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Facilitating circular site preparation; developing the instrument PrCiSi

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Abstract. The urge to strive for closed material loops is felt in the construction industry. However, before the built environment can be regarded as circular, not only the material usage in buildings, but also preparations taken on sites need to be circular. In this paper a new instrument is presented to help project leaders at municipalities and contractors to assess how circular their process of site preparation is. The instrument, by the name of PrCiSi, has been developed on basis of a literature study on sustainable material usage and interviews among stakeholders in this niche market. The instrument has been tested on the site preparation processes for the residential neighbourhoods Olstergaard and Noorder Koeslag in the municipality of Olst-Wijhe. Of course, there is still room for improvement and more test cases are welcomed, but three main subjects, namely materials, equipment and personnel, seem to form a proper basis. A large number of test cases might help us to further develop the scoring system. However, being convinced that we can cross a boundary here, we are happy to share with you the current status to inspire you to use and improve this instrument with us.

1. Introduction

The impact of the construction industry on the natural environment is severe, natural areas are changed into predominantly hard solid surfaces, the energy use in the built environment is high and the industry puts huge claims on materials. The Dutch construction industry for example claims 50% of the total resource usage [1]. Sustainable building has been the concept that aims to reduce the environmental impact caused by infrastructure and facilities throughout their lifecycle and create healthy structures, environment friendly, comfortable and productive built environment [2]. Although especially sustainable energy use has been in the centre of attention for quite a while, now material usage rapidly gains attention in a society that embraces circularity. The Dutch government started to broadly communicate their ambitions in 2016 with a programme on circularity for all industries. The ambitions are to have a 50% circular economy in 2030 and a 100% circular economy in 2050 [3].

Multiple construction companies, architects and suppliers of building materials try to reduce the need for new virgin materials, put effort in reclaiming used materials, products and building components, and reduce the amount of waste originating from their production processes. However, it seems that little is known about what can be done in the stages at site before actual buildings are being constructed.

The goal of this research project is to develop an instrument for those who are involved in the process of designing and executing site preparations to contribute to a circular economy by means of reducing the environmental impact of materials and energy used. The research was executed within the research

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group Sustainable Environment of Saxion University of Applied Sciences in close collaboration with the Netherlands municipality of Olst-Wijhe [4, 5].

Coming sections will address the research setup, theoretical framework and the process of designing the instrument. After these sections, the instrument will of course be tested on its usability, before a section with the conclusion is offered at the end of this paper.

2. Research setup

As in many research projects, our research also started with conducting a literature study. Two topics form the main focus in this study, namely circularity in the construction industry and site preparation. Having access to the international oriented ScienceDirect database and more national oriented governmental and educational documents, helped us to find out what a circular economy could mean for the Dutch construction industry. The amount of available documents on the process of site preparation was unfortunately considerable smaller.

Having available the theoretical framework, we then resided to experts in the field. Nine interviews were conducted to put the finger on where circularity and site preparation can meet each other. These experts have multiple years of experience in planning or executing site preparation in the Netherlands. They work at municipalities, contractors or consultancy firms. Conducted interviews took on average one hour.

The collected information forms the foundation of the instrument. Considering that municipalities give shape to zoning plans and often take the initiative to plan a certain residential area, the instrument needs to be able to help those working at municipalities and for municipalities in designing and executing site preparations. For this reason, we thought it would be a good idea to develop a list of questions that helps to start the site preparation design process and analyse site preparation plans. The answers to the listed questions make it possible to assess how circular the site preparation ambitions are.

3. Theoretical framework

The theoretical framework consists mainly of two pillars that are addressed in the coming two subsections, namely circularity in the construction industry and site preparation.

3.1. Circularity in the construction industry

From a national and chronological perspective it is relevant to explain that the Netherlands already adopted a vision on how to cope with waste in 1979. This was Lansink's Ladder that offered a waste hierarchy [6]. Incorporated into Netherlands law on environmental conservation, this scheme originally contained seven steps to cope with waste disposal:

1. Prevention: try to create as little waste as possible;
2. Consideration of the raw materials: use raw materials which do not harm the environment after product usage;
3. Product reuse: try to reuse a product in its original state as often as possible;
4. Material recycling: when the product cannot be used in its original form, then try to recycle its materials;
5. Combustion as a source of energy: when the product is assigned to be waste, then it can be incinerated in order to generate heat and electric power;
6. Combustion: less favourable is to burn the waste without the generation of heat and electric energy;
7. Landfill: the least preferable option for disposing products and materials.

