# Exploring a geodesign approach for circular economy transition of cities and regions
## Three European cases

Furlan, Cecilia; Mazzarella, Chiara; Arlati, Alessandro; Arciniegas, Gustavo; Obersteg, Andreas; Wandl, Alexander; Cerreta, Maria

**DOI**
10.1016/j.cities.2024.104930

**Publication date**
2024

**Document Version**
Final published version

**Published in**
Cities

Cities 149 (2024) 104930

Contents lists available at ScienceDirect

Cities

journal homepage: www.elsevier.com/locate/cities

# Exploring a geodesign approach for circular economy transition of cities and regions: Three European cases

Cecilia Furlan [a,b,*], Chiara Mazzarella [a], Alessandro Arlati [d], Gustavo Arciniegas [e], Andreas Obersteg [e], Alexander Wandl [a], Maria Cerreta [c]

[a] Department of Urbanism, Faculty of Architecture and the Built Environment, Delft University of Technology, Delft, the Netherlands
[b] Institute of Landscape Architecture, University of Natural Resources and Life Sciences, 1180 Vienna, Austria
[c] Department of Architecture, University of Naples Federico II, 80134 Naples, Italy
[d] HafenCity, University Hamburg, 20457 Hamburg, Germany
[e] Geo-Col GIS and Collaborative Planning, 2612 BB Delft, the Netherlands

A B S T R A C T

Transitioning towards a circular built environment and turning waste into resources have become one of the new sustainability paradigms today. However, a circular transition can be considered a 'wicked problem'. The multiple dimensions and scales of the circular transition and its substantial spatial implications fit well into the planning approach of Geodesign. The Horizon 2020 funded project "Resource Management in the periurban Areas - Going beyond Urban Metabolism (REPAiR)" implemented an innovative Geodesign approach. Moreover, it explored its capability to support spatial decision-making processes for the circular economy transition of the built environment within urban planning practices. This article aims to understand to what extent a process of Geodesign, which is conducted with the support of a digital tool and a Living Lab approach, can support the creation of localised circular economy strategies and foster the circular economy transition in cities and territories. The analysis explores and compares the results of three European cases -Amsterdam, Hamburg and Naples. It considers the kind of data input required to run the process in every phase, the stakeholders involved and their typology, the specific urban or territorial, planning and governance scales of analysis, and the final output definition after the Geodesign process implementation. The approach outputs constitute a decision support system for easing negotiations between local actors regarding the circularity strategies to implement. The findings reveal an intertwinement between different forms of knowledge included in the process, ranging from sustainability to governance and design, and the actors engaged in planning a circularity transition spatially. However, even using similar starting data, the local information and the starting conditions strongly influence the process and the types of strategies elaborated in each case.

## 1. Introduction

The world is rapidly urbanising, resulting in ever-increasing resource requirements and pollution flows. It is estimated that cities and urban territories nowadays are responsible for 80 % of the global energy consumption. Since 2010, more than 40 billion tons of mineral materials per year have been extracted, transformed, and transported for urban construction (Swilling et al., 2018). Under these conditions, the "Circular Economy Action Plan" was drafted in the framework of the European Green Deal. Herein, the main objectives of the previous Circular Economy Action Plan (European Union, 2017) are strengthened with an additional focus on the urgency to systematically apply circular schemes at regional and city scales all over the world, following the Only One Earth motto (UN, 1972).

In response to this urgency, the concept of Circular Economy (CE) concerning the built environment has recently been spearheaded by industries, political institutions, and other stakeholders. CE has many definitions and interpretations. Following the reflections of Christensen (2021) and Blomsma and Brennan (2017), CE is an "umbrella concept". It is a broad heuristic concept to develop strategies and policies at different scales where resource value is preserved, and regenerative design is prioritised for as long as possible (Kirchherr et al., 2017; Bauwens et al., 2020). At its core, the CE concept has two main interlinked aspects: the circular flows of physical materials more related to the industrial ecology perspective -the material aspect- and the economy of these flows -the business and actor-oriented aspect- (Christensen, 2021). Both aspects interact with the built environment in various ways. However, we agree with Williams (2019) that the current CE conceptualisation is inadequate when applied to cities and territories and their transition to a more sustainable use of resources.

Additionally, there are only a few examples of empirical research on how the implementation of CE takes place in a regional context (Bahers et al., 2022; Cramer, 2020). The material aspect focuses mainly on localising and quantifying material flows but neglects the drivers and

* Corresponding author at: Department of Urbanism, Faculty of Architecture and the Built Environment, Delft University of Technology, Delft, the Netherlands.
*E-mail address:* c.furlan@tudelft.nl (C. Furlan).

https://doi.org/10.1016/j.cities.2024.104930
Received 2 February 2023; Received in revised form 27 February 2024; Accepted 5 March 2024
Available online 18 March 2024

barriers for implementation in urban and landscape contexts (Furlan et al., 2022). Simultaneously, the more business-oriented aspect identifies drivers and barriers to implementing CE but has a limited understanding of the environmental and spatial impacts of the business model in the built environment (ibid.).

Fratini et al. (2019) point out that the imaginaries of circular cities are often stuck on diagrammatic levels. Only a few articles investigate the interrelationship between CE and the institutional dynamics underpinning urban transformations. As with other sustainability transitions, circular transitions of cities and territories pose a structurally complex wicked problem for which no definitive answer might be defined (Loorbach, 2017). Wicked problems have no clear solutions or goals until they are achieved (Rittel & Webber, 1974). It is unclear where they begin or stop. They might have multiple solutions or remain unresolved (Marin & De Meulder, 2018; Viganò, 2014).

One way to overcome CE inadequacy is to develop a better interdisciplinary understanding of the interrelations between different material flows (e.g., organic waste, construction and demolition waste), territories (cities, regions, functional territorial units) and groups of actors (industrial actors along the cycle of a given material flow, waste management companies, regional and local authorities, civil society groups, builders and developers). The complexity of this threefold interrelation requires careful conceptualisation, existing process analysis, forecasting, exploration of alternative solutions, and impact simulation and assessment. Each must be considered towards implementing a circular transition of the built environment. The complexity of the circular transition and its strong spatial relations require developing and adopting innovative approaches and tools of urban planning and design discipline. Therefore, the main research question behind this paper is: *How do we support the implementation of CE transition in cities and territories?*

Within this context, this article explores an adapted Geodesign approach presented as an alternative to tackle the wicked character of CE in the built environment. It showcases how waste and resource management can be faced through a spatial decision-making process based on specific spatial components that can address the challenges of the sustainability transition.

Geodesign is an adopted collaborative spatial planning approach involving local inhabitants, relevant professionals, and geographic information science and technologies (Batty, 2013; Steinitz, 2012). Like circular thinking, Geodesign follows a systems-based approach to analyse human, resource and environment interactions at multiple spatial scales to provide helpful information for urban planning design and decision support (Campagna, 2014; Gu et al., 2018). While Steinitz (2012) unfolds the system's complexity by addressing six essential questions and a collaboration component, Ervin (2016) adopts a more technological perspective. Indeed, Ervin (2016:145) describes Geodesign as an "*environmental planning and design activity that leverages the powers of digital computing, algorithmic processes and communications technologies*". He depends on timely feedback about the impacts and implications of proposals. This clearly emphasises the significance of technologies for the iterative design process, reflecting a procedural approach to simulate and model landscape changes in the future. Following the perspectives mentioned above, the advances of Geodesign compared to other landscape and environmental planning approaches are threefold. It allows for:

1) an extensive use of digital data in design, evaluation and communication;
2) a prominent role to design by developing spatial solutions to specific place-based problems;
3) transdisciplinary and iterative nature calls for collaboration among different stakeholders.

