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Facilitating Circular Economy in Urban Planning

Editors

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Editorial

Facilitating Circular Economy in Urban Planning

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Abstract

A shift towards a more Circular Economy is crucial to achieve a more sustainable and inclusive built environment that meets future demands. Circular Economy is a promising concept for industry and society. If implemented well, Circular Economy can deliver environmental benefits and economic advantages for which innovation is essential. To achieve a resource-efficient built environment the Circular Economy should be developed and implemented systemically and on a large scale, going beyond cities. To realise this, local authorities, citizens, and other stakeholders need a collaborative and science-informed decision environment that allows for developing different waste and resource management options, and assessing their impacts on the environment, resilience, spatial quality and quality of life. The articles in this special issue all discuss different aspects of research to deliver solutions and strategies for a circular economy in urban planning throughout Europe, focusing on peri-urban locations. The first article introduces Living Labs as a methodology to co-create circular solutions and strategies with local stakeholders. The second article focuses on governance for the shift towards a Circular Economy, unravelling hindrances and revealing objectives, whereas the third article develops a means to transfer circular strategies and solutions from one location to another. The fourth article presents an open-source tool based on the geodesign approach which links the co-creation of design proposals to impact simulations informed by geographic contexts, systems thinking, and digital technology—the Geodesign Decision Support Environment. Finally, the fifth article presents the first results of incorporating the concept of Circular Economy in an integrative manner in urban design and planning courses.

Keywords

circular economy; circular metabolism; geo decision support environment; knowledge transfer; new ways of governance; peri-urban living labs; resource management; urban metabolism; waste management; wastescapes

Issue

This editorial is part of the issue “Facilitating Circular Economy in Urban Planning”, edited by Hilde Remoy (Delft University of Technology, The Netherlands), Alexander Wandl (Delft University of Technology, The Netherlands) and Denis Ceric (Polish Academy of Sciences, Poland).

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1. Introduction

To meet future demands within a desired sustainable development we need change; a shift from a linear ‘take-make-waste’ mentality, or the act of converting renewable resources into waste faster than waste can be turned back into resources, to a Circular Economy. The Circular Economy approach introduced by the Ellen MacArthur Foundation, over a decade ago, is widely accepted and taken as a starting point: on the one hand with cascading (re)use within a technical context, and cascading (re)use within a natural systems’ context on the other. Awareness around Circular Economy is increasing and many countries in the world put Circular Economy on their agenda. It is a promising concept, for industry and society, as well as in policy developments. If implemented well, Circular Economy cannot only deliver key environmental benefits (e.g., reduced resource extraction, limited landfill, minimal pollution), but at the same time results in economic advantages (less dependence on decreasing stock of natural resources, new business opportunities, job creation) for which innovation is essential. Focusing on Europe, a resource-efficient Europe can only be achieved if the Circular Economy is developed and implemented in a systemic way and on a large scale, which goes beyond cities. To realise this, metropolitan and regional circular design solutions are needed. Currently there are few answers to Circular Economy related questions that arise, and the frameworks presently governing metropolitan solutions are not at all times capable of ensuring accountability. As the pervasiveness, complexity, and scale of these systems grows, the lack of meaningful (integrated) metropolitan solutions, which are tested, accountable and thus able to be implemented rapidly—including basic safeguards of responsibility, liability, and due process—is an increasingly urgent concern.

Effective implementation requires a policy mix that optimises synergies and addresses trade-offs between different areas and policies. Thus, local authorities, citizens, and other stakeholders need a collaborative and science-informed decision environment that allows for developing different waste and resource management options, while assessing their impacts on environmental effects, resilience, spatial quality and therewith supporting quality of life in general.

Transitioning towards a Circular Economy requires to work with and in complex systems. For decision-makers, it is crucial to understand the relationships between socio-economic and environmental dynamics and the built environment. Several aspects are crucial for this innovation to take place:

- Establishing a co-creation process that goes beyond individual projects or products and across scales and value chains;
- Understanding the spatial impact of the actual linear economy on the quality of land and soil;
- Different governance approaches;
- Ways of learning between cities and regions that go beyond the simplistic concept of good or best practice but incorporates cultural and spatial specificities;
- Further development of spatial decision environments that include spatial development and industrial ecology aspects and finally;
- The way we educate urban planners and designers, enabling them to include aspects of material flows and resources in their daily practice.

This thematic issue aims to bring together articles on this necessary wide array of attention related to Circular Economy. While touching upon different aspects of supporting the transition towards a Circular Economy on a regional scale, improving wastescapes and managing resource flows in relation to spatial development challenges will be the main focus. This thematic issue presents research that is conducted for the EU Horizon 2020 research REPAiR—REsource Management in Peri-urban Areas: Going Beyond Urban Metabolism. The authors are contributors to the project, working on the project's different aspects, or are involved in the education related to the project.