In the Dutch construction industry, with its vast flow of construction and demolition waste, separating different material streams on site is already being common practice for multiple decades. Meanwhile, our understanding of the environmental impact of not only waste, but also new materials has been increasing. Internationally, the thrive for sustainable development considering our needs and what this implies for fulfilling the need of future generations, introduced in 1987 [7], is nowadays firmly grounded

in seventeen sustainable development goals [8]. Thanks to the efforts of Braungart and McDonough, the traditional Cradle-to-Grave approach in linear economies started by 2002 to be replaced by a Cradle-to-Cradle approach with three main principles [9]:

1. Waste is food, because everything is a nutrient for something else;
2. Use current solar income: energy that can be renewed;
3. Celebrate diversity: species, cultural, and innovation diversity.

Since 2010, the Ellen MacArthur Foundation has continuously been inspiring others to re-think, re-design and build a positive future through the framework of a circular economy. Multiple large companies have joined this journey and the butterfly shaped model for a circular economy with biological and technical materials is world famous [10].

The quest in literature to define what circularity implies in the construction industry, might start with a reference to Kirchherr, Reike and Hekkert and their analysis of 114 definitions of a circular economy [11]. These researchers were able to distinguish two types of approaches in defining a circular economy: a R-approach and a system approach. The R-approach concentrates, in order of favourability, around the strategies: refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle and recover. In the system approach three levels of circular economy systems, where the transition needs to take place, are regarded, namely: at a macro, meso and micro-level. The macro-level considers a whole economic industry and the micro-level applies for example to an individual company.

Based on their sources and the applied coding framework, Kirchherr et al [11] *define circular economy as an economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes. It operates at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, thus simultaneously creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations. It is enabled by novel business models and responsible consumers.*

Considering that our research focuses on how building sites can be prepared circularly in the Netherlands, the efforts of the Dutch government to define this concept cannot be ignored. In 2018 the national Transition Agenda Circular Building of the Netherlands offered the construction industry the following translated description [12]: circular building means to develop, use and reuse buildings, areas and infrastructure without unnecessary depleting natural sources, without wasting the environment and without affecting ecosystems. It is a way of building that can be justified economically and that contributes to human and animal welfare. Here and there, at present and for the future.

3.2. Site preparation

If we are trying to come to a sustainable built environment and a circular construction economy, it makes sense to also have a closer look at the process of site preparation regarding input, throughput and output. In introducing a three step method for sustainable land use by the name of Trias Toponoma, Entrop and Brouwers [6] mention that the space occupied by constructions used by the present generation should ideally not jeopardize the needs of future generations. Locations which are used for buildings, will only rarely and in a time-consuming process be turned back into their original natural state. Therefore, it is necessary to reflect carefully on whether a certain location should be used for construction activities at all. When a certain land plot is being prepared for new construction activities, the process encompasses multiple stages. The activities that make up a traditional construction preparation phase are, according to Segeren and Hengeveld [13]:

- Clearing the site: this can include fencing off the location, removing and replacing vegetation and diverting existing infrastructure (e.g. cables and pipes);
- Executing groundwork: it can encompass raising or excavating the site, placing soil in a depot for later usage, dredging ditches, digging trenches at the location of future (construction) roads, soil compaction and soil improvement works;
- Applying drainage or other forms of dewatering by means of temporary systems;

- Installing sewerage and other facilities for waste water and storm water;
- Constructing civil engineering works as part of the water management, road and sewerage system, for example, weirs, culverts, bridges, tunnels, pumping stations, etc.;
- Applying pavements: temporary roads are laid out and will be replaced during the development phase by definitive pavements;
- Creating green and recreational facilities: interventions such as the creation of open water are also part of the preparation phase. Smaller green areas including the planting of (new) trees, shrubs, etc. make part of the development phase;
- Installing cables and pipes: main systems for the various utilities are installed and will be connected to the buildings during their development phase.

The activities mentioned above are reflected in the STABU specifications (specification system for residential and utility buildings). However, two additional phases can be distinguished [14]:

- Installing construction site facilities: for example the placement of trailers and sheds, the provision of equipment and personnel and organizing the layout of the work site;
- Providing support and executing demolition works for current structures at the site.

According to [15], activities that are part of the phase where construction site facilities are installed, are:

- Installing temporary infrastructure: this includes access to the construction site, the construction roads on the construction site and the layout for available storage space;
- Placing temporary accommodations: this means that temporary housing for construction site personnel and management is placed and that storage space is created for materials sensitive to weather influences;
- Installing temporary installations: these are installations for security and surveillance purposes, temporary utilities in the form of electricity, phone lines and data lines, (potable) water and sanitary installations.