In light of these reflections, the Horizon 2020 research project "Resource Management in Peri-Urban Areas. Going beyond urban metabolism" (REPAiR) delivered a Geodesign approach and corresponding digital tool to assist local and regional authorities in creating integrated spatial development strategies for CE transition. REPAiR approach focuses on the specificity of the place at hand and supports the elaboration of transdisciplinary and circularity. Thus, the Geodesign Decision Support Environment (GDSE) (REPAiR, 2016; Arciniegas et al., 2019) was developed as a digital spatial collaborative decision-making tool to facilitate the co-designing of place-based circular strategies. The GDSE is one of the many existing Geodesign tools and digital platforms. The most popular digital tool for Geodesign is the Geodesign Hub (Ballal, 2015). It is an open-source instrument primarily employed to operationalise the Geodesign method for managing and arranging intricate planning issues. It connects different geographical regions, fostering collaborative decision-making among various stakeholders. While the Geodesign Hub open-source platform is designed for spatial planning, the GDSE open-source platform aims to enhance the management of material resources and their waste in the studied territories (Cerreta et al., 2020). Furthermore, compared with other existing digital tools supporting circularity, Material Passport (e.g. Madaster), Building Information Modelling (BIM) and BIM 'add-ins' (Kovacic & Honic, 2021) IoT systems across life cycle stages (Li et al., 2021), and Urban Mining Models (Kleemann et al., 2017), the GDSE is an instrument that allows a holistic, iterative, and inclusive process, involving potentially many different actors with no *ad priori* exclusion (Wuyts & Marin, 2022). It is a decision support system for the transition towards circularity aiming to improve urban metabolism by promoting the reuse of waste itself as valuable resource streams. However, what types and levels of information and knowledge are to be provided and shared, and under which circumstances and approaches are needed to activate a collaborative decision-making process?

In the following sections, the article explains a refined Geodesign approach to support decision-making in the CE transition, addressing its spatial impacts more explicitly. Firstly, it describes the REPAiR Geodesign approach, its steps phases and how it is tailored for circularity challenges, and then tests the latter on the Amsterdam Metropolitan Area (AMA) (NL), Hamburg (DE) and Naples (IT). The three cases have been selected as they represent all ranges of commitment and ambition towards circular planning strategies. Still, they differ significantly in spatial dimensions, governance structures, population density and distribution. Lastly, the paper discusses the limitations and benefits of the approach based on the results and the comparison of the case studies.

## 2. Materials and methods: a Geodesign-based decision support approach for circular economy transitions in cities and regions

The Geodesign approach developed within REPAiR aims to address the two research questions by providing an alternative method for stakeholders to transition towards circular cities and territories. It seeks to produce alternative space-specific waste and resource strategies to overcome these above-mentioned challenges and to provide new instruments (Geldermans et al., 2018). Moreover, the REPAiR Geodesign workflow has been adapted into the GDSE tool to integrate metabolic aspects in a usually land-use-oriented approach (REPAiR, 2020). The developed Geodesign process was structured according to the Steinitz method, and the different phases and steps were implemented and tested through workshops and living labs. The three case studies revealed issues related to the information provided for the CE planning process.

*I phase - The study area and its flows.* The first phase shows the Study Area's spatial analysis, identifying and collecting the primary information about its most prominent material flows. This phase is divided into four steps: geographical maps, data charts, stakeholder analysis, and metabolic material flows.

*II phase - The metabolic flows of resources*. The second phase unfolds an understanding of the Status Quo of the metabolic flows mapped on the territory.

*III phase - The target definition.* The third phase defines CE Targets and indicators as parameters to assess the impact of the strategies impact.

*IV phase - The strategies for the circular management of resources.* The fourth phase requires an elaborating strategy for the circular management of the resources through the combination of place-based solutions across the study area.

*V phase - Evaluation and Conclusion - Negotiation phase.* The fifth phase presents the conclusions as a nine-step summary of the choices made by each stakeholder, their strategies, and their impacts (Fig. 1).

Along the workflow of the five phases, the REPAiR Geodesign approach provides for continuous interaction with the local stakeholders involved in the decision-making process through workshops (Amenta et al., 2019). In the first four phases, the stakeholders' groups work on separate tables and topics, while moments for sharing their knowledge and experience are foreseen at the end of every phase. The last phase takes place collectively and enables the dialogue and negotiation of the choices, supporting comparing the Geodesign results and making the collaborative planning of circular strategies. The developed Geodesign approach has been applied in six European regions through its digital tool, the GDSE. For the scope of this article, three case studies out of the six examined were selected and compared: Amsterdam Metropolitan Area (AMA) (NL), Hamburg (DE), and Naples (IT). The selection of the case studies was based on the maximum variation strategy (Flyvbjerg, 2011).

The three analysed cases differ in their spatial contexts, stakeholder typology, and waste and resource flow analysis. They represent three examples of environment, information, and conditions necessary to activate a collaborative decision-making process to co-plan and co-design eco-innovative strategies. Their selection was driven by:

- the completeness and variety of data available concerning spatial information and the flows addressed;
- the richness of the stakeholders' constellations engaged in creating local specialised strategies;
- the design and development of solutions elaborated to address the commonly defined challenges

The Amsterdam case was chosen for its focus on the extensive metropolitan scale within a CE transition, which includes places of supralocal interest (e.g., the Skypol Airport) and goes beyond the city scale. Amsterdam shows the most advanced transition awareness among the three cases with its CE strategies. As a city-state, Hamburg was selected because of a unique constellation of actors working on waste management at different levels in a limited geographical area. Hamburg has a long waste management tradition, but CE was never implemented due to communication barriers between governance sectors. Finally, the Naples case was chosen because of its regional approach to waste management issues and the relation of the latter to land use and socio-environmental conflicts (De Rosa, 2018). Lastly, among the six cases studied within the project, REPAiR, Amsterdam, Hamburg, and Naples feature the most data variability and availability.

The compared cases offer relevant information on the process of cities pursuing the CE transition following a Geodesign approach. Moreover, they are significant for identifying potentials and critical aspects of its implementation.

Concerning the three case studies, the analysis of the information to be provided for the CE planning process is structured according to four dimensions (Table 1):

1. the kind of **data input** required to run the process in every phase;
2. the **stakeholders** involved and their typology. Stakeholders were chosen concerning their interest, knowledge, and involvement towards a CE transition of the selected case study to respect principles of inclusiveness;
3. the specific urban or territorial, planning and governance **scales** of analysis;
4. the **output definition** after the Geodesign process implementation**.**

Each phase received data input from different sources:

- Geomorphological maps, stakeholders' information, and metabolic flow information for the Study Area. Much of this information has been processed through a cartographic operation. Maps are indeed optical instruments, synthesising on paper existing dynamics and highlighting future potentialities to explore place-specific transitions to CE (Furlan et al., 2022).
- Processed the collected information on flows and spatial data through the activity-based spatial material flow analysis (AS-MFA) for the Status Quo. The AS-MFA is an innovative method enabling the

**Table 1**
The REPAiR Geodesign information to run the process (authors' elaboration).

| Data input | Stakeholder | Scale of analysis | Output |
|---|---|---|---|
| **- I Study Area:** geomorphological maps, stakeholders' information, and flow information.<br>**- II Status Quo:** databases of the activity-based spatial material flow analysis for the Status Quo<br>**- III Targets:** targets of CE policies<br>**- IV Strategy:** circular strategies. | - Public administration, all levels (municipality, regional, national)<br>- Industry (third sector/businesses, SMEs, agriculture, start-ups, service providers)<br>- Research (universities and institutions)<br>- Civil society (NGOs, citizen groups, grassroots initiatives). | - World<br>- EU<br>- Country<br>- Region (urban, periurban, rural)<br>- Focus Area | - Strategies (flows, policy, behavioural changes, infrastructure)<br>- Flow assessment<br>- Groups' preferences comparison |

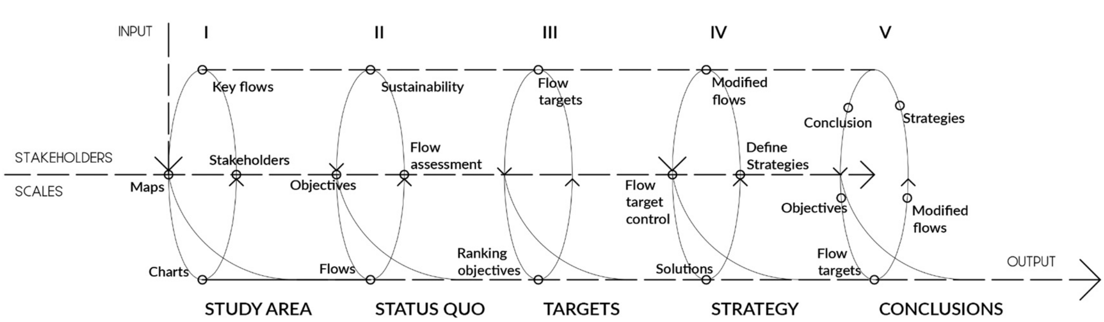


**Fig. 1.** The REPAiR Geodesign workflow has five iterative phases (authors' elaboration).

relation of specific activities and actors with their material flows and stocks in distinctive areas at a specific moment (Furlan et al., 2020). In particular, the AS-MFA provides a detailed baseline analysis of the current waste flow relations in geographically and administratively defined areas, mapping the flows between economic and domestic activities, thereby revealing material flow geographies through a system diagram and flow map. Flows were mapped by identifying the quantities of materials and wastes (according to their official European classification) against a base year. The actors that constitute the origin and destination of the flows were mapped and classified according to their economic activity categories.