2. The Contributions

2.1. Integrating Wastescape as a Spatial Element into the Living Labs Approach

Resource consumption and related waste production are rapidly increasing all over the world, and urban areas account for around 50% of global solid waste generation. This leads to social and environmental challenges, but also to the production of 'wastescapes'. Peri-urban areas—in-between urban and rural territories—are particularly vulnerable and prone to develop into wastescapes, because they are in general fragmented, low-density, often crossed by large infrastructure networks, and often selected as locations for waste management plants. Hence, they are crossed by waste flows of different natures. A circular approach can positively affect the spatial, social and environmental performances of peri-urban areas. However, the transition towards the Circular Economy has many challenges.

Amenta et al. (2019), in "Managing the Transition towards Circular Metabolism: Living 6 Labs as Co-Creation Approach", outline an approach to address these challenges, presenting a co-creation process among researchers, experts and stakeholders in Living Labs (LLs). In the LLs, public-private-people partnerships are developed by applying an iterative methodology consisting of five phases: Co-Exploring, Co-Design, Co-Production, Co-Decision, and Co-Governance. Two LLs, in the Metropolitan Areas of Naples (Italy) and Amsterdam (The Netherlands), are analysed here to illustrate this approach.

2.2. Understanding the Hinderances for Urban Regions in Their Aim of Shifting to Circular Economy

In the last decade, the European Union has supported numerous initiatives aiming at reducing waste generation by promoting shifts towards Circular Economy approaches. Governing this process has become imperative. Obersteg et al. (2019), in their article "Urban Regions Shifting to Circular Economy: Understanding Challenges for New Ways of Governance", focus on the results of a governance analysis of six urban regions in Europe. By means of semi-structured interviews, document analysis and workshops with local stakeholders, for each urban area a list of governance challenges which hinder the necessary shift to circularity was drafted. In order to compare the six cases, the various challenges have been categorised using the PESTEL-O method. Results highlight a significant variation in policy contexts and the need for these to evolve by adapting stakeholders' and policy-makers' engagement and diffusing knowledge on the Circular Economy. Common challenges among the six regions include a lack of an integrated guiding framework, both political and legal, limited awareness among citizens, and technological barriers. All these elements call for a multi-faceted governance approachable to embrace the complexity of the processes and comprehensively address the various challenges to completing the shift towards circularity in cities.

2.3. Learning from Each Other: The Difficulties of the Transfer of Circular Economy Solutions

'Learning from abroad' is a widely recognised and used means to innovate and improve strategies and policies implemented by regions and cities. However, literature on knowledge transfer and related concepts, such as policy transfer, policy mobility or lesson-drawing, does highlight the limitations of this process, especially when it entails simple transfer of (best) practices from 'place A' to 'place B'. Such a transfer may lead to suboptimal solutions particularly when the imported practices concern complex phenomena, entailing networks of multiple actors and relying on place-specific dynamics. Departing from this critique, the article sheds light on the process of knowledge transfer in the field of a Circular Economy, taking place between the two metropolitan regions of Amsterdam and Naples. This process is guided by an innovative methodology based on a network of LLs generating eco-innovative solutions for using material waste and wastescapes as a resource in peri-urban areas. Using participant observation in knowledge transfer workshops, stakeholder interviews and surveys, Dąbrowski, Varjú and Amenta (2019), in their article "Transferring Circular Economy Solutions across Differentiated Territories: Understanding and Overcoming the Barriers for Knowledge Transfer", investigate how the process of co-creation of knowledge in the relational space of the networked LLs takes place thanks to participation of stakeholders from both regions. This, in turn, allows for concluding what barriers are encountered in such knowledge transfer, what makes solutions transferable across different contexts, and, finally, how the solutions are adapted as they travel from one place to another.

While the first three articles of the thematic issue have a more mono-disciplinary approach, the remaining two articles show the integration of all aspects into urban planning practice and education.

2.4. A Geodesign Decision Support Environment to Facilitate Decision Making in the Transition towards a Circular Economy

Improving waste and resource management entails working on interrelations between different material flows, locations and groups of actors. This calls for new decision support tools for validating and translating the complex information on material flows into accessible knowledge usable by the stakeholders in the spatial planning process. By Arciniegas et al. (2019), article "A Geodesign Decision Support Environment for Integrating Management of Resource Flows in Spatial Planning" describes an open-source tool based on the geodesign approach which links the co-creation of design proposals together with stakeholders and impact simulations informed by geographic contexts, systems thinking, and digital technology—the Geodesign Decision Support Environment (GDSE). Though already used for strategic spatial planning, the potential of geodesign for waste management and recycling is yet to be explored. The article draws on empirical evidence from the pioneering application of the tool to promote spatially explicit Circular Economy strategies in the Amsterdam Metropolitan Area.