Before any work can be carried out on-site, a number of investigations must be carried out, which can include [16]:

- Ammunition research if the site is located in a former military area;
- WION - KLIC report in which information is collected about the presence of (underground) utility lines on and directly outside the site layout. Because this information is not always entirely reliable and other cables and pipes may also be present, test trenches must be dug to check the data available;
- Soil contamination testing to determine the presence and level of pollution;
- Groundwater research to determine its quality and level;
- Inventory of adjacent plots: when there are other constructions or infrastructures in the immediate vicinity of the site, it should be investigated whether these could be damaged by the foreseen construction work. Plans are necessary on how to cope with any foreseen risks;
- Trees and shrubs that need to be preserved, are measured and recorded in plans;
- To prevent the project from coming to a standstill when archaeological findings are made, a historical investigation beforehand is advised. Historical research is compulsory, when the site is located in an old town district;
- A risk inventory is drawn up, because unexpected things can always occur. This is used to estimate what might be in the underground and how to respond to it.

This part of the literature and document study made it possible to work out a flow chart of activities involved in preparing a site before constructing buildings, which is shown in figure 1.

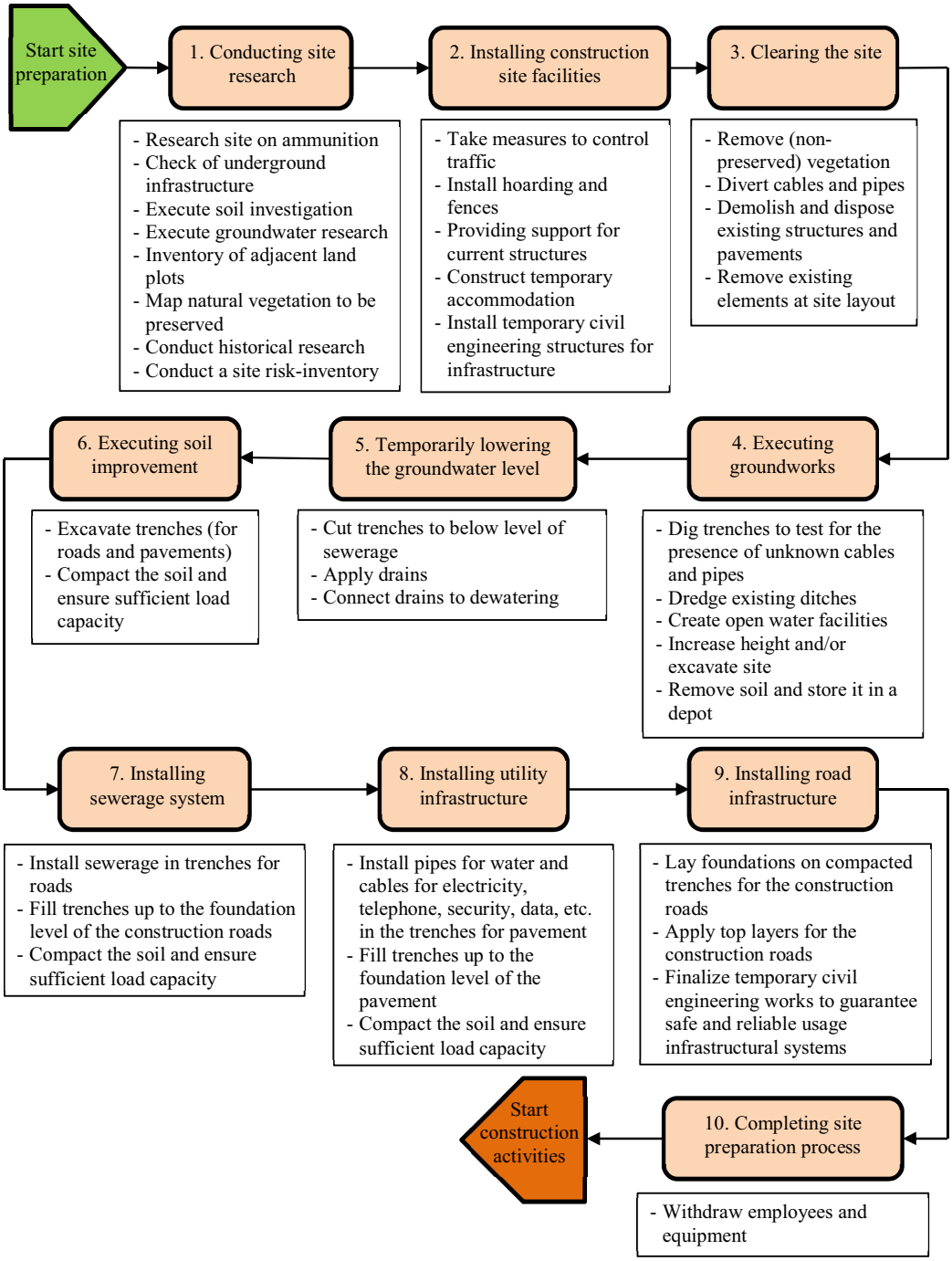

Figure 1. Flow chart of activities to prepare a site for (residential) construction activities [13-17]

To determine how circular the site preparation actually is, the measurement methods of circular constructing are transferred to site preparation. The input of a site preparation process consists, in line with [18] of land, materials, energy, and work. Materials need to be obtained, processed, transported, maintained and reused with the lowest environmental impact possible. Energy use needs to be reduced,

to come from renewable sources and to be available on location in time as efficient and as effective as possible. The work involved in site preparation is done by employees and equipment (work and energy), which are deployed to execute using materials the activities on the site (land). Since the site itself is different for every project, the parameters that can be influenced and will be regarded are materials, equipment, and employees. Therefore, circular site preparation can be defined as follows: in circular site preparation, the site is seen as a system where materials, equipment, and employees are input influencing the level of circularity being subject to A) the R-approach: refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle and recover and to B) the three step triad: reduce, renewable and efficient.

4. Designing the instrument