- Definition with the stakeholders of targets of CE policies for the third phase.
- Circular solutions to be combined in the strategy planning phase.

The stakeholders involved in the process were public administration, industry, research and civil society (Carayannis and Campbell, 2009). The scales of analysis were not chosen following the administrative boundaries but as a combination of urban-rural typologies and large-scale lever boundaries, which have been translated to different units of investigation differently in different cases, most often due to data availability and stakeholder interests.

As the output of the REPAiR Geodesign workflow, the strategies, their flow assessment, and the comparison of groups' preferences can support decision-makers.

The comparison between the three European cases allows us to clarify what environment, information, and conditions contribute to a Geodesign process for the CE transition, co-planning and co-design strategies for resource management, and the difficulties still to be addressed at the different scales.

## 3. Results

This section presents the results of the Geodesign method applied to the AMA, Hamburg, and Naples cases. The analysis results are summarised in Table 2 and aim to address the following: *Which is the information to be provided and knowledge to share, under which circumstances and approaches are needed to activate a collaborative decision-making process?* Each case has been analysed according to the four dimensions described in Section 2, namely: data input, stakeholders, territorial governance and planning scale, and output.

**Table 2**
Main information for each case study according to the four analytical dimensions (authors' elaboration).

| | AMA | Hamburg | Naples |
|---|---|---|---|
| Data input | Identification of small scattered abandoned and underused spaces based on the territorial analysis sourced from National database (Pdock)<br>ASMFA of CDW and OW Data from Orbis and<br>ASMFA of CDW and OW | Few and small underused spaces located at the fringe of the settlement.<br>Data from ORBIS plus manually inserted by the research team.<br>ASMFA | Contaminated rural sites and underused spaces<br>ASMFA of CDW and OW<br>Data from ARPAC Waste Cadastre |
| Stakeholders | Public Administration, Research Institutions, NGOs, international partners of the REPAiR project, Civil society, university students, local business representatives and circularity innovation SMEs | Public administration (planning department), public waste management companies, private SMEs (tree nurseries), university students, local grassroots initiatives or other stakeholders for awareness raising (school) | Public Administration (Regional department, Mayors and ARPAC), local NGOs from the Focus Area, Civil society |
| Territorial planning and governance scale of analysis | Regional scale encompassing 32 Municipalities, North-Holland and Flevoland, flow relations, national and neighbouring countries. | District of Altona, Hamburg<br>County of Pinneberg, Schleswig-Holstein,<br>Flow relations neighbouring Laender | City of Naples and the Municipalities of Acerra, Afragola, Caivano, Cardito, Casalnuovo di Napoli, Casoria, Cercola, Crispano, Frattaminore, Volla;<br>Flow relations national |
| Output definition | Alternative place-based eco-innovate circular strategies derived from 26 eco-innovative solutions categorised in:<br>- products solutions<br>- policy solutions<br>- spatial solutions for CDW, OW and abandoned and underused spaces | Alternative place-based eco-innovate circular strategies derived from 10 eco-innovative solutions categorised in:<br>- awareness raising solutions<br>- infrastructure solutions<br>- policy solutions For OW and GW | Alternative place-based 13 eco-innovate circular economy strategies:<br>- infrastructure solutions<br>- awareness rising solutions<br>- policy solution for CDW and OW Solutions and strategies have been developed with stakeholders as part of territorial strategies for waste space regeneration. |

### 3.1. Amsterdam Metropolitan Aarea

Located in the Netherlands, the Amsterdam Metropolitan Area (AMA) is one of Europe's top five economic regions, with a population of 2.5 million inhabitants (Metropoolregio Amsterdam, 2019). The region includes key infrastructure, such as the Schiphol Airport and the port of Amsterdam, business and service districts, natural areas, and a considerable concentration of tourism and leisure activities (Metropoolregio Amsterdam, 2019). This concentration also poses a significant challenge to urban planning regarding the quality and quantity of housing, resulting in the designation of expansion areas for AMA (Geldermans et al., 2018).

The input data were collected at the AMA scale through all five phases of the REPAiR Geodesign approach. This action involved collecting geomorphological and waste data for 32 municipalities within the AMA boundaries, which includes the city of Amsterdam and encompasses the boundaries of two provinces (North-Holland and Flevoland). The geomorphological analysis resulted in the identification of scattered and small waste spaces (Berger, 2006). They have been categorised as abandoned and unused areas located along the water and within the port industrial area; a fine grain of lands left as greenfield and without a specific destination; a fragmented pattern of polluted and possibly polluted lands located within the port area; the safety and noise area relative to the airport infrastructure. The data analysis shows that the abandoned and unused surface is minimal. This phenomenon is mainly due to the intense urbanisation pressure that the AMA region is experiencing, in which every area counts as potential space for buildings and infrastructures and the land value of real estate property.

Over four years, more than 30 stakeholders from the AMA, including different public authorities, private sector, research and education institutions, and civil society, were involved throughout the five phases of the development and implementation of the REPAiR Geodesign approach. Although the stakeholders' presence remained constant throughout the process, the most effort was spent defining an overall strategic view and negotiating different private and public interests on CE. This generated a vibrant context of learning and experimenting, with some challenges and limitations, such as meeting the demand and expectation to achieve circularity of the engaged stakeholders, researchers, and students, confronting the competitive interests of the stakeholders. In the AMA case, four interconnected workshops were organised following this process sequence: co-exploring, co-design, co-production, and co-decision (Arciniegas et al., 2019). Each workshop featured one of these four processes. Before the first workshop, the stakeholders answered a survey to collect their preferences regarding significant waste flows in the AMA and their wishes concerning CE. As a result of the survey, two key flows were deemed essential: Construction and Demolition Waste (CDW) and Organic Waste (OW). Key value chains were confirmed and further specified. The subcategory Food Waste (FW) was underlined concerning OW flows as a primary concern (Geldermans et al., 2018). The importance of CDW and FW was also confirmed in the evaluation of Amsterdam's circularity programme report. Several perspectives for action are identified regarding a shift towards circular food systems (Gemeente Amsterdam, 2020).

Data from CDW and FW were collected by LMA (Landelijk Meldpunt Afvalstoffen). The LMA database provided the most complete data on waste flows, specifying attributes such as the type of waste, from which company, by whom it is collected and where the waste is sent for further handling and processing.

The LMA database provided the most complete dataset on the type of waste, from which company, by whom it is collected, and where it is sent for further handling. Additional actor data relative to flow movement were also obtained through the ORBIS database.

As input to the co-design workshop, spatial maps, and a material flow diagram for the CDW and FW from AMA companies and households were produced to depict the existing territorial flow dynamic (*status quo*). By analysing these dynamics, the potential of FW and CDW to be reintegrated through alternative circular strategies became apparent. The 26 eco-innovative strategies obtained from the process differed in their affected material flows, actors, and processes. They have been categorised as products, policies, and spatial strategies. Each strategy played a different role in the transition towards circularity. Some are symbiotic, some exclude each other, and all have different, sometimes overlapping, claims on spaces and stakeholders. The variety of developed strategies demonstrates the difficulties and complexity of the design process in the pursuit of circularity. Most of the strategies tend in different ways towards circularity without ultimately achieving it, as eventually, they still lead to waste generation, even if limited. This result does not indicate a failure to develop fully circular solutions. However, it helps to demonstrate the difficulties and the complexity of the design process in pursuit of circularity. The result also demonstrates the limitations of the current technological, political, and legal systems within the AMA context. Lastly, the necessity of redesigning urban strategies and spatial processes involving CE principles in the regeneration and treatment of CDW and FW offered the possibility to go beyond the urban design and planning field of knowledge and consequently explore systemic thinking methods. Indeed, developing eco-innovative strategies involved the cooperation of designers and industrial ecologists. The cooperation led to co-developing strategies and solutions that simultaneously tackle FW and CDW systems, suggesting alternative and creative ways to redirect and eliminate waste from the stream. The co-production process integrates sectoral knowledge, shaping stakeholders and their ability to generate collaboration and action across the AMA (Marin & De Meulder, 2018). Interactions between researchers, designers, students, and stakeholders helped deepen the understanding and increase awareness of the AMA context and its specific needs and limitations in the transition towards a circular economy.