2.5. The Circular Economy Concept in Design Education

The concept of Circular Economy is high on the agenda of many planning agencies in European countries. It has also become a prominent issue in European academic education institutions. It is expected that spatial planning and design can support and add value to the spatial quality dimension of such a transition towards a Circular Economy. However, incorporating the concept of Circular Economy in an integrative manner in urban design and planning courses is challenging because of its metabolic and complex nature. The article "The Circular Economy Concept in Design Education: Enhancing Understanding and Innovation by Means of Situated Learning", by Wandl et al. (2019), presents the first results of integrating design teaching activities at a Faculty of Architecture with an H2020 financed research project. The integration of research and design education provided the students with a situated and indeed transdisciplinary learning environment. Students rather early in the design process understood that they need to address challenges from a systemic perspective, meaning to understand what are the relationships between different subsystems and their spatial structures. Furthermore, the experiment provided evidence that the eco-innovative solutions developed by the students are seen as an effective option to achieve objectives for a transition towards a Circular Economy by stakeholders.

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Conflict of Interests

The authors declare no conflict of interests.

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Article

Managing the Transition towards Circular Metabolism: Living Labs as a Co-Creation Approach

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Abstract
Resource consumption and related waste production are still rapidly increasing all over the world, leading to social and environmental challenges and to the production of the so-called 'wastescapes'. Peri-urban areas—in-between urban and rural territories—are particularly vulnerable and prone to develop into wastescapes because they are generally characterised by mixed functions and/or monofunctional settlements, as well as by fragmentation in a low-density territory that is often crossed by large infrastructure networks. Moreover, peri-urban areas are generally the selected locations for the development of plants for waste management. In this way, they are crossed by waste flows of a different nature, in a landscape of operational infrastructures and wasted landscapes. Implementing Circular Economy (CE) principles, interpreting waste and wastescapes as resources, is a way to significantly reduce raw material and (soil) resource consumption, improving cities' metabolism. A circular approach can positively affect the spatial, social and environmental performances of peri-urban areas. However, the transition towards a CE presents many challenges. This article outlines an approach to address these challenges, presenting a co-creation process among researchers, experts and stakeholders within Living Labs (LLs) processes. LLs are physical and virtual spaces, aiming at the co-creation of site-specific eco-innovative solutions (EIS) and strategies. In the LLs, public–private–people partnerships are developed by applying an iterative methodology consisting of five phases: Co-Exploring, Co-Design, Co-Production, Co-Decision, and Co-Governance. This article presents a case study approach, analysing the co-creation methodology applied in two peri-urban living labs, located in the Metropolitan Areas of Naples (Italy) and Amsterdam (The Netherlands), within REPAiR Horizon2020 research project.

Keywords
circular economy; circular metabolism; circular waste management; co-creation; co-governance; living labs; peri-urban living labs; resource scarcity; waste management; wastescapes

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1. Introduction

This article is based on the European Horizon 2020 research project "REPAiR: REsource Management in Peri-urban AReas: Going Beyond Urban Metabolism", interpreting waste and wastescapes as resources for sustainable regeneration. In this project, eco-innovative solutions (EIS) and strategies for waste and wastescapes are developed in co-creation workshops implemented in Living Labs (LLs).

Nowadays, urban and territorial metabolisms are mainly linear. They are characterised by a high degree of resource depletion and outbound loss. This is leading to resource consumption on one hand—related to scarcity—and to severe waste accumulation on the other. In this context, scarcity should be considered at two different levels. Firstly, related to the limited availability of raw materials; secondly, to the condition of the places where the availability of virgin land for agriculture is becoming scarce due to soil pollution, high imperviousness, abandonment, vacancy and decay. To overcome this situation, a transition from a linear to a circular model of growth (EC, 2014; Ellen MacArthur Foundation, 2015a; European Commission, 2018) becomes the priority.

Considering waste as an innovative resource supports the initiatives of the European Commission, in order to reduce waste flows for the year 2020 (EC, 2010; EC Horizon 2020, 2019; EEA European Environment Agency, 2015). Implementing Circular Economy (CE) principles facilitates sustainable urban growth, reducing possible negative environmental impacts and stimulating social inclusion (REPAiR, 2017d; UNEP, 2011).