In the early days of sustainable building, developing and contracting entrepreneurs in the Dutch construction industry were asked to invest in sustainable measures with the help of long lists. These lists summed up all kinds of possible options to make urban plans and buildings (slightly) more sustainable. These lists were the Nationale Pakketen Duurzaam Bouwen (loosely translated in English: National Packages Sustainable Building). Currently, in these early stages of coming to a circular economy, the authors think that asking questions more or less in line with the setup of these former National Packages can help in making involved organisations more consciousness about the impact of their plans. Therefore, we decided to collect and structure questions to be asked to project developers at municipalities and at contracted or at to be contracted organisations in the preparation phase. The name of the instrument in which questions, answers and a rating system are brought together is PrCiSi, being a contraction of Preparation Circularity on Site.

4.1. Circular measures derived from interviewing experts

As already was addressed in the section on the research method, a total of nine respondents were interviewed. The interview format used can be found in the appendix. Although four out of the nine respondents experience in the preparation phase barriers to circularity in forms of money and time, multiple opportunities were addressed. An important starting point is a process in which the site is properly analysed and an inventory is made of available materials. An online databank of locally available materials and products could help in the process of stimulating reuse. Multiple respondents have a scheme to accompany their vision of coming to a more circular site preparation phase, e.g. the Ladder of Lansink [19], metabolic scheme of Gladek [20], and a four step method, consisting of:

1. Reusing the materials available to close materials loops;
2. Preventing waste by using materials as economically as possible;
3. Using biobased solutions for the materials needed;
4. Construct flexible, adaptable and/or demountable, so that a building does not need to be demolished, but it can be adapted to future needs.

Regarding specific measures, individual respondents offered among others the following suggestions:

- The development of construction roads consisting solely of rubble foundations;
- A day for local residents to harvest or collect materials and products on site;
- Design constructions for the site that can later easily be disassembled.

4.2. Formulating questions for the instrument

The input from literature and experts made us distinguish three categories of measures needed to come to a more circular economy in the preparation phase of building projects, namely materials, equipment and personnel. In the first version of our instrument the category materials consists of 46 questions, while in the categories equipment and personnel respectively 35 and 16 questions are being asked. Due to the high adoption rate of Microsoft Office, it was decided to construct the instrument in Excel.