### 3.2. Hamburg

Situated in the north of Germany, the Hamburg case focused on two distinct focus areas: the Altona district in Hamburg and the County of Pinneberg in the neighbouring Federal State of Schleswig-Holstein. Although adjacent, these two areas present different socio-economic and spatial conditions.

The county of Pinneberg has a population of 317.085 inhabitants and a population density of 477 inhabitants per square kilometre (Statistisches Amt für Hamburg und Schleswig-Holstein, 2021a). Respectively, the district of Altona has a population of 274.702 inhabitants in 2018 and a population density of 3.526 inhabitants per square kilometre (Statistisches Amt für Hamburg und Schleswig-Holstein, 2022).

The input data for the geomorphologic maps were collected for both cases in parallel, featuring the same information. The maps highlight a series of waste spaces identified as sites related to dumping activities and where the planned developments have yet to occur, such as 'land without use' and 'abandoned productive site' (Berger, 2006). These areas were located close to dump sites, underused infrastructures, and nearby mineral extraction sites and along the borders between Hamburg and Pinneberg County, where most tree nurseries are. Considering the specificity of the Pinneberg and Altona case, the analysis concentrated on two different flows, requiring further data collection. Actor data relative to flow movement were obtained through the ORBIS database. However, not all needed actors' data (especially regarding NGOs) were available and had to be computed manually. Waste flow data derived from existing literature reports and a national database of waste authorities were manually filtered and processed. The District of Altona case dealt with Organic Waste (OW) generated at the household level. This case has already been thoroughly discussed by Obersteg et al. (2020) and needs to be presented in detail. For the scope of this paper, it is relevant to mention that the scale of analysis was reduced from the district to the neighbourhood level. The reason for this choice was the availability of a detailed waste analysis of the waste flows generated by household units according to five housing typologies, thereby calculating the amount of waste generated in each neighbourhood concerning the share of the different housing typologies.

For the Pinneberg focus area, the unit of analysis was the material flow of Garden Waste (GW) from tree nurseries. With 174 companies and a cultivated area of 2.617,2 ha, Pinneberg is one of the most significant clusters of tree nurseries in Northern Europe (Statistisches Amt für Hamburg und Schleswig-Holstein, 2021b; Statistisches Bundesamt (Destatis), 2021). The stakeholders involved in the Pinneberg case are the planning office of the County of Pinneberg, the public-private waste management company of the county of Pinneberg Schleswig-Holstein (GAB), the representatives of tree nurseries and the research team for the HafenCity University Hamburg (HCU). The planning office representatives and the research team of HCU were steering the process, bringing together public and private authorities and nursery representatives (REPAiR, 2017b). The stakeholders' constellations in the process differed along the phases in Hamburg. Many levels and different types of stakeholders were present initially. However, the more the process advanced and acquired a local character, the fewer stakeholders from the public sector remained. In contrast, more practitioners were engaged when the process evolved towards solutions and strategy generation.

Concerning the County of Pinneberg case, the most relevant problems for the scope of this article identified by the stakeholders are listed below:

- The quantity of GW generated in tree nurseries is high, and it generally is not reintegrated into the material cycle.
- Most of the GW is transported to compost sites or composted in the area of the tree nurseries; no biogas is extracted during the composting process, and the usage of the compost products often needs to be clarified.
- No law is impeding the burning of waste on the ground; the incineration of garden waste on the sites of tree nurseries created conflicts with neighbouring settlements;

- In the last decades, the surface of tree nurseries was constantly reduced due to settlement expansion pressure (REPAiR, 2017).

As input to the one workshop in 2018, a geomorphological analysis of spatial maps and a material flow diagram for the garden waste from tree nurseries were produced to depict the status quo. The data were retrieved from the geoportal of the Federal State of Schleswig-Holstein. Some information, however, was missing or not free to use, such as natural protected areas. Therefore, the REPAiR research team redesigned and recalculated the missing spatial data. The primary data on GW were deducted from official annual GAB reports, calculated per sqm, and projected for the entire surface of all tree nurseries without specific data. Based on the workshop's results, GAB and the tree nurseries' property decided to cooperate with the County of Pinneberg's support to initiate compost production for the sole purpose of the tree nurseries. In particular, GAB agreed to collect the GW of tree nurseries on-site and freely to produce an ad hoc compost. The excess compost produced would be stored or sold. Moreover, until today, local actors have continued this cooperation process independently from the project and the REPAiR research team concerning new challenges like design intervention for human and non-human beings.

Moreover, until today, local actors have continued this cooperation process independently from the project and the REPAiR research team. Due to the above-mentioned differences, the two cases have been treated as separate focus areas within Hamburg, each with its specific process. Nonetheless, representatives from Altona and Pinneberg participated equally in the respective workshops that were organised. Lastly, four eco-innovative strategies were developed out of the Geodesign process in Hamburg's case. The Developed strategies ranged from waste management solutions to awareness-raising practices and for provoking structural changes in planning policies. The features of the strategies were strictly related to the type of stakeholders that participated.

### 3.3. Naples

Located in the south of Italy, the Naples case study area included the City of Naples and ten Municipalities with a population of 1.362.398 inhabitants. Three infrastructure networks characterise the focus area in a formerly rural area, abandoned industrial areas, and a discussed waste treatment plant (i.e. the Acerra incinerator) (Geldermans et al., 2018).

Like the Dutch case per type, they differ per dimension, high pollution level, and relation to neighbourhoods, which are characterised by high social vulnerability and shallow settlement quality. Moreover, in Neapolitan, abandoned spaces are often linked to the waste cycle as deposits, treatment plants, and active and inactive landfills. They are usually scattered and distributed within the analysed area. Waste flow data were collected from the Waste Cadastre (ARPAC) database based on waste management companies' annual declarations and from the data provided by the Chamber of Commerce.

The input data for the Geodesign process was collected, processed, and implemented by the University of Naples' (UNINA) research group. The Status quo input data describe the Organic Waste (OW) and Construction and Demolition Waste (CDW) flows, chosen by the UNINA research team and the public authority partners. Both flows have issues in local waste management but also potentialities for CE. The AS-MFA of OW and CDW flow map produced for the eleven Municipalities of the study area focused specifically on the following:

- OW from households and companies: biodegradable kitchen and canteen waste; biodegradable waste; food and green from households; mixed municipal waste and the part of OW in mixed municipal waste.
- CDW from companies: concrete, bricks, tiles, and ceramics; wood glass and plastic; bituminous mixtures, coal tar and tarred products; metals; soil, stones, and dredging spoil; insulation materials; gypsum-based construction material; other construction and demolition wastes.

The data source to map the waste flows is the Campania Regional Agency for the Protection of the Environment (ARPAC) waste cadastre databases, which annually receive data from the official declarations of waste treatment plants. The mapping of Naples' waste streams was compiled from actual data on legally managed and registered regional waste streams. Although many issues in Campania have been due to illegal waste management to activate and manage CE processes, these data were considered accurate for the scope of the analysis.

The Geodesign workshop worked principally on the OW stream, and the stakeholder workshop groups developed strategies for the OW with a time horizon of ten years. The analysis scale was conducted at the municipal level, considering the municipalities of Afragola, Acerra, and Caivano. The interest in focusing on this area came from the documented socio-environmental problems due to waste management (Armiero & D'Alisa, 2012; De Rosa, 2018).

The stakeholders involved in the workshops and data collection include Public Administration at the Regional level, the Municipalities of Afragola, Acerra, Casalnuovo, Cardito, and Crispano and academic Researchers. Local NGOs, associations, and citizens participated in four workshops, highlighting long-standing local waste management issues, and proposing circular strategies. Two fundamental challenges have been identified in engaging them in the Geodesign process. Firstly, it was necessary to overcome the mistrust in waste management and enlarge the scope of the discussion beyond local spatial challenges at the centre of illegal activities *(Land of Fire)* (Armiero, 2014; Berruti & Palestino, 2020).