CE models do not generally tackle the reuse of land and are mostly focused on material, organic and mineral resources (Ellen MacArthur Foundation, 2015a, 2015b; Williams, 2019). In this perspective, this article presents research on circular reuse of wasted land resources, namely wastescapes (Amenta & Attademo, 2016; Amenta & Formato, 2016; Amenta & van Timmeren, 2018; Cerreta, Inglese, & Mazzarella, 2018; Formato, Attademo, & Amenta, 2017; REPAiR, 2017c, 2018c; Rigillo et al., 2018). The latter are interpreted as innovative resources to be reused to implement more sustainable, inclusive and circular urban and territorial metabolisms, decoupling economic growth from resource consumption and environmental depletion (UNEP, 2011).

Wastescapes have a twofold meaning. Firstly, they are defined as "drosscape" (Berger, 2006a, 2006b), which can be polluted lands, brownfields or 'land in limbo' in a waiting condition (de Martino, 2016), and more generally they can be the results of simultaneous urban growth and shrinkage (Oswalt & Rieniets, 2006). Second, wastescapes are defined as "operational infrastructure of waste" which constitute new waste geographies or the infrastructures of waste (Brenner, 2014; de Leo & Palestino, 2017; O'Shea, Hegeman, & Bennett, 2016; REPAiR, 2018c) being the new landmarks of contemporary territories.

A circular regeneration of wastescapes involves different dimensions such as environment, biodiversity, society, quality of life, accessibility and infrastructure (Amenta & van Timmeren, 2018). For this reason, the circular processes, which involve the regeneration of wastescapes, tend to be holistic and non-sectorial. Moreover, they include a focus on short-term and place-based EIS, as well as on long-term strategies, crossing different scales and involving different types of stakeholders. Moreover, EIS and strategies for the regeneration of wastescapes mix bottom-up and top-down approaches by also involving different stakeholders simultaneously.

The innovative approach related to the regeneration of wastescapes uses a new lens which is useful to observe and interpret the contemporary landscape. This new perspective focuses on relations among different territories, i.e., among people and their living environment. In this way, the regeneration of wastescapes involves a comprehensive approach which investigates the possibility of reconnecting formerly fragmented wastescapes in a well-connected network of regenerated lands. This is overcoming the common way of approaching brownfield regeneration, which is usually referred to as the mere implementation of technical solutions in a confined space or territory.

Moreover, the regeneration of wastescapes, in line with the principles of CE, is reversing the evaluation of wasted places that are no longer perceived as problematic areas but as resources and potential for improving the quality of life in the territories that are the subject of this study.

Metropolitan areas are currently challenged by complex environmental problems, often interrelated with social issues, especially in fragile environments worldwide, as in peri-urban areas. Peri-urban areas are typically spatially fragmented (Wandl, Nadin, Zonneveld, & Rooij, 2014) and have a higher presence of wastescapes than other urban areas (EC, 2016). Moreover, they are typified by systemic challenges. Spatial fragmentation is interlinked to social vulnerability due to lack of accessibility to spatial capital (Secchi, 2013), for example in the case of polluted or fenced areas.

It is crucial to reflect on this extensive global crisis and socio-spatial inequalities to address "the new urban question" (Secchi, 2010, 2013). Spatial injustice, unequal access to opportunities, and environmental vulnerability are creating a demand for planners to design devices that are able to address inequalities and overcome social and environmental challenges.

The traditional model of planning must be redefined in consideration of the redefinition of welfare policies in response to the global crisis. Furthermore, the search for transparent and inclusive decision-making processes and the extension of involved actors can be at the core of an expansion of the democratic conditions of management, accessibility and use of resources (Russo, 2017).

Innovation in urban planning calls for innovation in the methodologies used, as the demand for new actors and new challenges implies the flexibility of devices and tools that cannot be achieved using old-school paradigms and settings (Attademo, 2015).

The shallow involvement of generic stakeholders in urban transformations is to be avoided in order to establish cooperation between actual end-users, working in a "user-driven open innovation ecosystem" (EC, 2009) with common goals, and various competences (Innovation Alcotra, 2013).

In this article, the activities developed in two pilot laboratories located in the Metropolitan Areas of Naples (MAN) and Amsterdam (AMA) are presented. These specific cases are relevant because of the variety of challenges they encompass. In the MAN, between 1994 and 2009, the regional Waste Emergency and the more recent phenomenon of the Land of Fires increased the level of environmental damage (Berruti & Palestino, 2019; Palestino, 2015). Both crises are dependent on government inabilities and the poor governance model in use (REPAiR, 2017b). Acting as a driver for further improper use of land and non-regulation, the two environmental emergencies contributed to turning open spaces and agricultural plots into waste landscapes (Berruti & Palestino, 2017). In this context, circularity principles are far from being applied (Berruti & Palestino, 2018). Conversely, in the Amsterdam context, the reuse of land is already an implemented tool for combining urban regeneration and circular metabolism. The existing perception is already intrinsically connected to the new urban question and its demands. CE principles are already widely accepted and shared, however, the majority of initiatives are merely focusing on the recycling principle of CE, leaving aside the principles of reduction and rethinking (PBL Planbureau voor de Leefomgeving, 2018), which would entail a completely different kind of growth (Russo, 2014).