4.3. Setting the scores in the instrument

With almost one hundred questions in multiple categories, we felt the urge to make sure an easy overview can be maintained (see figure 2). Therefore, a first column indicates by using a mark and the colours green and red, if a certain question in the second column already has been answered or not. The answers to the questions can be selected from a drop down menu in the third column. Each individual answer corresponds with a numerical value in a fourth column. For this value the typical Dutch rating system is being used, which means that a 10 indicates an excellent score high in the R-approach with a focus on reducing the need for materials and a 1 stands for the worst possible outcome low in the R-approach. Depending on the specific question and the result of an accompanying literature study on that topic, it was defined what matches with which score exactly. This means that for materials 28, for equipment 12 and for personnel 7 different answer models were developed. In column five and six additional questions can be raised, explanations can be provided and proof needs to be given to substantiate the selected answer in the third column, before the score is taken into account for the overall category score. The user of the instrument or, so you wish, assessor will end up with three scores between 1 to 10, namely one score for materials, one for equipment and one for personnel. In this first version of PrCiSi every question in each individual category has the same impact in the overall category score. In the very last column an indicator shows at a glance the difference between sufficient and insufficient scores.

Materials	6.4
Equipment	4.0
Personnel	4.3

Project:	Noorder Koeslag
Assesed by:	Anonymous
Date:	25/08/2020

Question completed yes/no	Question	Materials	Answer	Score	Additional question	Arguments, proof and substantiation	Score counted	Indicator insufficient score
	1	**Necessity of the need for**						
v	1.1	Are crawl spaces going to be allowed or applied?	Yes	1.00	Why are crawl spaces applied or not?	*Unknowen*	1.00	insufficient
v	1.2	Is the soil at the project site contaminated?	No	10.00	What contamination is present at the project	*Unknowen*	10.00	
v	1.3	Is it possible to leave contaminated soil?	There is no contaminated soil	10.00	How can contaminated soil not have to be removed?	*Unknown*	10.00	
v	1.4	How is contaminated soil remediated?	There is no contaminated soil	10.00			10.00	
v	1.5	Is pipework going to be installed below groundwater level?	Yes	1.00	At what level should the piping be installed?	*Groundwaterlevel is lowered approximately 1.1*	1.00	insufficient
v	1.6	How will it be prevented that groundwater temporarily needs to be lowered?	Temporary lowering of groundwater cannot be prevented, source dewatering is used	1.00			1.00	insufficient
v	1.7	How is the material use for piping reduced or prevented?	No material reduction has been applied to the pipework	1.00			1.00	insufficient
v	1.8	How is the material use for the construction roads reduced or	No reduction in the material use of construction roads has been applied	1.00			1.00	insufficient

Figure 2. Screenshot providing an impression of the PrCiSi instrument

5. Testing the instrument

In the municipality of Olst-Wijhe (with approximately 18,000 inhabitants) PrCiSi was tested by assessing two sites. The first site with a surface of 33,500 m^2, for 90 dwellings at maximum, was recently prepared and is known by the name of Noorder Koeslag. The second site still needs to be prepared for construction purposes and is called Olstergaard. This site covers an area of 35,000 m^2 and offers around 71 separate land plots to the housing association and for (collective) private commissioning.

The commissioned organisation that conducted the site preparation activities at Noorder Koeslag, was asked to make use of the instrument. This contractor experienced no severe problems in answering the questions except for rating the durability of the materials used for cables, pipes, civil construction works and the road infrastructure. When preparing the site, excess materials were made available for reuse. These materials were not reused on site, but did find a new purpose within the province of Overijssel. Materials needed for the roads in this project were also found within the province, but from a transport point of view it would have been better to collect them locally. The scores for Noorder

Koeslag were, as assessed by the contractor, a 6.66 for materials, a 3.7 for equipment and a 4.3 for personnel (see figure 2). These scores are the results of a great number of questions that could not be answered positively, because 43% of the questions in the category material were rated as insufficient, as well as 67% in the category equipment and a staggering 69% in the category personnel. Although little irrefutable proof to substantiate the answers was provided by the contractor, it was a positive experience for the researchers to find out that the contractor was willing to answer all questions, associated the questions asked to circularity and considered himself to be able to complete the instrument.

The test for Olstergaard could not fully be completed, because no specific contractor had yet been commissioned at the time the first version of PrCiSi became available. Because no contractor was commissioned, questions regarding the transport of materials, equipment and personnel could not be answered. Due to fluctuating ground water levels in the area, uncertainties exist in estimating how much ground water needs to be extracted and which method could be applied. Regarding material use the respondent expressed his doubts on reusing materials, when it comes to pipes, but also cables, their quality needs namely to assured. The scores for the categories equipment and personnel could not yet be assessed. The category materials scored a 8,1. This fairly high, but questionable score was possible, due to the relatively small material usage. In other words, not all infrastructure was installed yet, nor were infrastructural works designed or planned yet. The only possible solution here is to wait, before more information becomes available. All things considered Olstergaard was in fact not yet assessable.

