created and appropriate steps to initiate change must be determined. In the second phase, *Change*, the steps are executed and requirements are implemented. In the final phase, *Refreeze*, the change must be reinforced and stabilised to ensure it becomes permanent (Kazmi & Naaranoja, 2014; Hamdo, 2021). Regarding Prosci's model, in the first phase, *Preparing for Change*, the goal is to prepare for the change by defining steps for the change management strategy. In the second phase, *Managing Change*, change must be managed by developing and implementing management plans that enable the change. In the third phase, *Reinforcing Change*, the change is reinforced by assessing and evaluating the steps, and making necessary adjustments (Abdulkadhim, Bahari, Bakri, & Ismail, 2015).

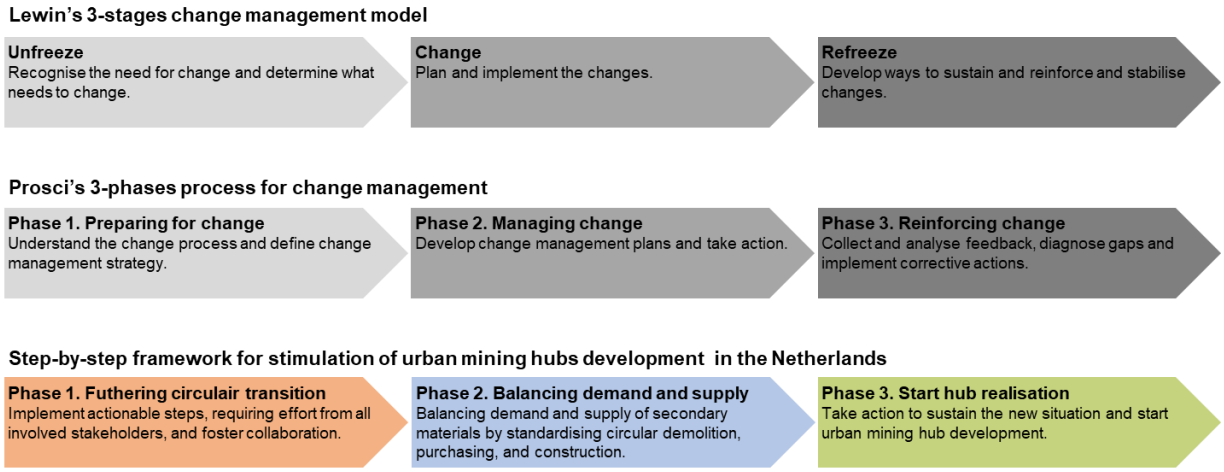

Figure 8. Overview of the change management model of Lewin and Prosci (Lewin, 1951; Hiatt & Creasey, 2003) and the research framework for stimulation of urban mining hubs development in the Netherlands.

The step-by-step framework of this research is constructed based on theoretical and practical results. As illustrated in the bottom framework of Figure 8, the first step is to further advance the transition to a circular economy, with the aim of increasing material reuse. This requires preparing for change and organisations detaching themselves from the current state. The ambition of this phase is to create urgency to increase material reuse. Subsequently, to enable material reuse on a larger scale, balancing the supply and demand of secondary materials is necessary. This is the phase in which the change must be managed by executing the necessary steps and implementing requirements. Since the practical results demonstrate a clear connection between material reuse and the need for hubs, an increase in material reuse will lead to an increased need for hub realisation, resulting in the third phase. In the final phase, stakeholders need to take steps to sustain the taken actions and the previously made changes. Unlike the aforementioned models of Lewin and Prosci, this framework requires further elaboration on the steps taken and developments. In the last phase, hubs need to be developed and an evaluation should be conducted to determine if the steps and responsibilities of each stakeholder have been addressed. To progress through these three phases and stimulate urban mining hub realisation, stakeholders are required to undertake various steps across all phases. Each phase will be elaborated on in more detail below.

Phase 1: Currently, private parties, and to some extent also public parties, are not taking sufficient actions to achieve the goal of a fully circular build environment by 2050 and to advance the transition towards a circular economy in general. According to the private parties, this is mainly a result of the lack of legislative mandate and guidance. Consequently, there is a need for enforcement by public organisations and clients to strive for circularity within projects. However, as this enforcement can only be applied to a limited degree, a voluntary aspect, such as a change in mindset and business operations, is also required. In order to start the realisation of urban mining hubs, legislation and internal policies need to be in place.

Phase 2: As the demand for secondary materials will gradually increase after phase 1, it is crucial to ensure that the supply of these materials aligns with the needs of the construction industry. To boost supply and meet demand, circular demolition and construction are essential. This underscores a significant role for construction and demolition contractors. Simultaneously, the utilisation of secondary materials influences the necessity to develop hubs. Only when material reuse escalates further, beyond the new and revised regulations outlined in phase 1, does the facilitating role of a hub become necessary. All stakeholders play a role in balancing the demand and supply of secondary materials.

Phase 3: Continuing to phase 3, the construction sector is increasingly focused on circularity, and the alignment of supply and demand for secondary materials is improving, leading to the emergence of a facilitating role for the hubs. Addressing the issue, there is a need for storage space due to the often mismatch in schedules between demolition and new construction projects. The final phase revolves around initiating the realisation of urban mining hubs. According to practical results, this initiative has the highest likelihood of success if undertaken by a private organisation or a collaboration among various private parties. Additionally, urban mining hubs will only play a significant role in circular construction processes when all parties, both private and public, utilise them. In this phase, public organisations serve a facilitating function by designating land, connecting organisations, and streamlining processes (such as expediting permit issuance).

For initiating hub development organisations, it is crucial to consider three key features to maximise the potential of urban mining hubs. The hub should:

- Exclusively store materials with a guaranteed market, such as secondary materials already allocated to new projects, commonly required materials in new projects, or surplus new materials from construction sites.
- Ensure transparent insight into the hub's inventory through a digital marketplace accessible to all stakeholders, providing materials' quality and technical specifications.
- Implement logistical and processing capabilities to facilitate efficient transport and customisation of stored materials.

After phase 1 to 3: The subsequent phase of this step-by-step framework should evaluate the impact of the initial hub implementations. Additionally, it should explore the potential of a network of various hubs, varying in size and material focus.

The comparison between the current theoretical and practical insights on urban mining hubs lead to a visual representation of a step-by-step framework towards the stimulation of urban mining hub development with actionable steps for all involved stakeholders. The first version of this framework is shown in Figure 9.

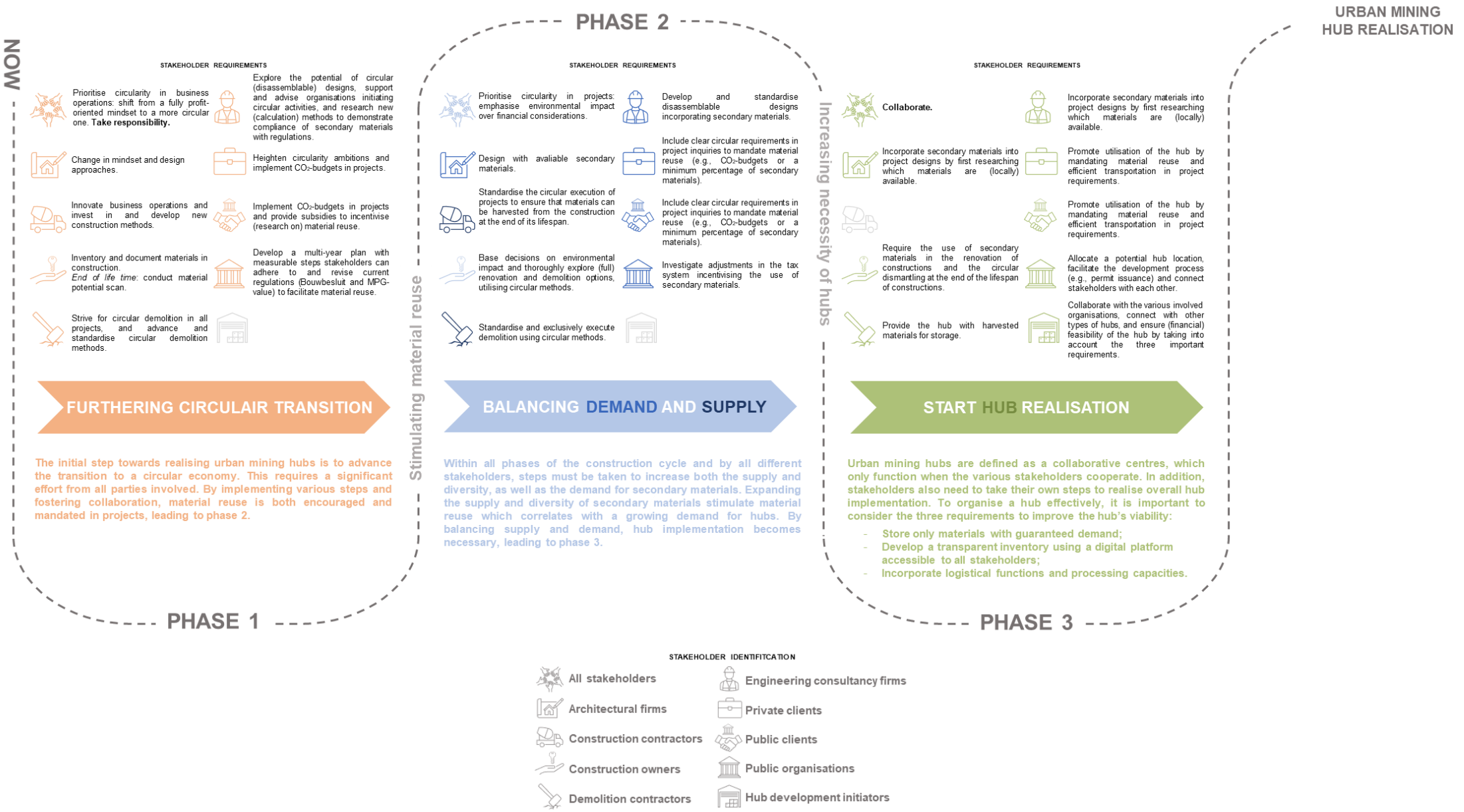

Figure 9. First version of step-by-step framework to stimulate urban mining hub realisation in the Netherlands.