The methodology explained in the following paragraphs reflects these asymmetries. The case study approach allows the exploration of complex issues in real-life settings, as researchers have established an open-process of learning by doing, working on potentials solutions for case studies, by being flexible and open to hybridise their original mindsets (REPAiR, 2018b).

Thus, this article—organised in five sections—begins by defining an approach to address the challenges for the transition towards a more CE by outlining the co-creation approach implemented in two Peri-Urban Living Labs (PULLs) in the MAN and the AMA (in section two). Secondly, in section three, it explores differences and similarities among the two approaches implemented in the abovementioned case-studies, focusing specifically on how EIS and strategies are developed within each Lab. In section four the application of a metabolic perspective to reinterpret the peri-urban areas of the two case studies is discussed. In this way, this research links the study of the metabolic flows within the urban and peri-urban landscape with the territorial condition of wastescapes. Finally, in section five, the lessons learned on institutional and social innovation, wastescape definition and regeneration, and circularity are outlined for both case-studies.

2. Methodology and Approach

2.1. PULLs and Decision Support Tools in Two Case Studies across Europe

In this research, the complexity of waste management in peri-urban areas is unpacked and articulated within LL environments. LLs are case-specific approaches for developing (eco)innovations, combining planning and design (Cerreta & Panaro, 2017a, 2017b; Concilio & Rizzo, 2016). This requires a versatile methodology that is flexible and adaptive to the different local contexts (REPAiR, 2017d).

In PULLs—a place-specific variation of urban LLs—conceived as new forms of good local governance are implemented in the development of innovative services and processes for circular peri-urban regions. PULLs are interpreted as innovative approaches for effective planning strategies and inclusive decision models (ENoLL, 2016; ENoLL & World Bank, 2015).

Generally, in urban LLs, the innovation process is assured thanks to co-creation activities (Steen & van Bueren, 2017). By co-creation, unusual and new ideas can be developed thanks to the presence and the co-working of several stakeholders at the same time and in the same place. They can help identify problems and challenges, desired trajectories that are seen as feasible solutions and can be followed in order to deal with complex systems. At the same time, PULLs rely on Public–Private–People–Partnerships (Innovation Alcotra, 2013), as citizens and local associations are considered to be an important source for the innovation process (REPAiR, 2018b).

Central aspects for developing a PULL are regional context and place-specificity, data, models, and the availability of information on stakeholders (REPAiR, 2018b). This research places this framework in relation with Steinitz's Geodesign approach (EC, 2016; Steinitz, 2012). Based on six representation models, geodesign questions are combined with phases of the PULL, as described below, providing a methodological structure to the activities.

In general, co-creation processes implemented in LLs differ case by case and are site-specific, depending on the different stakeholders involved in the general decision-making process, as well as how they can contribute. The LL co-creation process aims at assuring larger participation and cooperation of local stakeholders who are actively involved in the decision-making process for the regeneration of the selected peri-urban areas. It follows that the outcomes of the co-creation workshops implemented in LLs—the EIS and strategies—are the result of wide participation of actors since the first phase of the idea development. In this way, the ownership of the project/solution ideas is shared among several stakeholders and better management of its implementation can be assured. For instance, in the case of Naples, citizens belonging to local citizens' associations have been involved in the co-creation workshops of the REPAiR PULL. In this way, the identification of EIS for the regeneration of polluted wastescapes was not just limited to the technical remedy for soil reclamation based on phytoremediation, but it became a wider project including the social and cultural dimensions. This was done by identifying traditional local crops as the most appropriate species for this purpose (e.g., hemp), the cultivation of which could also contribute to the implementation of traditional cultivation in the territory, and eventually bring opportunities for new jobs.

Furthermore, the involvement of local communities has shown to positively influence citizens by having them struggle together in order to identify solutions and strategies for achieving the sustainability of their territories, resulting in increased trust in their institutions.

The implementation of co-creation processes in LLs can help to overcome institutional lock-in situations. Indeed, in LLs, the different stakeholders cooperate to identify strategies that can help to create new bridges between roles and points of view which normally function in a sectorial manner. For instance, in the case of Naples, one of the most fruitful experiments of interaction among stakeholders was conducted in one of the PULL workshops in the MAN in a group working on homogeneous ecological islands. The goal was to establish an integrated collection and reuse centre for construction and demolition waste. The idea was to create a service for the city located on land that had been confiscated from organised crime. The objective of this group was the reduction of waste, favouring the re-use of durable goods while limiting illegal dumping along the peri-urban infrastructures. This action met the goals of a project proposed by the Regional Waste Prevention Plan of the Campania Region of 2013 (called "CIRO" project, from the Italian acronym for "integrated centre for optimal reuse"), but not included in the general provisions of the Regional Waste Law (no. 14/2016). After the work done within in the REPAiR PULL, these CIRO areas have been regulated by the Regional Law no. 29 of 2018 and have returned to regional attention, after having been overlooked for a long time. Even if such integrated centres have not been the object of the EIS developed by this research project, it can be stated that the activities of the PULL accelerated a regional policy process involving the topic of circularity, forgotten spaces, discarded objects, and policies that have momentarily been put aside.