Twelve workshops featured the phases. Three workshops of co-exploring discussed waste management issues. Three successive workshops combined the co-exploring and co-design of eco-innovative solutions (Cerreta & Mazzarella, 2021). The final five workshops addressed co-design and the co-decision decision-making of the solutions and strategies. The participation of stakeholders featured the prevalence of representatives from public administration and citizens.

The workshops concentrate on a specific focus area comprising Afragola, Acerra, Casalnuovo, Cardito, and Crispano municipalities. The identified area resulted from geomorphological mapping analysis and was elaborated by REPAiR researchers, local NGOs, public administration, and civil society. Furthermore, through the different workshops, the stakeholders identified the main problems of OW management in the area. For instance, the AS-MFA analysis showed long-distance shipping of an ample OW flow between the south and north of Italy due to the lack of local OW treatment plants. To improve circularity in this context, as input of phase 3, a series of different cross-scale objectives was proposed:

- Realising small-size plants for the treatment of organic waste in the focus area;
- Reducing food waste;
- Improving the recovery of biodegradable green organic waste;
- Raising the awareness of proper separate waste collection;
- Improving the quality of the separate collection.

As the output of phase 3, the stakeholders ranked the different objectives. They set the flow indicator targets considering the specific spatial reference of the focus area of Afragola, Acerra, Casalnuovo, Cardito, and Crispano, given a temporal horizon to 2031.

The strategies developed in Phase 4 have been planned at the municipal and local levels in the area. The circular strategies are actions and strategies to improve OW management through spatial policies for flow reduction and new small-size OW treatment plants. The primary focus of the eco-innovative strategies revolved around preventing and reducing waste production and revitalising waste spaces, i.e. areas previously marred by waste. For instance, UNINA PhD students have developed circular strategies from the Waste Management Regional Plans (P.R.G.R.U, 2016). Projects aimed at regenerating contaminated rural sites and underused spaces were designed with a circular approach, utilising resources derived from the solutions for CDW and OW. Various challenges surfaced during the design process, including issues related to land use and addressing citizens' scepticism towards innovative approaches. While the single strategies did not propose brand-new innovations, their systemic combination of strategies constituted a novelty to address circularity in this territory. Lastly, the conclusion phase shows how public administration delegates (ARPAC, Campania Region and local authorities) and stakeholders have different points of view on the kind and location of the new OW treatment plants. In contrast, all the stakeholders agreed on the OW reduction policies.

## 4. Discussion

Since the beginning of the project REPAiR in 2016, most of the research on circularity ambitions has been mainly addressed from an economic perspective, neglecting the relationship with the urban environment and its actors (Murray et al., 2017). This section compares and discusses the findings outlined in both Sections 3 and 4, aiming to reveal possibilities and challenges to integrating a spatial dimension in the CE transition of cities and territories. Considering their differences, the three case studies are exemplary in understanding possibilities, obstacles, similarities, and differences to territorialise in CE models and tackle the institutional dynamics underpinning urban transformations. The ambition is to go beyond the diagrammatic levels. The discussion of the cases follows the four dimensions described in Section 2.

### *4.1. Data input*

For each case, three data types were identified, collected and analysed: spatial data on the study area, material flow data on the status quo and data on actors and targets. The three data analyses were strongly interconnected and partially overlap each other. For all three case studies, the data input and metabolic flow analysis required intensive prior data collection and processing where the type and difficulty level could differ significantly per case. For instance, for household-related waste flows, in the first version of the Dutch analysis, a novel disaggregation method is based on national data (Sileryte et al., 2021). In the case of Hamburg, data are provided by the public waste management company (SRH - Stadtreinigung Hamburg) and extrapolated later by HCU. These data are based on a study conducted by a consultancy company that presents a somewhat detailed sampling of household typologies in specific parts of Hamburg. Therefore, different data input quality led to different types of specialisations of waste flow movement (Fig. 2). However, the waste flow visualisation is related to data availability, data process, and confidentiality. For instance, although the Italian case had access to refined regional data sets, company data has been provided confidentially and, therefore, cannot be published.

A refined data input and consequent refined mapping of flow movement allows spatial planners to outline new spatial relationships in which business activities, infrastructures, urban conditions and urbanisation structure are brought into proximity and develop alternative economic-environmental coalitions (Furlan et al., 2022). Lastly, Fig. 2 highlights how, in all cases, the input data led to a more extensive network of flow movements going beyond the initial scale of spatial analysis. For policymaking, this could mean that either policy on CE could be integrated at the territorial governance level in which waste is travelling now, or it needs to facilitate the definition of optimal scales and amount of land necessary to develop CE strategies.

### *4.2. Stakeholders*

Stakeholder engagement is the main distinguished factor of the Geodesign method (Steinitz, 2012) and is at the base of the REPAiR approach to CE. In the three cases, different types of stakeholders at various levels of governance joined the process at each stage. The participating stakeholders proved to be representing different genders, age, and belonged to heterogeneous cultural backgrounds. The diverse types of stakeholder participation steered the discussion differently in addressing contingent problems. In each case, each project partner was responsible for developing the methodology for organising the stakeholder workshops and engagement strategy. For all three cases, the organisation, the consultation, and the involvement of the stakeholders required intensive and careful preparation. Not only holding the workshop itself but also the preparation (including data gathering and processing) proved arduous, and new data was always required to respond to the new challenges and ideas brought up by the stakeholders during the meetings.

Additionally, following the Geodesign approach, having the right stakeholders on board at the appropriate moment proved to be the most demanding and challenging part, given the project's timeframe and the topic's difficulty. (Arciniegas et al., 2019). Firstly, a relevant debate within the research teams occurred in identifying the target stakeholders. Successively, the group of stakeholders varied according to the stakeholders' inputs and the problems that arose. Also, the data provided along the way showed the necessity of including further stakeholders to address specific issues. Finally, each research team was confronted with possible excluded stakeholders. This is reflected in a matter of interest-driven decision. While the attempt was to always bring on board the maximal variety of stakeholders, in some workshops, the high number of participants led to stagnation in the decision rather than pushing it forward. This stagnation occurred mainly due to a

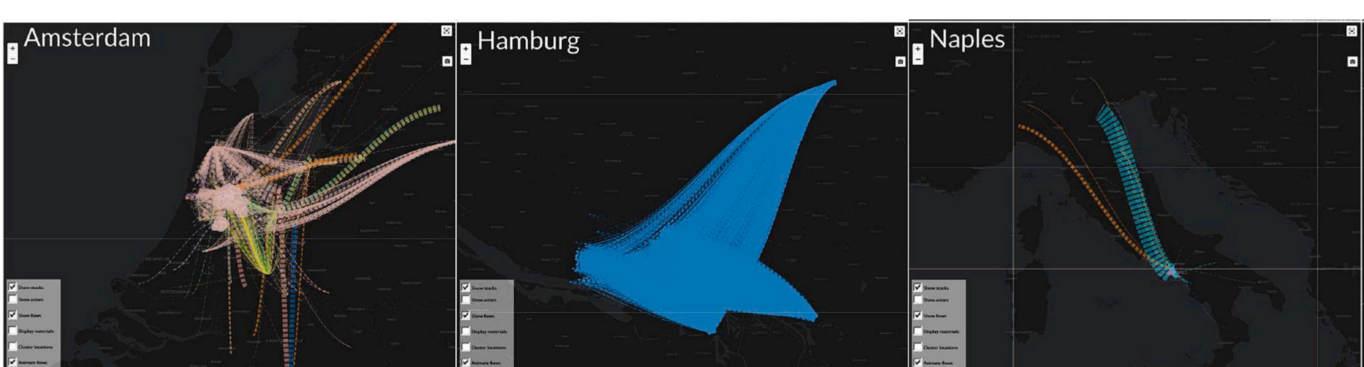


**Fig. 2.** Household and company organic flows in the three case study areas. The image highlights the territorial scales of organic waste flow movements among the three cases.
Source: REPAiR (2017a).

discussion of legitimation and responsibility of various levels of governance. If, on the one hand, the mix of stakeholders brought innovative thinking, on the other, language barriers such as technicisms and the other types of gap generated situations of conflict (Charbit & Michalun, 2009). In all three cases, the engagement of stakeholders at various moments of the process followed a trial-and-error logic, whereby the stakeholders' constellation constantly adapted to the need at stake. Communication was vital in each of the three cases. In fact, according to the context, language, and knowledge barriers to engage citizens had to be overcome (Amenta et al., 2019). For instance, in the Hamburg case, the research team's most important task was to bring all participants the same level of knowledge, thereby creating a common language. Decisions during the process were not guaranteed based on the data gathered but on internal dynamics (e.g. conflict, dialogue, argumentation) between participants.