5.3. Answer to sub question 3

The comparison of the theoretical and practical findings aimed at addressing the third sub question of this research. Sub question 3 was stated as: *What are the first steps to kick-start the realisation of urban mining hubs in the Netherlands?* The theoretical and practical findings identified three phases toward hub establishment: advancing the transition to a circular economy, balancing the supply and demand of secondary materials, and responding to the increasing need for hubs by starting hub realisation. To achieve this, stakeholders must (simultaneously) undertake various actions across all phases, as outlined in both the theoretical and practical findings, as well as in the comparison between them.

The conclusion drawn from the comparison is that, currently, stakeholders do not perceive significant potential in realising urban mining hubs. This contrasts with the theoretical findings, which emphasises the prospects and benefits of urban mining hubs. The interview results highlighted the need for stakeholders to take steps to address the barriers prevent hub realisation and encourage the transition to a circular economy. Furthermore, this comparison indicated again the crucial connection between material reuse and the demand for circular hubs, including urban mining hubs.

Regarding the definition of urban mining hubs, it is evident that a hub should not only facilitate sorting, storing, and transport but also encompass logistical functions and processing capabilities or establish strong relationships with processing organisations. In urban mining hubs, to enhance prospects, only materials with assured demand should be stored, made transparent to all stakeholders through a digital marketplace.

The literature review identified stakeholder groups involved in urban mining, including architectural firms, construction contractors, construction owners, demolition contractors, engineering consultancy firms, harvesting and material experts, and public organisations. These stakeholders guided the selection of interview participants, and the practical results confirmed their influence. Manufacturers emerged as a crucial stakeholder, with stakeholders advocating for their involvement in reclaiming and processing materials. Both private and public stakeholders emphasised the expertise of manufacturers in addressing various barriers, particularly concerning quality assurances and volume generation. Clients, architects, and engineering consultancy firms play key roles in boosting demand for secondary materials, particularly through mandating their use, implanting specific circularity requirements in projects, and incorporating demountable and modular construction practices. Contractors have limited influence on urban mining hub realisation but are expected to adapt their operations to embrace circular practices. Additionally, circular building methods like demountable or modular construction facilitate circular demolition in future projects. Demolition contractors are already contributing significantly to the circular economy and play a pivotal role in providing secondary materials.

Lastly, various advantages and (development) barriers are identified in both theoretical and practical results, showing that stakeholders perceived material reuse as complex (difficult to find sufficient secondary materials) and costly (reuse is labour-intensive). Along with strict building standards, in many new projects primary materials are still preferred. The comparison of the barriers identified in the literature review and the interview results showed overlap. However, the practical findings supplemented two significant barriers that hinder the development of urban mining hubs. Firstly, the lack of a circularity strategy from public organisations leaves private organisations uncertain and reluctant to invest. Secondly, an inadequate tax system fails to incentivise material reuse. The current tax structure makes new materials comparatively cheaper, leading to a preference for primary materials in new construction projects, as secondary materials require more labour, increasing costs.

As this research aimed to outline actionable steps for stakeholder to stimulate the establishment of urban mining hubs, the framework in Figure 9 has been developed. In the

first phase, the goal is to advance the transition to a circular economy. The results revealed that the transition is a precondition for the development of hubs. Additionally, urban mining hub realisation is a means to achieve a circular economy, not an end in itself. In phase 1, the initiative lies mostly with the parties themselves. Advancing the transition will partly need to be done voluntarily, while another part can be facilitated or mandated through revised regulations or CO_2-budgets in projects. Developing a strategy with clear and measurable steps is also part of this phase. It is crucial that public organisations initiate this process so that private parties can align with it and take appropriate actions. Practical results clearly indicated that private parties will only take action when they are certain that circularity is either mandatory or the new standard.

Regarding phase 2, both theoretical and practical results indicated that the current supply of secondary materials does not meet the demands of the construction sector. The demand side requires more supply, of better quality, and in larger quantities. Construction and demolition contractors play a pivotal role in the provision of good secondary materials. A sufficient and high-quality supply can only be achieved if demolition contractors adopt circular demolition practices. Additionally, contractors must adopt disassemblable construction methods for new projects to facilitate easier circular demolition in the future. The financial risks associated with circular demolition (high labour costs) are mitigated when there is sufficient demand for secondary materials. This is because there is a guaranteed market for these materials, and the labour costs can be covered by the revenue from their sale.

On the demand side, architectural firms, engineering consultancy firms, and clients play crucial roles. In this phase, it is important for clients to set clear and measurable requirements for material reuse in new projects, for example a minimum percentage of reused materials or CO_2-budgets that prioritise secondary materials over primary ones. Additionally, architects and engineering consultancy firms need to design with available secondary materials in mind. It is important to note that the demand and supply of secondary materials will never be completely equal. As mentioned by Espinoza, Rostek, Loibl, & Stijepic (2020), the current reserves of materials in anthropogenic stocks are insufficient for the amount being newly built. Therefore, it is crucial to minimise the environmental impact of construction projects by maximise material usage in projects and, if more material is needed than available, to consider other circular materials, such as biobased materials.

Moving into phase 3, the construction sector is increasingly embracing circularity, with a better alignment of supply and demand for secondary materials, leading to the rise of hubs playing a facilitating role. However, storage space is needed due to scheduling mismatches between demolition and new construction projects. This phase focuses on initiating urban mining hubs, which are most likely to succeed when led by private organisations or collaborations. These hubs will be pivotal in circular construction processes only if both private and public sectors engage with them. Public organisation can facilitate the process by providing land, connecting organisations, and streamlining processes. Initiating hub development requires considering three vital features: exclusive storage of materials with a guaranteed market, transparent inventory management through a digital marketplace, and efficient logistical and processing capabilities for material transport and customisation.

Summary of answer to sub question 3:
The comparison between theoretical and practical findings has yielded new insights on the alignment, divergence, and/or complementarity of theory and practice. Concerning the definition of urban mining hubs, it became apparent that urban mining hubs should not only offer storage but also logistical and processing capacities. Furthermore, the stakeholder

landscape should include manufacturers. Moreover, the comparison revealed that the practical results also identified two additional barriers, namely: public organisations lack a circularity strategy, and the existing tax system fails to incentivise material reuse. This comparison has outlined three essential phases toward establishing urban mining hubs in the Netherlands: advancing the transition to a circular economy, balancing the supply and demand of secondary materials, and initiating hub realisation. In each phase, both public and private stakeholders are responsible for progression and must simultaneously take various actions.

The first version of the step-by-step framework for simulating the realisation of urban mining hubs in the Netherlands, developed through comparing theoretical and practical findings, will be evaluated by experts in the subsequent chapter.

6. EVALUATING THE FRAMEWORK

This chapter will describe the experts evaluation session and will address sub question 4, which is phrased as: *How do experts evaluate these defined first steps?* Section 6.1 will outline the participating experts and the process leading up to the session. In Section 6.2, the evaluation of the step-by-step framework, distinguishing between the evaluation of visualisation and content, will be detailed. In Section 6.3, the final framework, as adjusted based on the evaluation feedback, will be presented, followed by the answer to fourth sub question in Section 6.4.

6.1. Participants of experts evaluation

As described in the research by Veen et al. (2017) and de Jongh et al. (2017), the knowledge and expertise from experts are considered valuable sources to verify research results on accuracy and comprehensiveness. Three inclusion criteria were established beforehand to select suitable experts for the evaluation process. All participants must (1) have experience in circular construction and have collaborated with all relevant public and private stakeholders, (2) possess a minimum of four years of work experience, and (3) hold at least a bachelor's degree. Four experts from Brink Groep were invited by email to evaluate the research deliverable: a step-by-step actionable framework on stimulation towards urban mining hub realisation in the Netherlands. Once the experts confirmed their participation in the experts evaluation meeting, the specific appointment was sent by e-mail. The details of the experts involved in the evaluation session are outlined in Table 17.