2.2. The Phases of Co-Creation

One of the first LL methodologies is the FormIT (Ståhlbröst & Holst, 2012), an iterative method developed to suit and support LL activities. An evolution of FormIT methodology, combined with the 4Co model—CoDesign, CoDecide, CoProduce, CoEvaluate (Pollitt, Bouckaert, & Loeffler, 2006)—was already tested in some experiences of LLs (Cerreta & Panaro 2017a, 2017b). It is the basis for the Co-creation process implemented in REPAiR PULLs, based on the five iterative phases listed below (see Figure 1; REPAiR, 2017d):

- Co-Exploring;
- Co-Design;
- Co-Production;
- Co-Decision;
- Co-Governance.

The Co-Exploring phase (Phase 1) deals with two of the Geodesign models. Firstly, there is the Representation Model, tackling the definition of a common understanding of the territory, developed with the collaboration of all the researchers, stakeholders and experts identified and involved in the project. Secondly, the Process Model is investigated. Key resource flows are selected through the definition and mapping of material flows and waste management system. The thematisation of the main challenges/problems and objectives is eventually conducted as the end of phase one.

The Evaluation Model and Change Model are the objects of the Co-Design phase (Phase 2). Local teams conduct research and experiments to assess the status quo, further identifying specific challenges and problems in order to define EIS and their functioning.

Phase 3, Co-Production, addresses the Change Model, deepening the understanding and development of EIS and Eco-Innovative strategies. This phase is crucial for the transition to more circular models in peri-urban areas and for boosting the innovation processes.

Phase 4, Co-Decision, explores the Impact Model, evaluating EIS efficiency and their transferability to other contexts. In addition to that, research teams should deal with the Decision Model. This model coincides with the documentation of agreements and conflicts between different interests and groups of decision-makers involved in the project. The ultimate goal becomes to trigger future local development and influence the decision-making process through co-creation.

Phase 5 of the PULL consists in Co-Governance. This is related to the Decision Model of the Geo-design framework and it is about delivering decision-making models based on co-creation and making them transferable to further cases.

2.3. The Case-Study Approach as a Method: MAN and AMA as Fields of Action

The case study approach helps in decoding methods from experiences, reflecting on the differences in challenges, data sources and then in potential results.

Since 2016, the PULLs of Amsterdam and Naples have been carrying out their experimentations. Accordingly, based on the difference in territorial challenges and in stakeholder's awareness, the methodology has been