### 4.3. Territorial, planning and governance scale of analysis

The different levels of awareness and ambition towards the CE transition and economic and planning framework obliged the REPAiR research teams to focus on different territorial scales in each case. Therefore each case adopted a different territorial dimension during the five phases. In the Dutch context, the AMA and the city of Amsterdam had already developed a CE vision document. Therefore, the focus was on the territorial dimensions of potential strategies and whether Amsterdam, as the largest city, would outcompete the smaller municipalities concerning the advantages and that the less favourable effect of the transition would fall onto the other municipalities. Concerning the Hamburg case, CE was a new topic for all relevant decision-makers at the beginning of the process. Hamburg municipality does not own a CE strategy; each of its seven districts is committed to drafting a local climate and circular management plan. Therefore, working on a county and district level was fundamental, although it came with the risk of losing a more extensive regional perspective. In the case of Naples, the study concentrated on the focus area, although the flows originating in the focus area touched the national scale. Invited stakeholders and inhabitants demanded to work locally due to their awareness of the territory and its waste issues. The exploration of the three cases highlights how governance structure is fundamental in specialised CE policies and should be further explored to understand competencies and decisional powers (Obersteg et al., 2019). In each case, an overarching CE strategy was sometimes present to discuss CE strategies at different levels. Lastly, in all three cases, the five phases of the REPAiR Geodesign approach structured the negotiation among stakeholders towards decision-making and circularity targets.

### 4.4. Output definition

The strategy's design required combining all the dimensions mentioned above (Fig. 3). The entire participatory process of the data provided to the stakeholders and the knowledge of the existing regulatory frameworks permitted and shaped the project's outcomes. Each case considered a different set of material flows, which was, in turn, commonly defined among the stakeholders' workshops based on local challenges. For this reason, the CE strategies are highly different from each other, even for those which address the same material flow.

As a result, the technical expertise required to understand the problem and design specific solutions in the field of waste management was considered a challenge in all cases.

Although the CE is one of the AMA's key priorities, most design strategies stay on the product and policy levels. Moreover, most circular strategies tend to go differently towards circularity without ultimately achieving it. Eventually, they still lead to reducing waste generation, even if consistently compared with the status quo.

In the Hamburg case, dealing with waste and the highly technical related processes (and relevant laws) was challenging for developing

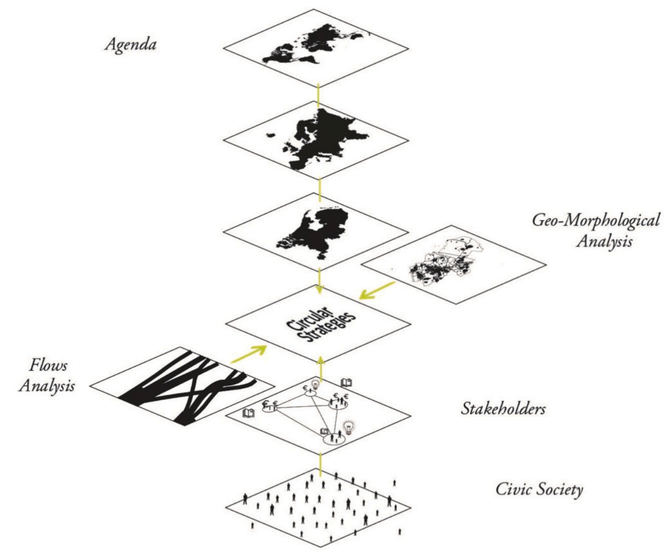


**Fig. 3.** Scheme of the design process of circular strategies based on the scheme developed by FABRICation office in Metabolism of Antwerp 2018.
Source: Geldermans et al. (2018)

circular strategies. Although there was no clarity around the concept and its implications, the Geodesign approach helped to align CE principles and stakeholders' needs into a set of strategies coherent with the circularity principles. In the case of Naples, the CE strategies were developed, combining infrastructure solutions and awareness-raising solutions for waste problems. The main difficulty was working with citizens and local associations towards changing the perception of waste as a potential local resource. Additionally, only some of the input data was valid. In some cases, the solutions obtained contradicted the data provided: most of the reasons for this were related to the sharing of internal knowledge by the stakeholders, which had more power than the others. However, within the project framework, the project team applied the knowledge transfer process between the Amsterdam and the Hamburg cases. A knowledge transfer process allows sharing of learnings and ideas, with subsequent adaptation and modification in the local context.

To conclude, technicalities were not the only issue. In fact, a complex concept such as circularity and the process constructed around it with the support of the GDSE, posed the research teams involved in the three cases in front of additional challenges linked to a social dimension (Vanhuyse et al., 2021). This aspect resulted in strategies that had less to do with new technology and more with awareness raising and adoption at city administrations of new practices.

## 5. Conclusions

This paper presents an alternative methodology developed for the European project REPAiR that brought together geospatial information, actors, and flow data to create strategies for a circular transition in cities. The approach is territorial-based, linked to a local context, and foresees the engagement of local stakeholders. The article started by understanding Geodesign as an approach that combines different kinds of information and data and helps to communicate and visualise them to a broader public. The first ambition aims to demonstrate whether and to which extent CE had a spatial dimension, an element neglected before the project started. To overcome this gap, the REPAiR Geodesing approach introduced waste flows as spatialised data and metabolic processes as essential components in identifying transformative actions and assessing the relative impacts. As the components of a process that makes cities circular need a defined spatial dimension, the process built within REPAiR was not only based on Steinitz's Geodesign approach.

Still, it was also complemented with the Living Lab methodology to highlight the necessity of bringing diverse urban stakeholders and their knowledge to the discussion table, integrating deliberative processes in spatial planning and combining complex data with soft data. The second ambition was to test the proposed Geodesing method in different territorial contexts to understand which instrument, circumstances and approaches are needed for a CE transition. Therefore, the method was tested in three cases. Thus, although the Amsterdam, Hamburg, and Naples cases adopted the same methodology, the kind of Data Inputs varied according to their specificity. The various phases were shaped according to the typology of Stakeholders engaged and the specific Territorial Planning and Governance Scale of Analysis. In all three cases, extensive data collection on waste flows, governance structure and spatial analysis was necessary. Data were synthesised in different cartographic representations and data visualisation. Like synthetic, visual instruments, maps and diagrams allow different stakeholders to negotiate and modify existing policies and governance, identify new policy and governance developments and even define spatial and environmental design proposals. How the process was conducted depended also on the different data found, the commonly defined objectives, and the peculiarities of each city. Therefore, it is unsurprising that the same Geodesign approach in the three European cases led to different CE strategies as final outputs.

The application of the Geodesign approach of Steinitz in the three cases revealed the following limitations:

1) The abstraction of metabolic flows visualisation. The elaborated flows were represented as detached from the surrounding environment, overlooking the potential physical interrelation between the flow and the morphology of the built environment.
2) The stakeholder engagement processes observed in the three cases revealed that, at all costs, they are not always beneficial. In some cases, reducing the variety and number of stakeholders was necessary to proceed with the process, especially during crucial decisional steps and responsibility sharing.
3) Evident barriers in communication, both vertically and horizontally, were observed among institutions and local stakeholders. This is because of the different languages spoken between practitioners and laypersons. This barrier had to be overcome to continue the process, eventually leading to specific stakeholders' momentary exclusion.
4) Data availability was essential in the entire Geodesign process, especially for the output definition. As the topic of CE was new, there was no clear establishment on which data to include, and even once the required data were defined, retrieving them from current data banks at the desirable scale was arduous.
5) The choice of the scale of intervention drove the decision on the further development of the strategy and on the selection of which stakeholders to involve and which additional data were needed.
6) Time was undoubtedly an issue compared with the ambitious goals of the project. In all three cases, the processes presented a very diverse timeline, which increased costs and willingness for the participation of certain stakeholders while favouring the choice of specific solutions rather than others.
7) Throughout the entire geodesign process, diversity in terms of personalities, resources, and competencies of the different stakeholders was only sometimes consistent, balanced and monitored (see/cf. Wuyts & Marin, 2022). This might have sometimes led to some unbalances in genders, ages, races and types of educational backgrounds in the stakeholder's representation, and perhaps this might have influenced the type of design choices made.
8) Although the geodesign is an inclusive process aiming to integrate different aspects and stakeholder groups the question of social and spatial justice for humans and beyond humans was not directly addressed and is able to participate in every thought.