Table 17. Identification of participants involved in experts evaluation.

	QUALIFICATION	POSITION	EXPERTISE	EXPERIENCE
				Years
1.	Master's degree	Process manager	- Circular campus and hub development - Involvement in Cirkelstad development	5
2.	Master's degree	Project manager	- Consultant in circular construction - Involvement in Cirkelstad development	4
3.	Bachelor's degree	Project manager	- Experience within construction contractors - Involvement in Cirkelstad development	10
4.	Master's degree	Senior manager	- Circular campus and hub development - Experience within architectural firms, construction contractors, and project developers.	25

The step-by-step framework was sent prior to the evaluation session to all participants via email. This allowed the experts to review and become familiar with the model. The evaluation meeting started with a brief presentation on the research topic and the methodology, followed by a discussion on the model. Throughout the presentation, the experts were encouraged to ask questions and further explore the topic. During the meeting, both the visualisation and the content of the framework were evaluated.

6.2. Step-by-step framework evaluation

The evaluation of the framework started with general feedback regarding the presentation method and how the model was perceived and understood by the experts. The feedback on this aspect will be detailed in Section 6.2.1. Subsequently, the evaluation of the content was also conducted, which will be described in Section 6.2.2.

6.2.1. Evaluation of visualisation

The experts evaluated the model as clear and well-organised but noticed that the framework appeared to illustrate a linear process. They pointed out that an innovation process, such as the stimulation of urban mining hub development, is not linear and often involves iterative steps. The visualisation is adjusted to address this feedback: light grey lines are added indicating the iteration, and the names of the different phases are replaced in blocks instead of arrows. The first phase is not an iterative phase, as each step brings the transition closer to the goal of a fully circular built environment. After each step, it becomes increasingly difficult and less desirable to return to the old situation/the starting point. The other two phases do have an iterative nature.

Additionally, the experts suggested incorporating the significance of a stakeholder's influence per phase. However, this was intentionally excluded to prevent parties from blaming each other and to avoid visualising the *chicken-and-egg* problem in the framework. Similarly, indicating which step within a phase should be taken first was excluded. The phasing indicates which steps various stakeholders must take first to expand hub implementation. It is essential for parties to take simultaneous steps to achieve innovation and stop waiting for other parties to take the first initiative. Therefore, the specific sequence of steps within a phase is therefore not important.

6.2.2. Evaluation of content

As previously indicated, experts have observed that the visual representation appears to depict a linear model. This perception is supported not only by the method of presentation but also by the numbering of various phases. Consequently, the phases have been renamed, with the final phase focusing on expanding the hub network, which emerged as the most promising vision from practical results. These adjustments have also necessitated revisions in the phase descriptions. Besides that, the experts discussed that project developers should have been considered in the semi-structured interviews as a key stakeholder as well, given their significance in the construction industry. However, project developers were not mentioned during the interviews, and interviewees did not specify any steps involving them, so they remained excluded from the framework. Another general feedback point was that steps could be described more sharply and precisely. This feedback has been integrated into the development of the final model. At last, the experts proposed incorporating a small description of the current situation and the existing problem. According to the experts, this would provide greater insight into the ultimate goal following completion of the framework. This feedback has been addressed.

Phase 1: During the evaluation meeting, a discussion centred on the terminology of the phases in the model. From this, it was concluded that the first phase is essential in initiating the learning process on material reuse and the implementation of urban mining hubs. Renaming this phase from phase 1 to *initiation* phase, encouraged the experts to suggest several new steps in this phase, particularly for hub initiating organisations. These organisations can undertake actions to develop the type of hubs outlined in this research. According to the experts, this step should be executed in the first phase, as hubs are needed for balancing supply and demand in the second phase. They also proposed a division in public organisations at the scale level to be a crucial addition. All feedback points have been addressed and incorporated into the model.

Phase 2: After a discussion on renaming this phase, the experts confirmed that this phase is crucial for scaling up hub realisation and should certainly serve as the second component in the framework. This phase has been renamed to the *optimisation* phase following the discussions with the experts. Here, the experts also suggested that hub initiators should conduct an exploratory step. According to the experts, hub initiators are responsible for making secondary materials available to all stakeholders and should continuously assess the lessons learned regarding supply and demand. For instance, they should monitor stakeholders' material preferences (which materials are always needed), materials that are challenging to reuse, and materials that must meet strict quality standards or requirements. This data and experience are essential for optimising individual urban mining hubs and implementing a network of various hubs. This feedback and rewriting the steps per stakeholder have been incorporated into the model.

Phase 3: The term *start hub development* in the third phase was criticised by experts. A discussion was held during the evaluation session on this topic. The experts noted that already some progress has been made in the development of local urban mining hubs. However, this concerns local initiatives around urban mining hub development, primarily carried out by intrinsically motivated organisations, which are not adequately be developed and implemented. Furthermore, these hubs do not meet the definition of urban mining hubs outlined in this thesis. According to the experts, terms like *scaling up hubs*, *increasing hub efficiency*, or *developing a network of hubs* would be more appropriate. By considering both perspectives, this led to the renaming of the third phase to the *expansion* phase, which is further elaborated as scaling up hub realisation. In this phase as well, the steps per stakeholder have been adjusted and articulated more precisely to better align with the phase.

After phase 1 to 3: The subsequent actions of this framework should aim to evaluate the impact of a network of diverse hubs, differing in size and material focus. As an addition to the continuation, experts recommended assessing a possible connection between the hub's network serving the business market and hubs serving to the consumer market, such as hardware and do-it-yourself stores. Enabling the transfer of materials from regional operating hubs to local hubs ensures that materials are not stored for extended periods, especially when there might be higher demand for those materials in (local) consumer-market hubs.

6.3. Final framework

The evaluation feedback has been incorporated into the model, resulting in the final framework depicted in Figure 10.

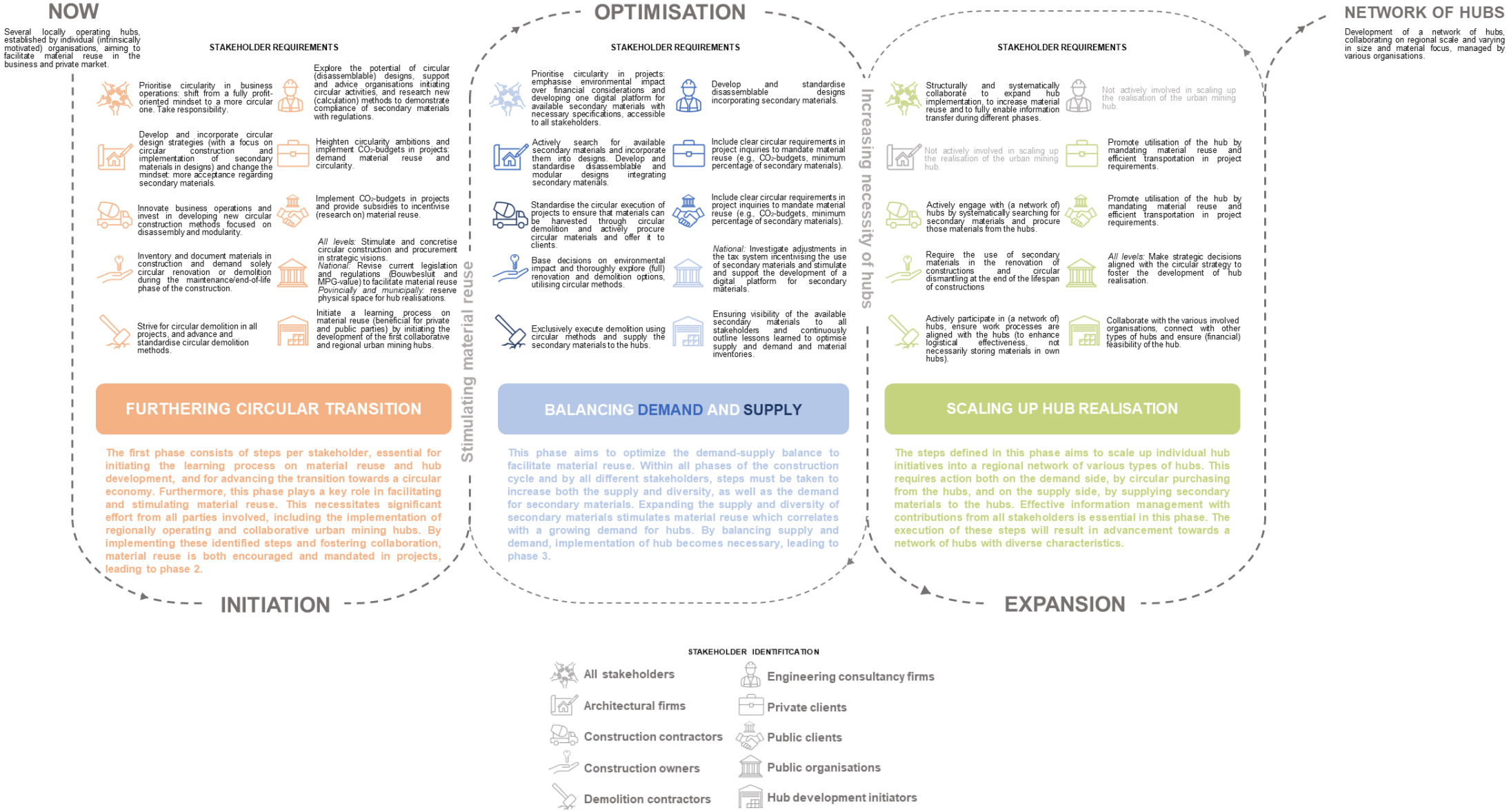

Figure 10. Final version of step-by-step framework to stimulate urban mining hub realisation in the Netherlands.