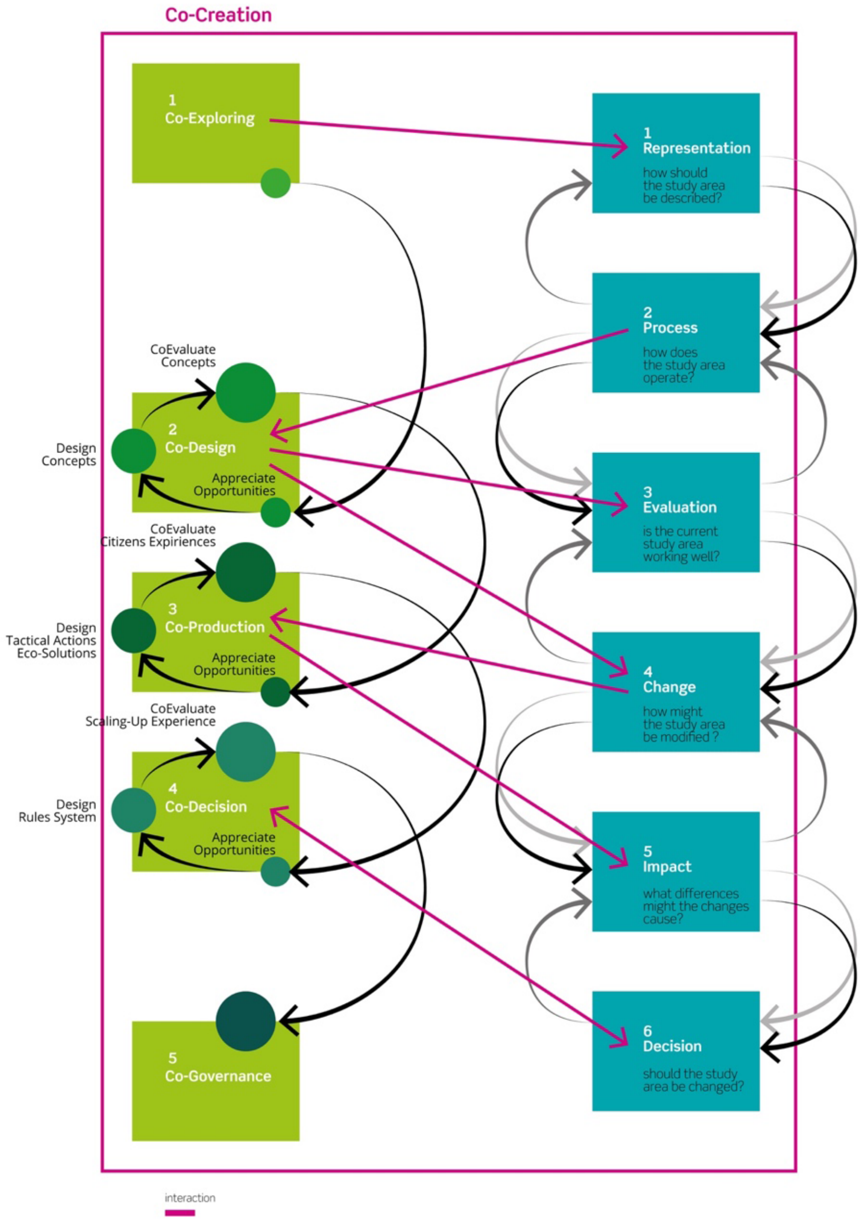

Figure 1. LL & Geodesign interaction: REPAiR methodological proposal. Source: REPAiR Unina Team.

slightly adjusted during the process, which shows the implementation of an open and place-based process. In the co-exploration phase, two large mapping experimentations were relevant in both cases. The first mapping experimentation was referred to the selection of the group of relevant stakeholders. The elaborated selection evolved during this process in a recursive way. The second extensive mapping experimentation referred to the definition of the project focus area. Each case-study area definition has been unique, depending on the local context, the specific challenges and thematic and spatial coverage (REPAiR, 2017c). Included in the mapping exercise on the focus area, the research project followed an iterative process to identify, categorise and select wastescapes, with the collaboration of different types of stakeholders.

In both cases, the involvement of students in the spatial analysis has been a crucial element. They have contributed to basic research activities and they worked on real-life projects on multidisciplinary teams.

2.3.1. The MAN Case-Study and the Definition of Its Boundaries

The MAN includes 92 municipalities in a total area of 1171 square kilometers and inhabited by about 3 million people. The definition of the area has been carried out in the co-exploration phase, among researchers and selected stakeholders. The defined area was a physical, socio-ecological and administrative sample for the matter of waste and resource management. The guiding principles in the selection of the focus area (Figure 2; REPAiR,