Despite these limitations, and through the critical guidance of planners and designers, the described approach proposed an innovative Geodesign methodology for a circular transition of cities and territories. While the latter can be performed exclusively by technicians, the added value of having accomplished an enlarged participation among other stakeholders has considerably influenced the shape of a spatial decision-making process. This helps create a clear link between users, decision-makers, and practitioners, who must work together to achieve the desired results for cities and territories. The GDSE has a multi-actor approach that supports the inclusion of different stakeholders throughout the co-design process. It can enable the active participation of any stakeholder in collaborative decision-making processes, from the knowledge phase to the negotiation of final group preferences. However, ethical choices in participatory planning on the circular economy transition depend on the context. Who should be involved in a GDSE co-design workshop and according to what criteria, it is up to decision-makers. In this context, a limitation of the method is the need for more social impact assessment to compare the strategies. The lack of attention to this topic still needs to be improved in most scientific literature on circular cities (Vanhuyse et al., 2021). Ethical choices, social inclusion, and intersectional environmentalism (Wuyts & Marin, 2022) constitute significant new challenges to integrating methods and tools for circular city planning. Integrating Social inclusion and justice for humans and beyond humans in the circular transition of cities and regions requires a deep reflection in future research and academic debate.

To conclude, the Geodesign method attempts to conceptualise a possible approach to transition circular cities and territories. It arises through a systemic process and thinking that refers to the interconnectedness and dynamic interaction between different actors, waste flows, policy and governance factors influencing the innovation process in the built environment. Moreover, the method stretches flow and waste data to design integrated and complex flows and mechanisms that impact specific place dynamics. The changes in multi-scalar waste processes that the method proposes require input and feedback from stakeholders (e.g. the municipality, business developers, etc.), and various experts (e.g. landscape ecologists) in an open co-explorative process. Systems thinking is here revealed to be at the core of the design of the proposed Geodesing method. By being rooted in the ecological idea that processes and scales are interlinked with another system, system thinking allowed the REPAiR Geodesing approach to treat material flows as spatial phenomena as the starting point for more resource-efficient spatial planning rather than approaching the transition to a circular economy from a numbers-driven perspective.

## CRediT authorship contribution statement

**Cecilia Furlan:** Writing – original draft, Writing – review & editing, Formal analysis, Investigation, Methodology, Visualization, Conceptualization, Resources. **Chiara Mazzarella:** Data curation, Investigation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing, Conceptualization, Formal analysis. **Alessandro Arlati:** Conceptualization, Formal analysis, Investigation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing. **Gustavo Arciniegas:** Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing. **Andreas Obersteg:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Validation, Visualization, Writing – original draft, Writing – review & editing. **Alexander Wandl:** Data curation, Methodology, Project administration, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Maria Cerreta:** Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Supervision, Visualization, Writing – original draft, Writing – review & editing.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

Data will be made available on request.

## Acknowledgements

The authors would like to thank the whole REPAiR and CINDERELA Team, primarily the Research Team at the Delft University of Technology, in the Netherlands, and the University of Naples Federico II Research Team.

This research has been carried out within the frameworks of the European Horizon 2020 funded research REPAiR: REsource Management in Peri-urban AReas: Going Beyond Urban Metabolism. This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no. 688920. This article reflects only the authors' view. The Commission is not responsible for any use that may be made of the information it contains.

## References

Amenta, L., Attademo, A., Remøy, H., Berruti, G., Cerreta, M., Formato, E., & Russo, M. (2019). Managing the transition towards circular metabolism: Living labs as a co-creation approach. *Urban Planning, 4*(3), 5.

Metropoolregio Amsterdam, 2019. Werken aan de toekomst. https://www.metropoolregioamsterdam.nl/wp-content/uploads/2019/08/Werken-aan-de-toekomst-%E2%80%93-Metropoolregio-Amsterdam-2019.pdf. Accessed January 8, 2022.

Arciniegas, G., Šileryté, R., Dąbrowski, M., Wandl, A., Dukai, B., Bohnet, M., & Gutsche, J. M. (2019). A geodesign decision support environment for integrating management of resource flows in spatial planning. *Urban Planning, 4*(3), 32–51.

Armiero, M. (2014). Garbage under the volcano: The waste crisis in Campania and the struggles for environmental justice. In M. Armiero, & L. Sedrez (Eds.), *A history of environmentalism: Local struggles, global histories*. London: Bloomsbury.

Armiero, M., & D'Alisa, G. (2012). Rights of resistance: The garbage struggles for environmental justice in Campania, Italy. *Capitalism Nature Socialism, 23*(4), 52–68.

Bahers, J. B., Athanassiadis, A., Perrotti, D., & Kampelmann, S. (2022). The place of space in urban metabolism research: Towards a spatial turn? A review and future agenda. *Landscape and Urban Planning, 221*, Article 104376.

Ballal, H. (2015). *Collaborative planning with digital design synthesis. Doctoral dissertation*. London: UCL (University College.

Batty, M. (2013). Defining geodesign (= GIS+ design?). *Environment and Planning. B, Planning & Design, 40*(1), 1–2.

Bauwens, T., Hekkert, M., & Kirchherr, J. (2020). Circular futures: What will they look like? *Ecological Economics, 175*, Article 106703.

Berger, A. (2006). *Drosscape: Wasting land in urban America*. New York: Princeton.

Berruti, G., & Palestino, M. F. (2020). Contested land and blurred rights in the land of fires (Italy). *International Planning Studies, 25*(3), 277–288. https://doi.org/10.1080/13563475.2019.1584551

Blomsma, F., & Brennan, G. (2017). The emergence of circular economy: A new framing around prolonging resource productivity. *Journal of Industrial Ecology, 21*(3), 603–614.

Campagna, M. (2014). Geodesign from theory to practice: From metaplanning to 2nd generation of planning support systems. *TEMA Journal of Land Use, Mobility and Environment*. May, 20214, 211–22.

Carayannis, E. G., & Campbell, D. F. (2009). "Mode 3"and'Quadruple Helix': Toward a 21st century fractal innovation ecosystem. *International Journal of Technology Management, 46*(3–4), 201–234.

Cerreta, M., & Mazzarella, C. (2021). Collaborative decision-making processes for adaptive wastescapes regeneration. In *Cultures and local practices of sustainability. ROUTES towards sustainability network* (pp. 148–175). UPB: Publisher.

Cerreta, M., Mazzarella, C., & Somma, M. (2020). Opportunities and challenges of a geodesign based platform for waste management in the circular economy perspective. In *, 20. Computational science and its applications–ICCSA 2020: 20th international conference, Cagliari, Italy, July 1–4, 2020, proceedings, part IV* (pp. 317–331). Springer International Publishing.

Charbit, C., & Michalun, M. (2009). Mind the gaps: Managing mutual dependence in relations among levels of government. In *OECD working papers on public governance, no. 14*. OECD Publishing, © OECD. https://doi.org/10.1787/221253707200.

Christensen, T. B. (2021). Towards a circular economy in cities: Exploring local modes of governance in the transition towards a circular economy in construction and textile recycling. *Journal of Cleaner Production, 305*, Article 127058.

Cramer, J. M. (2020). Practice-based model for implementing circular economy: The case of the Amsterdam metropolitan area. *Journal of Cleaner Production, 255*, Article 120255.

De Rosa, S. P. (2018). A political geography of 'waste wars' in Campania (Italy): Competing territorialisations and socio-environmental conflicts. *Political Geography, 67*, 46–55.

Ervin, S. M. (2016). Technology in geodesign. *Landscape and Urban Planning, 156*, 12–16.

European Union. (2017). *Circular economy action plan: Environment* (p. 2019). Accessed October: European Commission.

Flyvbjerg, B. (2011). Case study. In N. K. Denzin, & Y. S. Lincoln (Eds.), *The sage handbook of qualitative research* (4th ed.). Los Angeles: Sage.

Fratini, C. F., Georg, S., & Jørgensen, M. S. (2019). Exploring circular economy imaginaries in European cities: A research agenda for the governance of urban sustainability transitions. *Journal of Cleaner Production, 228*, 974–989.