6.4. Answer to sub question 4

The experts evaluation aimed to verify and discuss the step-by-step framework and to provide an answer to sub question 4, which was formulated as: *How do experts evaluate these defined first steps?* The experts evaluated the framework positively, acknowledging its clarity and structure. They confirmed the problems the framework aims to resolve, but argued that it would be more clarifying when the current state and the end goal were described in the model. They noted that the framework seemed to depict a linear process, which not accurately represents the iterative nature of an innovation and circularity process. Considering this comment, adjustments were made to the visualisation. Additionally, experts suggested incorporating stakeholder influence per phase, but this was intentionally excluded to prevent passive attitude among stakeholders and avoid confirming the *chicken-and-egg problem*. Descriptions of the phases and the steps were sharpened based on general feedback to improve clarity.

Regarding the first phase, renamed as the *initiation* phase, experts confirmed the importance of advancing the transition towards a circular economy. They highlighted that this phase initiates the learning process on material reuse and the implementation of urban mining hubs. Additionally, they suggested that hub initiators should take initial steps towards realising larger scale and collaborative hubs. Furthermore, a distinction was suggested and implemented on steps for public organisations. In the final model, steps depend on the operational level of the public organisations. All levels of public organisations should develop and concretise a vision for circular construction and acquisition. At the national level, public organisations need to revise current legislation and regulations to stimulate and incentivise material reuse. At the local level, such as provinces and municipalities, a strategic step would be to reserve physical spaces for expanding hub realisation. Overall, the experts agreed on the significant effort required from all stakeholders to encourage and mandate material reuse in projects.

The participants viewed the second phase, *optimisation* phase, as crucial in hub development. During the discussion, it was noted that while circular demolition is currently being carried out, there remains a lack in demand (mainly caused due to insufficient supply, financial considerations, and challenges related to quality and liability), resulting in demolition contractors being unable to sell secondary materials. This makes it financially risky for them to store circular materials. The experts also experienced this within their own projects and agreed that this cycle needs to be broken by taking steps on both the demand and supply sides. The demand of secondary materials needs to increase, with architects, engineering consultancy firms, and clients playing a large role. The supply side needs to be boosted through the execution of circular demolition by contractors. Furthermore, the expert suggested that public organisations have a supportive role in this by exploring solutions solving the financial barriers of material reuse and facilitating the development of a digital marketplace. Additionally, the experts suggested that hub initiators should monitor operations within the hub to ultimately optimise the hub's functioning and material inventory.

The experts evaluated the third phase the least favourably, primarily because the term *start hub development* contradicted with the current first initiatives in hub development. They pointed out that some progress has already been made in the development of local urban mining hubs. A discussion comparing the current status according to experts and theoretical research findings led to renaming the third phase as the *expansion* phase, with the aim of scaling up urban mining hub realisation. The ambition to develop a network of various types of hubs aligns with practical research findings and is therefore incorporated into the model. By renaming this phase and considering the input of the experts, new steps per stakeholder were defined to better align with the phase description. Additionally, experts emphasised the necessity of strong information management in this phase, highlighting the importance of contributions from all stakeholders.

Overall, experts acknowledged that executing the defined steps during the three phases will lead to advancement in the overall process progressing towards a network of diverse types of hubs.

Summary of answer to sub question 4:
Experts evaluated the model positively, highlighting its clarity and structure, but suggested including the current state and end goal to enhance understanding of the framework's objective. They also noted the model's linear visualisation did not represent the iterative nature of innovation, leading to adjustments. The first phase, renamed the *initiation* phase, emphasises advancing towards a circular economy. Experts recommended hub initiators take initial steps toward larger collaborative hubs. Steps for public organisations were distinguished by operational levels and the required significant stakeholder effort to increase material reuse in projects was underscored. The second phase, renamed *optimisation* phase, was seen as crucial, with experts suggested steps to increase the demand through architects, engineering firms, and clients, and boosting supply via circular demolition. Public organisations should address financial barriers and support a digital marketplace. The third phase, renamed the *expansion* phase, aims to scale up hub realisation and develop a network of diverse hubs. Experts emphasised strong information management and the significance of stakeholder contributions. Overall, they agreed that following these phases would advance the development of diverse urban mining hubs in the Netherlands. The comprehensive discussion resulted in adjustments to the initial framework, leading to the final version of the step-by-step framework for stimulating urban mining hubs.

In the next chapter, the discussion, all theoretical and practical findings, and their comparison will be considered, elaborating on the contribution of this research to literature and practice, the research limitations, critical reflection, and any additional findings not previously detailed.

7. DISCUSSION

This chapter aims to explore and evaluate the relevance, limitations and (additional) findings of this research. In Section 7.1, the contribution of this research to both theory and practice will be discussed. The research limitations will be addressed in Section 7.2, with critical reflection on the results in Section 7.3. Afterwards, Section 7.4 will further elaborate on additional research findings.

7.1. Contribution of research

This research aimed to provide new understanding about the strategy essential to stimulate urban mining hub realisation in the Netherlands by developing a step-by-step framework. To establish this framework a systematic literature review and semi-structured interviews were conducted, after which the developed framework was evaluated through an experts evaluation. The comparison of the literature study and practical findings, covering both the theoretical and practical perspectives on hub development, was beneficial for thorough exploration of this topic and valuable input for the framework.

During the systematic literature review, numerous and diverse (scientific) articles have been analysed, none of which provided a clear definition and role of urban mining hubs in the overall process of urban mining. It became evident that this novel concept is not yet well studied or defined in scientific literature as noted by Adams et al (2017) and Tsui et al. (2023). Various references including Van Rijn et al. (2020), Van Merriënboer et al. (2022), and Yang et al. (2023) have been combined to establish the definition and role of urban mining hubs and identify the involved stakeholders. This research contributes to the current theory by providing a clear definition and role of urban mining hubs and by identifying all stakeholders involved in the process of urban mining.

Furthermore, in the theoretical and practical findings, it became clear that many steps still need to be taken to realise the transition to a circular economy and a fully circular built environment. The Transition Agenda and the analysed literature described a positive outlook on hub development (Rijksoverheid, 2018; Zeng, et al., 2022; van der Merwe, Cabernard, & Günther, 2023). Besides outlining several barriers, the literature review mainly focuses on the advantages of these hubs and the solutions they offer, seeing great potential in various types of hubs, including urban mining hubs. In contrast to the literature review, the practical findings shed light on the practical aspects of the hubs, revealing that stakeholders saw less value and necessity in the implementation of hubs. This could mainly be attributed to the limited material reuse and the insufficient alignment of the construction industry with circular processes. When comparing the theoretical findings with the practical findings, it became apparent that the first necessary steps to stimulate hub development are primarily aimed to advance the transition towards a circular economy and stimulate material reuse.

Comparing the findings from both the literature review and semi-structured interviews, encompassing theoretical and practical perspectives on hub development, provided an overview of where the findings confirm, contradict, or complement each other. In this study, it was discovered that the practical findings supplement the existing literature regarding current legal barriers hindering the establishment of hubs. For instance, the insufficient tax system, which fails to incentivise material reuse, and the absence of a concrete circularity strategy from public organisations contribute to the reluctance of private organisations to invest in circular approaches.

Additionally, this research contributes an actionable framework on how hub realisation can be stimulated in the Netherlands, serving as a discussion document for all involved stakeholders and initiating hub developers to clearly understand what steps need to be taken to stimulate urban mining hub realisation in the Netherlands. Theoretical research mainly focuses on the benefits and positive key features of implementing hubs and little research is conducted on the practical reasons why hubs implementation remained unrealised on a large scale (Adams, Osmani, Thorpe, & Thornback, 2017; Tsui, Furlan, Wandl, & Timmeren, 2023). Additionally, the literature studies fail to describe steps that need to be taken to achieve hub implementation. In the current practice, several hub initiatives operating at a local scale have been developed by single organisations, but both theoretical and practical results have shown that the most potential is seen in a network of various types of hubs. Therefore, the framework developed in this study contributes to literature and practice by outlining the precise steps stakeholders need to undertake in distinct phase to ensure that local initiatives develop into a regionally operating network of hubs.