6. Conclusion

In this paper the research process to come to a practical instrument to assess the rate of circularity of a site preparation process was explained. Although the authors are aware that among the readers of this paper questions might exist on how questions and answers in the tool are exactly formulated, conciseness is a great asset and only a Dutch version of the tool was developed and tested.

In this first version of PrCiSi every question in each of the individual categories has the same impact in the overall category score. However, testing the instrument and new insights might steer us in other directions, where the impact of individual questions is differentiated. With more sites to be tested, future research can also clarify more profoundly what can be regarded as insufficient, sufficient, good, excellent levels of circularity. Hence, this can set the pass mark for site preparation projects.

The instrument was originally developed to facilitate the sustainable property development process in Olstergaard. However, at the time a first (Dutch) version of the tool came available, not all necessary data could be provided. It is, therefore, recommended to revisit this case to re-explore the strong and weak points of the instrument and, of course, of the preparation phase for Olstergaard.

The authors are aware that the instrument still needs further development. Considering that granting high scores (marked 8 to 10) already for nowadays projects might not be the best incentive to stimulate developments towards a circular economy in 2050. Thus regarding verification, the instrument operates as expected, but the current way of computing might result in scores that overshoot the actual level of circularity. Further research is necessary to validate this instrument and the underlying model.

However, we are confident that providing information about the development of this instrument helps in raising circular awareness among those that are currently involved in site preparation. As Mulhall & Braungart [8] could phrase it: this first version of PrCiSi might make the current situation less bad.

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Appendix: interview format

In July 2020, nine respondents were interviewed on circular site preparation. This appendix shows the interview format used.

Name respondent	*< titles, initials, first name and family name respondent >*		
Email address	*< email address respondent >*		
Job description	*< respondent's job description >*		
Name organisation	*< name of the organisation, where the respondent works >*		
Work experience	*< relevant work experience of the respondent >*		
Subject interview	Circular site preparation		
Start time	*<##:##>*	End time	*<##:##>*
Date interview	*<##-##-2020>*	Date feedback report	*<##-##-2020>*
Location interview	*<due to covid19 regulations online meetings were held>*		

A. Introduction
As an introduction the first few questions were always related to completing the table with the personal and job characteristics, e.g.:

1. Which organisation are you working for?
2. How would you describe your job at this organisation?
3. What is your work experience regarding the preparation of sites?

B. Definitions

1. What does building circularly mean to you?
2. What does site preparation mean to you?

C. Tender phase

1. What are types of clients your organisation is working for?
2. Do these clients specifically ask for circularity or do you bring this subject up?
3. What could be improvements in the tender phase to execute the site preparation in a circular way?

D. Circular site preparation

D.1. Clearing the site

1. How can existing structures be handled at a site in the most circular way?
2. How can (non-preserved) vegetation be removed in the most circular way?
3. How can cables and pipes be diverted in the most circular way?

D.2. Executing groundworks

4. How can groundworks be executed in the most circular way?
5. How can contaminated soil be remediated in the most circular way?

D.3. Installing sewerage system and utility infrastructure

6. How can the groundwater be temporarily lowered in the most circular way?
7. How can the sewerage system be installed in the most circular way?
8. How can the utility infrastructure be installed in the most circular way?

D.4. Installing road infrastructure

9. How can the road infrastructure be installed in the most circular way?

D.5. Additional activities

10. Are there additional activities during the site preparation that could be executed in a circular way? If so, how could this be done in the most circular way according to you?

D.6. Withdrawing employees and equipment

11. How could equipment be deployed and withdrawn in the most circular way?
12. How could employees be deployed and withdrawn in the most circular way?

E. General

1. What are important laws and regulations that apply to site preparation? Do these laws and regulations have, in your opinion, a positive or negative impact on circularity?
2. How can municipalities facilitate the circular measures mentioned by you in section D?
3. When focusing on the maintenance of equipment, are there types of equipment we should not be using anymore during site preparation?
4. When focusing on the maintenance of materials, are there types of materials we should not be using anymore during site preparation?

F. Completion

1. What can in your opinion be interesting characteristics of and opportunities for a site to prepare it in a circular way?
2. What are in your opinion possible barriers to a site to prepare it in a circular way?
3. Do you have a reference site preparation project that offers information on quantities and materialization that can be used for this research project?
4. Do you have maybe any additional comments that are worth sharing in relation to this circular site preparation research project?