Furlan, C., Wandl, A., Cavalieri, C., & Unceta, P. M. (2022). Territorialising circularity. In *Regenerative territories: Dimensions of circularity for healthy metabolisms* (pp. 31–49). Cham: Springer International Publishing.

Furlan, C., Wandl, A., Geldermans, B., & Sileryte, R. (2020). A refined waste flow mapping method.: Addressing the material and spatial dimensions of waste flows in the urban territory through big data: The case of the Amsterdam metropolitan area. *Contesti. Città, territori, progetti, 1*, 74–89.

Geldermans, B., Wandl, A., Steenmeijer, M., Furlan, C., Streefland, T., Formato, E., Cerreta, M., Amenta, L., Varju, V., & Inglese, P. (2018). *REPAiR: REsource Management in Peri-urban AReas: Going beyond urban metabolism: D3.3 Process model for the two pilot cases: Amsterdam, The Netherlands & Naples, Italy*. revised version 30 April 2019. Delft, The Netherlands. n: Delft University of Technology http://h2020repair.eu/wpcontent/uploads/2019/11/Deliverable-3.3-Process-model-for-the-two-pilot-casesAmsterdam-the-Netherlands-and-Naples-Italy-final.pdf.

Gemeente Amsterdam. (2020). Amsterdam circular 2020–2025 strategy. Retrieved from https://assets.amsterdam.nl/publish/pages/867635/amsterdam-circular-2020-2025_strategy.pdf.

Gu, Y., Deal, B., & Larsen, L. (2018). Geodesign processes and ecological systems thinking in a coupled human-environment context: An integrated framework for landscape architecture. *Sustainability, 10*(9), 3306.

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling, 127*, 221–232.

Kleemann, F., Lehner, H., Szczypińska, A., Lederer, J., & Fellner, J. (2017). Using change detection data to assess the amount and composition of demolition waste from buildings in Vienna. *Resources, Conservation and Recycling, 123*, 37–46.

Kovacic, I., & Honic, M. (2021). Scanning and data capturing for BIM-supported resources assessment: A case study. *Journal of information technology. Construction, 26*.

Li, C. Z., et al. (2021). A blockchain- and IoT-based smart product-service system for the sustainability of prefabricated housing construction. *Journal of Cleaner Production, 286*, Article 125391.

Loorbach, D. (2017). Urban sustainability transition. In M. Eames, T. Dixon, M. Hunt, & S. Lannon (Eds.), *Retrofitting cities for tomorrow's world* (pp. 153–170). Chichester, UK: John Wiley & Sons, Ltd.

Marin, J., & De Meulder, B. (2018). Interpreting circularity. Circular city representations concealing transition drivers. *Sustainability, 10*(5), 1310.

Murray, A., Skene, K., & Haynes, K. (2017). The circular economy: An interdisciplinary exploration of the concept and application in a global context. *Journal of Business Ethics, 140*, 369–380.

Obersteg, A., Arlati, A., Acke, A., Berruti, G., Czapiewski, K., Dąbrowski, M., et al. (2019). Urban regions shifting to circular economy: Understanding challenges for new ways of governance. *UP, 4*(3), 19–31. https://doi.org/10.17645/up.v4i3.2158

Obersteg, A, Arlati, A, Knieling, J (2020): Making cities circular: Experiences from the living lab Hamburg-Altona. In ESR&P 27 (2), pp. 59–77. DOI: 10.18778/1231-1952.27.2.05.

P.R.G.R.U. (2016), Piano Regionale per la Gestione dei Rifiuti Urbani in Campania.

REPAiR. (2016). Deliverable 2.1. vision of the GDSE application. In *REPAiR report*. Retrieved from: http://h2020repair.eu/wp-content/uploads/2017/09/Deliverable_2.1_Vision_of_the_GDSE_Applications.pdf.

REPAiR. (2017). *D3.2: Socio-cultural/socio-economicand company-related investigations for pilot cases*. Pécs: MTA KRTK—Institute for Regional Studies. http://h2020repair.eu/wp-content/uploads/2019/03/Deliverable-3.2-Socio-culturalsocio-economic-and-company-related-investigations-for-pilot-cases.pdf.

REPAiR. (2017a). Deliverable 3.1 introduction to methodology for integrated spatial, material flow and social analyses. In *REPAiR report*. Retrieved from: http://h2020repair.eu/wp-content/uploads/2018/03/Deliverable_3.1_Introduction_to_methodology.pdf.

REPAiR. (2017b). Deliverable 6.2 governance and decision-making processes in follow-up cases. In *REPAiR report*. Retrieved from: http://h2020repair.eu/wp-content/uploads/2019/03/Deliverable-6.2-Governance-and-Decision-Making-Processes-in-Follow-up-Cases.pdf.

REPAiR. (2020). Deliverable 6.5. Cross analyses of decision models. In *REPAiR report*. Retrieved from: http://h2020repair.eu/wp-content/uploads/2021/06/Deliverable-6.5-Cross-Analyses-of-Decision-Models.pdf.

Rittel, H. W., & Webber, M. M. (1974). Wicked problems. Man-made. *Futures, 26*(1), 272–280.

Statistisches Amt für Hamburg und Schleswig-Holstein. (2021a). Kreise und Städte in Schleswig-Holstein im Vergleich, Band 1 der Reihe "Schleswig-Holstein.regional". https://www.statistik-nord.de/fileadmin/Dokumente/NORD.

regional/Schleswig-Holstein.
regional/Band_1_-_Bevoelkerung/SH_regional_Band_1_2020.pdf.

Statistisches Amt für Hamburg und Schleswig-Holstein. (2021b). Baumschulen, Baumschulflächen und Forstpflanzenbestände in Schleswig-Holstein 2021 STATISTISCHE BERICHTE Kennziffer: C II 5 - 4j/21 SH. https://www.statistik-nord.de/fileadmin/Dokumente/Statistische_Berichte/landwirtschaft/C_II_5_j_S/C_II_5_4j21_SH.pdf.

Statistisches Amt für Hamburg und Schleswig-Holstein. (2022). Bevölkerungsentwicklung in den Stadtteilen Hamburgs bis 2035 STATISTISCHE BERICHTE Kennziffer: A I 8 - j 21 HH Stadtteile. https://www.statistik-nord.de/fileadmin/Dokumente/Statistische_Berichte/bevoelkerung/A_I_8_j_HH-Stadtteile/A_I_8_j_21_HH-Stadtteile_Kor.pdf.

Statistisches Bundesamt (Destatis). (2021). Land- und Forstwirtschaft, Fischerei Landwirtschaftliche Bodennutzung - Baumschulerhebung. https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Landwirtschaft-Forstwirtschaft-Fischerei/Obst-Gemuese-Gartenbau/Publikationen/Downloads-Gartenbau/baumschulerhebung-2030317219004.pdf?_blob=publicationFile.

Stockholm Declaration on the Human Environment. (1972). *Report of the United Nations Conference on the Human Environment*. UN Doc.A/CONF.48/14, at 2 and Corr.1.

Sileryte, R., Wandl, A., & van Timmeren, A. (2021). A bottom up ontologybased approach to monitor circular economy: Aligning user expectations, tools, data and theory. *Journal of Industrial Ecology, 27*(2), 395–407.

Steinitz, C. (2012). *A framework for geodesign: Changing geography by design*. CA: ESRI Press.

Swilling, M., Hajer, M., Baynes, T., Bergesen, J., Labbé, F., Musango, J., Ramaswami, A., Robinson, B., Salat, S., Suh, S., Currie, P., Fang, A., Hanson, A., Kruit, K., Reiner, M., Smit, S., & Tabory, S. (2018). The weight of cities: Resource requirements of future urbanization. In *A report by the international resource panel*. https://www.resourcepanel.org/reports/weight-cities.

Vanhuyse, F., Fejzić, E., Ddiba, D., & Henrysson, M. (2021). The lack of social impact considerations in transitioning towards urban circular economies: A scoping review. *Sustainable Cities and Society, 75*, Article 103394.

Viganò, P. (2014). *Les Territoires de l'urbanisme, le Projet Comme Producteur de Connaissance*. Paris, France: Metis Presses. ISBN 978-2-940406-61-6.

Williams, J. (2019). Circular cities. *Urban Studies, 56*(13), 2746–2762.

Wuyts, W., & Marin, J. (2022). "Nobody" matters in circular landscapes. *Local Environment, 27*(10–11), 1254–1271.