7.2. Research limitations

Due to the novel nature of this research topic and the fact that hubs have not yet been widely developed and implemented, one limitation of this research is the limited amount of available scientific research regarding circular construction hubs and their practices. Research primarily focused on circularity, transitioning to a circular economy, and circularity initiatives. Additionally, existing studies concentrated on different types of hubs in general, and specific characteristics such as size and geographic locations (Tsui, Furlan, Wandl, & Timmeren, 2023).

Moreover, the number of involved participants in the semi-structed interviews and experts evaluation can be viewed as a limitation. This research involved conducting ten interviews (two organisations per stakeholders), meaning that data saturation has not been fully achieved. Furthermore, the interviewed stakeholders do not form the complete field of stakeholders, as practical findings later revealed that manufacturers may also play a significant role in the process of hub development. In addition, in the experts evaluation, it was mentioned that project developers are important stakeholders in the construction industry as well and should have been included in the research. The fact that not all chain partners were included in the interviews is limitation of this research. Also, the interviewed stakeholders are not a complete and perfect representation of the wider stakeholder field, as the interviewees were selected by several inclusion criteria and their interest in participating to this research, not through thorough analysis of their representativeness. Besides that, the step-by-step framework was evaluated with four experts, where the number of experts can also be considered as a limitation of this research.

7.3. Critical reflection

The research has resulted in the framework depicted in Figure 10, detailing the steps each stakeholder must take within each phase. The entire progression to expand current small-scale initiatives into a regionally operating network of hubs is divided into three phases. The first phase aims to advance the transition to a circular economy, leading to an increase in material reuse. The second phase is crucial for optimising supply and demand to facilitate material reuse and increase the necessity of regionally operating hubs. In the final phase, steps are defined to integrate all individual actions to scale up hub implementation, ultimately aiming to establish a network of hubs. A critical analysis of the model reveals that the steps per phase are broadly defined and may consist of several more concrete steps not examined in this research. The main reason for this is attributed to the research's focus on all stakeholders involved and their interactions with each other. Consequently, specific actions and concrete guidance per stakeholder were not retrieved. Additionally, practical results have shown that

further progress in hub implementation requires advancing the transition first. This necessitates voluntary steps per stakeholder, with clients and public organisations playing a crucial role in demanding and mandating steps (within projects) focussed on circularity.

Furthermore, regarding the development of the step-by-step framework, it must be noted that the models of Lewin and Prosci, which served as inspiration for the foundation of the framework, were not entirely applicable to the objective of the step-by-step framework (Lewin, 1951; Hiatt & Creasey, 2003). Despite this research's framework being developed based on theoretical and practical findings, both change management models had an influence on the input and structure of the framework. Both of the models can be criticised for being relatively general, which contrasts with the research objective to create an applied change management model. The Lewin's model presents a structured change process, but is considered somewhat simplistic. It lacks detail on sustaining change and assumes that change can be permanent, making it difficult to translate this to actionable measures (Hughes, Dwivedi, Simintiras, & Rana, 2016; Hebinck, et al., 2022). Additionally, the encouragement in the final stage to reinforce the steps and permanently seal the change does not align with the ambition of this research's framework. Furthermore, Lewin's model mainly focuses on employees and individuals within organisations, in contrast to the broader scope of collaborating chain partners that must be connected to lead to change (Kazmi & Naaranoja, 2014; Hughes, Dwivedi, Simintiras, & Rana, 2016). Similarly, Prosci's model also has limitations in fully addressing the complexities and dynamics of change, as it is very conceptual, too broadly defined, and depicting a linear process. Furthermore, this model also focuses on individual change and does not offer strategies or guidance on how to manages resistance to change (Hamdo, 2021; Bekmukhambetova, 2021).

Another critical reflection focuses on terms such as the government and public organisation. In the analysed literature, both terms frequently emerge. Also, during the interviews, stakeholders expressed expectations about themselves and other stakeholders, especially from private stakeholders aimed at public stakeholders. Critical questions should have been asked to better define towards which specific public organisations stakeholders expressed those expectations. This would have led to more concrete steps per public organisation. In addition, there was limited introspection by the stakeholders themselves. They had a clear idea of what other stakeholders should do. Even more detailed questions should have been asked regarding the action stakeholders themselves should undertake as they possess the most knowledge about their own business, leading to more in-depth steps.

The final point of critical reflection focuses on the participants of the interviews versus non-participating parties. The organisations willing to participate in this research already showed some interest in circularity by their participation. At least, they were willing to discuss this topic and were, due to the inclusion criteria, already engaged with circular construction. Especially the architectural firms that participated in the interviews proved to have an above-average interest and ambition in circularity compared to other stakeholders. Therefore, since the practical results were provided by parties already somewhat involved in circularity, the findings miss input from parties that have not taken any steps or shown interest in circularity in general. Within the initiation phase, the first step to implement circularity more in business operations and projects (applying to all stakeholders) applies more to parties that have not undergone sustainable and circular progress yet.

When further elaborating on the non-participating parties, construction manufacturers were frequently cited as a key stakeholder in the practical findings and in the experts evaluation project developers were suggested as key stakeholder. However, both were not included in the research because these stakeholders were not identified in the theoretical findings.

Nevertheless, particularly regarding the manufacturers, the frequency of them being mentioned indicated their influential role. By not including manufacturers, important findings about their role and perspective were overlooked. Additionally, the implementation of Extended Manufacturer Responsibility legislation was not evaluated with this stakeholder, which would have been highly interesting.

7.4. Additional findings

From the various steps of the research methodology, additional findings were obtained. The three most significant additional findings emerged from the semi-structured interviews and the experts evaluation, focussing on (1) circularity initiatives from stakeholders, (2) the implementation of the Extended Manufacturers Legislation in the construction sector, and (3) circularity versus financial considerations in projects.

Firstly, this study primarily focused on the steps needed to stimulate the realisation of an urban mining hub. However, during the interviews, important initiatives and actions related to circularity by stakeholders were also discussed. These circularity initiatives encompass a range of activities, from the development of hubs and conducting research to establishing standardised agreements.

With regard to the development of hubs, both Demo1 and Contr2 have established their own hub. Demo1 focuses with their hub on selling secondary materials from demolition projects as quickly as possible. The hub of Contr2 aims to execute three core tasks: recycling waste streams, upcycling reusable materials and elements, and enabling efficient transportation. For both parties, these initiatives remain financially challenging, but both see them as important steps to motivate their own organisations and explore circularity opportunities. Contr2 is also collaborating with other parties on a pilot for Rijkswaterstaat to demonstrate the reuse of infrastructure elements (such as beams and girders) (Demo1, 6 December 2023; Contr2, 14 December 2023). All three activities serve as significant examples of the *initiation* phase of Figure 10 on how to stimulate the transition towards a circular economy.

Regarding the *optimisation* phase of Figure 10, the interviewed public organisations are also taking important steps. Public1 acknowledged the barrier where the current tax system hinders material reuse. Therefore, they lobby to reduce and shift the tax burden from labour to primary materials, making secondary materials cheaper. Public1 is also conducting research to develop a demolition inventory showing which structures will be demolished when. Stakeholders noted that late announcements of demolition projects often leave no time to demolish structures in a circular manner, find potential purchasing organisations, and allow architects time to assess the availability. This research could provide stakeholders with perspective on demolition projects and ultimately contribute to hub development (Public1, 11 January 2024). Public2, in collaboration with the Ministry of Interior and Kingdom Relations, is developing a digiDeal. Agreements with private organisations are being made to use the same data structure for offering secondary materials, making it easier to share the availability of materials. The offerings from one marketplace platform will also be visible on other platforms, making the total offering much larger and more manageable for demanding stakeholders. With this agreement private parties can maintain their own marketplace model. This digiDeal is an important step as, unanimously, the interview participants indicated that a single online market platform for secondary materials was important to facilitate material reuse. Additionally, a clear overview of the available secondary materials will encourage clients to demand stricter requirements for material reuse in projects (Public 2, 20 December 2023). Besides these important actions undertaken by stakeholders, the strategy outlined in Figure 10 remain crucial

for making overarching progressing in the transition to a circular economy and the realisation of a network of hubs.

Secondly, the implementation of Extended Manufacturer Responsibility legislation in the construction industry is often highlighted in the practical findings. As already mentioned, stakeholders find it challenging to work with secondary materials because there are many factors to consider (e.g., matching, processing, quality, transport). The Extended Manufacturer Responsibility legislation could play a significant role in resolving those barriers, closing material loops, and thereby addressing the issue of expected material scarcity, and returning materials to the market with maximum value conservation. Many stakeholders see this as an important solution that might bypass the need for hubs. However, the Extended Manufacturer Responsibility legislation demands a lot from manufacturers in terms of expertise, costs, and storage space. Manufacturers will need to acquire new knowledge and develop new methodologies as producing new materials and products is different from processing a secondary product into something new. Additionally, manufacturers may currently lack the right resources (machinery, personnel) and sufficient budgets. These considerations are leading to the question of which party will finance this shift. Furthermore, the costs incurred by manufacturers for processing secondary materials will also be reflected in the price of the reintroduced materials. Even though little to no new material may be needed for secondary material, processing them will still incur costs. Therefore, there needs to be a counterbalance to new products, otherwise, primary materials will remain the preferred choice. If no financial solution is found, the preference will still lean towards primary materials even with the Extended Manufacturer Responsibility legislation. Besides that, the Extended Manufacturer Responsibility legislation still requires changes among primarily private stakeholders identical to the defined steps in the framework depicted in Figure 10. The Extended Manufacturer Responsibility legislation is only meaningful if construction and demolition contractors fully adopt circular demolition practices in all projects, resulting in a larger supply of secondary materials. Architects, clients, and engineering consultancy firms will need to change their mindset, work with the available (semi)secondary materials, and implement design approaches aimed at demountable construction.

Thirdly, during the evaluation session, a discussion among the experts elaborated on the prioritisation of circularity within business models of private organisations and projects. It was discussed that current projects are mainly driven by financial considerations and/or available investment budgets for realisation. The costs associated with subsequent phases (e.g., operational costs) are often overlooked, while operational costs for sustainable options can be lower than for non-sustainable options, potentially resulting in lower total costs over the entire lifespan of a construction. Making the investment budget the determining factor leads often to the exclusion of more sustainable options, as the initial costs for sustainable options are typically high. By reevaluating this approach, investments in sustainable initiatives, despite their higher initial costs, can be favoured over less sustainable projects, acknowledging the importance of considering both initial and operational costs.

The insights from this chapter will be carried over to the next chapter, the conclusion of this research, where the answer to the main research question will be provided, along with recommendations and possible future studies.

8. CONCLUSION

This research aimed to offer a comprehensive understanding of the current theoretical and practical insights leading to the essential first steps per stakeholder to stimulate urban mining hubs realisation in the Netherlands. The comparison between the theoretical and practical insights led to the development of an actionable step-by-step framework addressing the main question which was formulated as: *How can the realisation of urban mining hubs in the Netherlands be stimulated?* To answer this question, a qualitative study was conducted, consisting of three steps: data gathering, data analysis and data validation. Firstly, data collection involved conducting a systematic review based on Wright et al. (2007) and Templier et al. (2015). This was followed by conducting semi-structured interviews with architectural firms, construction and demolition contractors, engineering consultancy firms and public organisations (in the role of construction owner and client). The systematic review formed the basis for developing an interview guide to properly conduct semi-structured interviews, as described by Kallio et al. (2006). In the second step, the interview results were analysed using thematic analysis, employing the six-phase framework of Braun and Clarke (2006). Lastly, the methodology ended with an experts evaluation of the research deliverable: the step-by-step framework.

This chapter is divided in four sections. Section 8.1 will describe the answers to the four sub research questions. Following this, Section 8.2 will provide the answer to the main research question. Section 8.3 will offer recommendations and this chapter will end with an elaboration on potential future research in Section 8.4.

8.1. Answers to sub research questions

Based on the literature review, it can be concluded that the public organisations are prioritising sustainability across various sectors, including the construction sector, aiming to transition towards a circular economy. A sustainable initiative concerning this transition is the implementation of construction hubs, which can be divided into circular and non-circular construction hubs. Circular construction hubs focus on closed-loop material chains and maximising material life spans, while non-circular construction hubs focus on efficient transportation by minimising transportation movements. This research focus on a specific type of circular construction hubs known as urban mining hubs, which were defined using the theoretical findings as: *a physical, regional, and collaborative centre which sorts, stores, and transports directly reusable and upcyclable building materials and products, extracted from anthropogenic stocks, to construction projects.* Within the overall urban mining process, which included the *inventorying, collecting, sorting and storing,* and *reuse and distribution* phases, the role of urban mining hubs in the *sorting and storing* phase remained unclear. The literature review did identify the stakeholders involved in the process of urban mining and hub realisation: architectural firms (in the role of architect and material expert/scout), construction contractors, demolition contractors, engineering consultancies (in the role of consultant and harvesting expert), and public organisations (in the role of public client and construction owner). During the interviews and the experts evaluation, this list of stakeholders was supplemented with manufacturers and project developers, who also might play a key role in stimulating the realisation of urban mining hubs.

The theoretical findings offered both advantages and disadvantages of urban mining hubs and the process of urban mining. Environmental benefits focused on conserving valuable resources and minimising emissions, along with financial advantages by minimising material costs, waste generation and transportation movements. Moreover, this initiative and process

contribute to social advantages by creating employment opportunities. Despite all benefits, current barriers, such as insufficient material demand, uncertainties in material inventories, and inadequate legislation supporting material reuse are hindering the implementation of those hubs and material reuse in general.

The practical findings obtained from the results of the semi-structured interviews aligned and supplemented the theoretical findings. Based on the practical findings, it can be concluded that three distinct types of barriers are preventing the realisation of urban mining hubs.

Firstly, one practical barrier focussed on the significant challenge in aligning secondary materials with new construction projects. This complexity is amplified due to uncertainties in material inventory scans, insufficient supply, and ambiguity surrounding the quality of secondary products and potential liabilities. Furthermore, the findings mentioned the lack of physical space for urban mining hub realisation as a second practical barrier. Secondly, regarding the financial barriers, many stakeholders stated that traditional construction and demolition methods are seen as more cost-effective compared to sustainable alternatives. This perception is mainly influenced by the higher labour requirements for extracting and processing materials, leading to increased costs. Therefore, it is crucial to consider the residual value of materials, even in the context of new project development, as these materials retain value beyond their initial use and should be regarded as investments. Both the practical and financial barriers were supported by the theoretical and practical findings. Thirdly, the legal barriers were described as existing regulations that reduce the demand for secondary materials and diminishing the need for urban mining hubs. The practical findings supplemented the legal barriers with two barriers. Firstly, they indicated that the current tax system also does not incentivise material reuse. Secondly, the lack of a sustainability vision and budget allocation from the public organisations and clients has impeded the development of such hubs because stakeholders are uncertain about the long-term plans and therefore hesitant to invest in innovations.

All barriers were often referred to during the interviews when diving deeper into the expectations the different stakeholders have of each other for the stimulation of urban mining hub development. The various stakeholders had a clear understanding of the steps they and other stakeholders need to take to enable urban mining hubs. All stakeholders are expected to prioritise circularity in their own business models and execution of projects, moving from a fully profit-focused mindset towards a circular mindset. Contractors are required to invest more in research and development towards new construction methods aimed at circularity and demountable construction, as well as retraining employees on circular construction practices. From architects, stakeholders expect a new mindset and design approach where they will design using available secondary materials, emphasising sustainability and circularity as their primary focus. A stakeholder towards whom no expectations (only a single desire) has been expressed is the demolition contractor. Manufacturers were frequently mentioned by interviewees, although they were not identified as key stakeholders in the literature study. Stakeholders expressed a desire for manufacturers to take responsibility for reclaiming materials and products, process them while preserving their original value as much as possible and reintroduce them to the market with quality assurances and warranties. As mentioned, interviewees underscored the need for increased governmental guidance, including stricter circularity regulations in projects through adjusted legislation, financial incentives, and the implementation of Extended Manufacturer Responsibility legislation (*Uitgebreide Producentenwetgeving)* in the construction sector. A noticeable difference in circularity ambitions exists between private and public clients. The interviewed stakeholders are

advocating for higher circularity standards among developers and other private entities, as those ambitions are often lacking.

Regarding urban mining hubs, the practical results revealed various perspectives from stakeholders, contradicting and supplementing the theoretical findings. While the theoretical research highlighted the potential of urban mining hubs, the practical findings revealed a variety of perspectives regarding their role and necessity. According to various interviewees, a network of diverse types of hubs holds the most potential. Within this network, hubs will vary in scale and material focus. From the practical findings, it became evident that the relationship between material reuse and the demand for hubs is crucial: an increase in material reuse corresponds to a greater demand for hubs, which currently results in the practical implementation of hubs remaining unrealised. The practical results also indicated that the functions of urban mining hubs, as described in the definition, did not fully meet the needs of the stakeholders. In addition to sorting, storing, and transporting secondary materials, an urban mining hub must also facilitate logistical and processing functions. Therefore, the revised definition of urban mining hubs based on theory and practice is: *a physical, regional, and collaborative centre that facilitates the sorting, storing, processing, and efficient transportation of reusable and upcyclable building materials and products, extracted from anthropogenic stocks, to construction projects.* Moreover, the practical findings led to three key features of hubs for enhancing their potential, including solely storing materials with assured demand, a transparent insight in the hubs' inventory (potentially through a website of platform), and logistical and processing capabilities. Derived from both the theoretical and practical findings, active participation of all organisations within the construction sector is essential for the effective functioning of hubs.

8.2. Answer to main research question

With all circularity ambitions and initiatives aiming to transition to a circular economy and a fully circular built environment in the Netherlands, the realisation of hubs proved to be interesting. This research aimed to provide a comprehensive understanding of both the current theoretical and practical insights in urban mining hubs and their development steps to stimulate hub realisation. By bringing together these findings, the objective was to create a step-by-step plan accessible to all stakeholders, presented in an actionable framework, addressing the main research question: *How can the realisation of urban mining hubs in the Netherlands be stimulated?*

The literature review indicated that urban mining hubs hold potential and advantages as an initiative in the circular economy. Although the potential seems clear, the practical implementation of hubs currently remains unrealised. Several barriers were identified hindering their realisation both in the theoretical and practical findings, with one significant challenge being the difficulty in matching secondary materials to new projects. The correlation between material reuse and the necessity for hubs became apparent: an increase in material reuse corresponds to a greater demand for hubs. Currently, the development of hubs may still seem far off, but in the results of this research steps per stakeholder were identified to stimulate this development. The findings from the literature review, semi-structured interviews and the experts evaluation have led to the step-by-step framework illustrated in Figure 10 which presents that each stakeholder has a part to play in driving this development forwards. Although the steps for each stakeholder were broadly defined, the framework provided valuable guidance for each stakeholder per distinct phase to stimulate hub realisation. By progressing through these phases, the ultimate goal of stimulating hub realisation will be achieved.

The first phase in the framework (Figure 10), *initiation* phase, indicated the significance of considering the circular economy with a broader scope than solely urban mining hub realisation. This phase should serve as an initiator to start a learning process on material reuse and hub development and as a facilitator aiming to stimulate material reuse in projects. To progress through this phase, all organisations must take the initial step for advancing the transition. The initiatives primarily rest with the parties themselves and should focus on prioritising innovation and educational advancement within their business models, shifting from a purely profit-oriented mindset to a circular one. Progressing the transition will demand voluntary efforts from private organisations, while other measures can be incentivised or mandated through revised regulations or CO_2-budgets in projects. It emerged as crucial for public organisations to kickstart this process, enabling private organisations to align and take necessary actions. Developing a strategy with clear and measurable steps appeared to be essential during this phase as practical results clearly indicated that private parties will only take action when they are certain that circularity is either mandatory or the new standard.

The *optimisation* phase underscored the gap between the current supply of secondary materials and the demands of the construction sector, as evidenced by theoretical and practical findings. Meeting these demands necessitates an increase in supply, both in quantity and quality, with construction and demolition contractors playing a central role in this. Achieving a sufficient and high-quality supply depends on the adoption of circular demolition practices by demolition contractors and on the implementation of disassemblable construction methods by contractors for new projects. The financial risks associated with circular demolition, mainly due to the high labour costs, can be reduced through a strong demand for secondary materials covering labour costs through revenue from sales. To establish a stable secondary material market, on the demand side, it appeared crucial for clients to incorporate strict requirements regarding material reuse in their projects. Architects and engineering firms must actively seek available secondary materials and integrate them into designs, as well as develop and standardise disassemblable designs incorporating those secondary materials. Towards all stakeholders, organisations must take responsibility in their role and in decision-making of projects to ensure that circularity is prioritised throughout the entire project. This involves considering environmental impact as well instead of solely letting financial considerations fully control the decision-making process. Both public organisations and hub initiating organisations have an investigative role in this phase. Public organisations should investigate adjustments in the tax system to incentivise the use of secondary materials, which was often mentioned in the practical findings, while hub initiating organisations should monitor the efficiency of the hub's functioning and inventory striving for optimisation. This phase aimed to optimise the balance between supply and demand, fostering material reuse across all phases of the construction cycle and involving diverse stakeholders. By expanding the supply and diversity of secondary materials and stimulating demand, the implementation of hubs becomes imperative, leading into the third phase of the framework depicted in Figure 10.

Moving into the *expansion* phase, the construction sector increasingly embraces circularity, with a more balanced alignment of supply and demand for secondary materials, fostering the expansion of hub realisation. A network of hubs resolves a frequently mentioned barrier in practical findings: the lack of storage spaces helping to align varying demolition and construction schedules. Moreover, a network of hubs holds the most potential according to the theoretical and practical findings. To facilitate the scaling up of hub realisation, two key actions must be undertaken by stakeholders. Firstly, it is essential for stakeholders to continue collaborating structurally and systematically. This is crucial to ensure a consistent supply and active engagement of parties with the hubs through circular purchasing from hubs and stimulating material reuse by requesting it in projects. The second key action builds upon this

collaboration, emphasising the need for effective information management during the various construction phases from all parties involved. After progressing through this third phase, focus should be on evaluating the impact of a network of diverse hubs, investigating the potential of a connection between regional and local hubs, and reassessing the individual actions of stakeholders, verifying that their participation is sufficient or if improvements can be made.

Summary of answer to main question:
This research has shown that all stakeholders must take a step forward to enable the stimulation of urban mining hub realisation, and that only in this manner can the often mentioned *chicken-and-egg* problem be resolved. Public organisations can contribute to this stimulation by mandating and demanding increased circularity through adjusted legislation and stricter project requirements, thereby initiating market movement. Conversely, private organisations must adapt and advance this market movement by taking responsibility and proactive steps, implementing circular methodologies, and actively engaging with urban mining hubs. Only when all organisations critically assess their own operations, systematically collaborate, and prioritise circularity in business operations and projects does the potential increase to develop various types of hubs in the Netherlands, including urban mining hubs, and create a network where material reuse and efficient transportation are the primary objectives.

8.3. Recommendations

The main recommendations focus primarily on the *initiation* phase of the step-by-step framework. Practical results indicated that the construction sector currently lacks sufficient alignment with circular processes to fully support the ambition of developing regional-operating urban mining hubs. There are too many diverse barriers hindering this ambition and there is insufficient urgency among private parties to change. Therefore, further research conducted by different stakeholder is needed on how material reuse can be facilitated.

For public organisations such as the Ministry of Internal Affairs and Kingdom Relations, the Ministry of Finance, the Ministry of Infrastructure and Water Management, and the Tax and Customs Administration, it is crucial to examine the current construction (calculation) norms and methods and the current tax systems critically to verify whether they stimulate material reuse. It would also be interesting if these organisations explore the possibilities surrounding the Extended Manufacturers Responsibility legislation. As indicated by interviewees, engineering consultancy firms can support in all these investigations. Furthermore, there is a role for engineering consultancy firms in collaboration with architectural firms to explore the potential of AI and 3D scanners in improving material inventory scans.

For local or regional public organisations like municipalities and provinces, a recommendation is to reserve and allocate a physical location and collaboratively develop a pilot hub with stakeholders who are willing to look beyond the complexity and uncertainty of circularity and material reuse. Practical experience will reveal necessary development requirements, stakeholder roles, collaboration forms, suitable materials for storage, and stakeholder relationships with the hub. By implementing a pilot hub and clearly requesting material reuse from it, the cycle of expecting other stakeholders to initiate action will be disrupted. Architects and construction contractors will need to work with these materials as it is requested in their projects, solving the passive attitudes of these stakeholders. In addition to gaining experience, such a pilot could provide valuable insights for further research and feasibility testing of hubs with minimal financial commitment.

Regarding circular demolition, a recommendation is to standardise practices so that materials from every demolition project are collected, ensuring valuable materials are not lost. To enable circular demolition, an advice for construction owners is to allocate enough time for the circular execution. Furthermore both clients and public organisations play a role in mandating and making circular demolition financially viable through subsidies. Demolition contractors, on the other hand, need to take responsibility and aim to execute projects in a circular manner. By executing circular demolition more often, additional knowledge and skills are acquired and the possibilities of standardised approaches within circular demolition can be explored and investigated.

Furthermore, a recommendation for Brink Groep is to utilise the step-by-step framework in projects and collaborations to illustrate the current status of urban mining hubs according to the theoretical and practical findings. The framework provides guidelines and strategic steps valuable for projects and clients to initially promote material reuse and thereby increasing the necessity for hubs. Additionally, this framework is useful for Brink Groep's active role in Cirkelstad, where they can engage all connected stakeholders on the defined strategy to stimulate urban mining hubs realisation. This visualisation can serve as a discussion document to address each stakeholder's steps, roles, and responsibilities. Because the steps are presented for each stakeholder separately, it is a valuable document to introduce in sessions with all stakeholders together to discuss and evaluate the described steps. The framework can facilitate collective discussions and help connect stakeholders, preventing the emergence of only small-scale initiatives hindering the realisation of a regional network of hubs.

8.4. Potential future research

In follow-up studies, it is advised to take manufacturers and project developers into account as this will enrich the understanding of the dynamics within the construction industry.

For further research, investigating the economic aspects of the Extended Manufacturer Responsibility legislation could be valuable, because while it sounds like an overarching solution in theory, serious consideration is needed to determine the extent to which it contributes to the circularity ambition.

The critical reflection in the research discussion (Section 7.3) revealed that the steps per phase were broadly defined. This research has been conducted at the very beginning of the concept of hub realisation, leading to the focus on mapping out the whole stakeholder field and defining high-level steps. Potential future research would be of significance investigating the stakeholders individually, leading to more concrete and stakeholder-specific steps.

Future studies could also evaluate the success and efficiency of establishing a network of hubs. The financial feasibility and the individual business models of hubs have not been discussed in this research and could therefore be investigated to provide insights into their economic viability. Furthermore, as it is possible that the management of urban mining hubs could be undertaken by an organisation outside the currently identified stakeholder field, investigating potential management organisations would be of interest.

Additionally, research studies are lacking information on the cost and time differences between circular and traditional construction and demolition. Investigating this in future studies would allow for a more detailed examination of potential solutions and adjustments to minimise the cost and time differences. Additionally, it may be possible that the costs difference is smaller than currently assumed, enabling clients to make more specific requests in their projects.

V. REFLECTION

As the closing chapter of this research about urban mining hub realisation, a self-reflection has been written on the overall graduation process: what a dynamic period. Prior to the graduation process, I felt uncomfortable about starting with the graduation process. I was afraid it would be a lonely and exhausting process where I would constantly have to search for solutions and ideas on my own. The initial topic that interested me, focussing on sustainability stimulation in contract management of large infrastructure projects, was immediately rejected in favour of a completely new topic: urban mining hub development. As a number of conversations about hub development were had with Brink Groep, I immediately knew I wanted to learn more about it. Particularly, due to the fact it concerns a current and novel topic, my interest in circularity, and tangible characteristics of hubs in general. With this intrinsic motivation, my enthusiasm for the graduation process started to grow.

Conducting a literature study was an iterative process for me. I often found it difficult to find valuable (scientific) articles, which I partly attribute to the novelty of the subject. Additionally, reading and making good analyses are not among my strongest qualities, but I definitely improved on that during the thesis. I now have a much better understanding of where to find articles and how to quickly scan those studies for potential relevance. Additionally, I have learned the proper way to reference these articles (after conducting this insufficiently a few times).

After almost completing the literature study, I moved to the next step: preparing the semi-structured interviews. I was nervous about this, partly because of the unfamiliarity of how it would go and how to conduct it. I learned a lot during the interviews: on one hand, how to get good answers by asking the right questions, and on the other hand, I learned a lot about the distinct functions and organisations and how they perceived the topic. I found conducting interviews a very enjoyable process. Engaging in conversation about such a novel concept created a safe atmosphere where questions and answers were neither right nor wrong. Later on in the process, I realised that I sometimes should have asked additional questions or delved deeper into certain answers and concepts to reach to more specific outcomes. From all participants, there was a lot of enthusiasm to explore further into and elaborate more on the concept of urban mining hubs. Looking back on the start of the research and conducting interviews, I can conclude that I often find things thrilling when I do not know how they will unfold.

After conducting the interviews, a number of practical actions were needed, such as transcribing the interviews. I wanted to do this as carefully as possible, which took much time. I found this to be a very tiresome task and it drained a lot of my energy. However, I eventually noticed during the thematic analysis of the practical results how beneficial it was to have such clear interview transcriptions.

Describing the results and writing (sub)conclusions went well for me. I had clearly worked out the results, and I found the *writing part* pleasurable. Also, because it finally produced something tangible and concrete, which as a goal-oriented person, made me feel very good. Developing a framework based on the results and sub conclusions was an interesting process for me. I did notice, especially during this process, that I do not hesitate to ask for help and continued doing it as I noticed that people react enthusiastically to the topic and are eager to help. During some brainstorming sessions with my company supervisor and some colleagues, I was very satisfied with the visualisation of the step-by-step framework. The creative thinking process, resulting in the visualisation as the end product, demanded a quite different approach from me.

One that was not often required of me during my bachelor's and master's studies. I found the iterative part very enjoyable, especially because each step clearly led to an improvement.

When writing the discussion, I got stuck several times. Especially writing critical reflections on the results was difficult for me. I often took some time because I could not think beyond the boundaries of my own thoughts. By brainstorming with others, I managed to overcome this. It also gave me the feeling that I was tackling the problem with others, despite the research being an individual project.

In addition to all the practical components and steps of graduation, there was also a social and personal process during the graduating period. I found the social process surrounding graduation at times challenging, especially when managing different conflicting opinions and feedback. I always did my utmost to process the feedback as well as possible, but the amount of feedback and the manner it was sometimes given left me feeling insecure about my work and reluctant to continue working on my thesis. Despite these complex situations, I learned a lot about myself and how to handle demanding situations. I felt free to express my feelings to others, which allowed me to share my story, discuss alternative options, and view this part as separate from me as a person and from the research I was conducting.

Ultimately, I can say that conducting research was more exciting than I initially thought. Being involved with a company and having contact with my first and company supervisors on a weekly basis made me feel like I was not doing it alone or just for myself. It is noticeably clear to me that I prefer to function in a team and tackle things together. Even though I carried out this entire process by myself, comments like "*we are going to tackle this*" made me feel very good. Reflecting on this, I can conclude that my motivation is much greater when I realise that I am doing something together or for a goal that is collectively supported.

In the end, I am very happy with my outcome and of course, looking back I would have approached, processed or written things differently. However, I can genuinely look back with pride on the end result and how I navigated through the entire process.

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APPENDICES

Appendix A. Organisation-specific questions for semi-structured interviews

Table 18. Interview questions for architectural firms.

ARCHITECTS
Paul de Ruiter Architecten and Superuse
What factors influence the choice to use second-hand materials in designs and projects?
What would support/assist/encourage your organisation to use urban mined materials on large scale and to utilise an urban mining hub?
How does your organisation gain insight into the availability of secondary materials?
How can this process be smoothed?
In what way does the supply affect the design process?
How could an urban mining hub assist in overcoming the current barriers in reusing materials?
What do the diverse private and public organisations need to change to better encourage urban mining (hubs)?

Table 19. Interview questions for engineering consulting firms.

ENGINEERING CONSULTANCY FIRMS	
ABT	**Meijs Ingenieurs & Uitvoering**
What factors influence the choice to use second-hand materials in designs and projects?	How does your organisation ensure that materials are inventoried and collected as comprehensively as possible?
What would support/assist/encourage your organisation to use urban mined materials on a large scale and to utilise an urban mining hub?	How can this process be smoothed?
What challenges does your organisation face in using urban mined materials?	How does your organisation ensure that the materials can be utilised in new projects?
What needs to be done to address these issues?	What role can an urban mining hub play in this?

How does your organisation handle difference in supply and demand?	In what manner does your organisation provide quality assurances and warranty for the urban mined materials?
What happens if there is less in stock than your organisation requires for a project?	Why is the demand for secondary materials so low, considering it should be much higher, given the number of new construction projects?
What role can an urban mining hub play in this?	What do the diverse private and public organisations need to change to better encourage urban mining (hubs)?
Why is the demand for secondary materials so small, when it should be much higher looking at all new construction projects?	
What do the diverse private and public organisations need to change to better encourage urban mining (hubs)?	

Table 20. Interview questions for construction contractors.

CONSTRUCTION CONTRACTORS
BAM and Dura Vermeer
What factors influence the choice to use second-hand materials in projects?
What would support/assist/encourage your organisation to use urban mined materials on a large scale and to utilise an urban mining hub?
What challenges does your organisation face in using materials from an urban mining hub?
What needs to be done to address these issues?
How does your organisation handle difference in supply and demand?
What happens if there is less in stock than your organisation requires for a project?
What role can an urban mining hub play in this?
In what manner does your organisation provide quality assurances and warranty for secondary materials in projects?
What do the diverse private and public organisations need to change to better encourage urban mining (hubs)?

Table 21. Interview questions for demolition contractors.

DEMOLITION CONTRACTORS
Adex Groep and VERAS Sloopaannemers
In what manner does your organisation/do your members provide quality assurances and warranty for secondary materials?
How can this process be smoothed?
How do your members ensure that the secondary materials can be utilised in new projects?
How does your organisation establish the selling price of second-hand materials?
What are the primary obstacles for urban mining (hubs) perceived by your organisation/your members?
What role can an urban mining hub play in your organisation/industry?
What can your organisation/members do to get these hubs operational?
What do the diverse private and public organisations need to change to better encourage urban mining (hubs)?

Table 22. Interview questions for public organisations.

PUBLIC ORGANISATIONS
Provincie Zuid-Holland and Rijksvastgoedbedrijf
Why is the demand for secondary materials so low, considering it should be much higher, given the number of new construction projects?
What can your organisation do upfront to get these hubs operational?
How does an urban mining hub contribute to the government-wide sustainability objectives?
Why does your organisation not impose stricter requirements in their tenders and procurement processes?
How does current legislation stimulate the use of urban mining hubs and second-hand materials?
How does current legislation hinder the use of urban mining hubs and second-hand materials?
In what way does your organisation incorporate urban mined materials in projects?