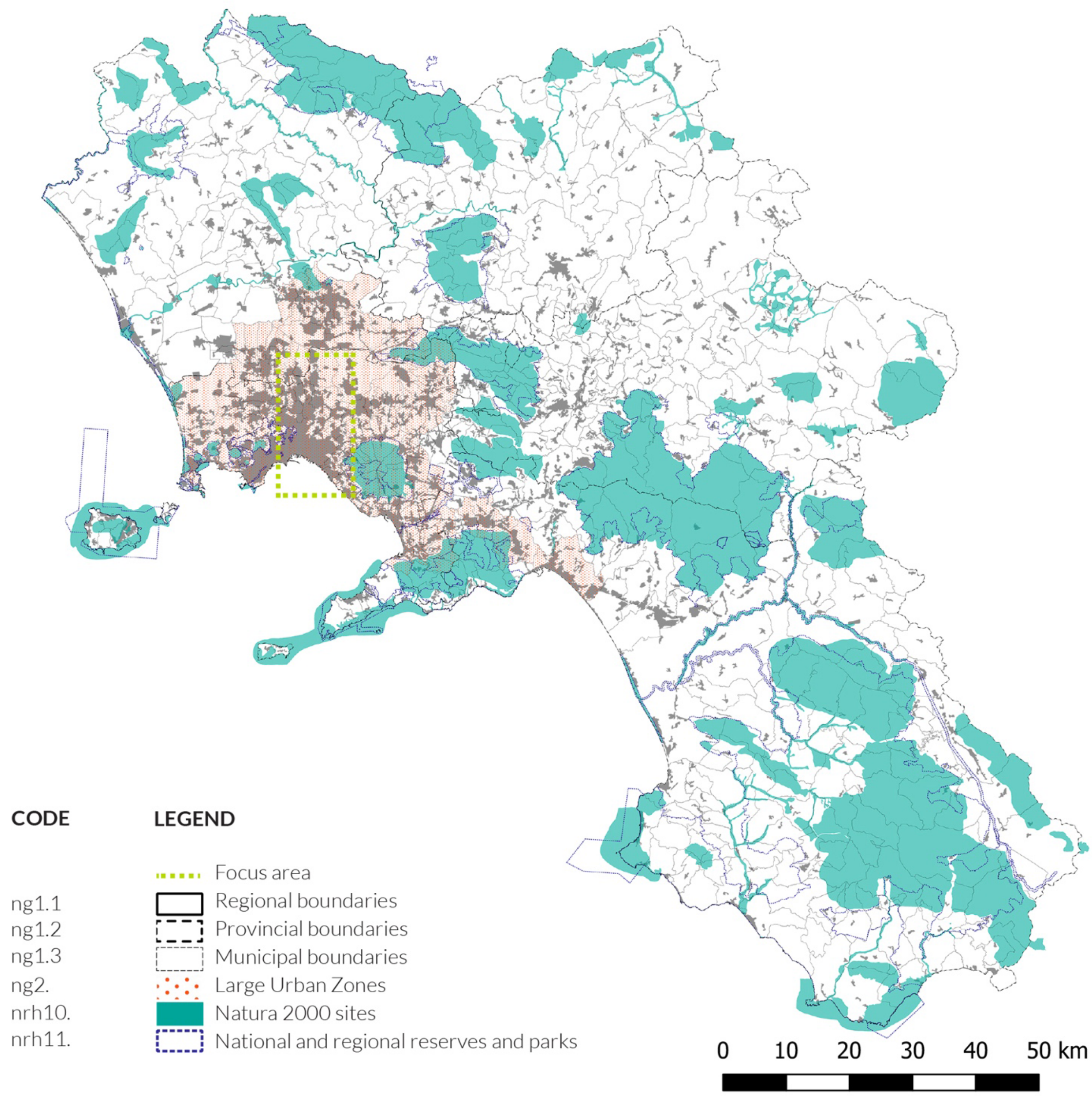

Figure 2. Administrative, demographic and planning issues. Pilot case of Naples. Source: REPAiR (2018c); map by REPAiR UNINA Team.

2018c) were defined as follows (REPAiR, 2017b):

- The connection with the area of the waste crisis in Campania Region, the Land of Fires;
- The ATOs' (Optimal Territorial Area; in Italian, the Ambito Territoriale Ottimale) boundaries, defined for the waste management by Campania Regional Authority;
- The high amount and variety of wastescapes.

The basic idea was to define the appropriate scale to deal with specific urban issues. Moreover, the definition of boundaries and scales of intervention became a negotiation point among participants and administrations in the PULL, in order to foster the debate on critical conditions that affected territories. In particular, the selection of a sample area (composed of five municipalities, characterised by similar problems and challenges) allowed the combination of several layers of spatial, socio-economic and material flow information in an iterative and discursive process, stimulated by stakeholder's perspectives. Research groups developed spatial analysis on sample areas in parallel to PULLs activities. Participants—including local citizens' associations, researchers of the University of Naples Federico II, Regional and Municipal Authority representatives—co-created a map of wastescapes for the case study, in which layers of spatial information, landscape perceptions, as well as material flow analysis are overlapped.

2.3.2. The AMA Case-Study and the Definition of Its Boundaries

The AMA consists of the city of Amsterdam, the provinces of North Holland and Flevoland with 36 municipalities, and a population of over 2.4 million inhabitants. AMA Central Administration has administrative responsibility for the area. In the AMA, the focus area was defined starting with an analysis of key challenges for developing a more CE in peri-urban areas in the region, and an analysis of key resource flows. Based on that, the focus area was defined as the three 'main ports' in the region: 1) the Amsterdam North-West urban docklands (key areas with circular urban developments), including the Ijmuiden port area (wastescapes and the port); 2) the Schiphol airport area (airport and the Valley CE initiative); and 3) South-East with the Greenport Aalsmeer (agricultural production in greenhouses and flower trading; see Figure 3). The stakeholders involved in the Amsterdam PULL workshops were very diverse. Among them, there were Municipalities (Haarlemmermeer; Amsterdam), the Amsterdam Economic Board, TU Delft researchers, experts on CE (e.g., EVOLV), hogeschool, AMS Institute, professional firms, Waste Team city of Amsterdam, and so on.

2.4. How to Develop EIS in MAN and AMA

The experimentation in the PULLs involved the definition and implementation of eco-innovation (EC, 2012).

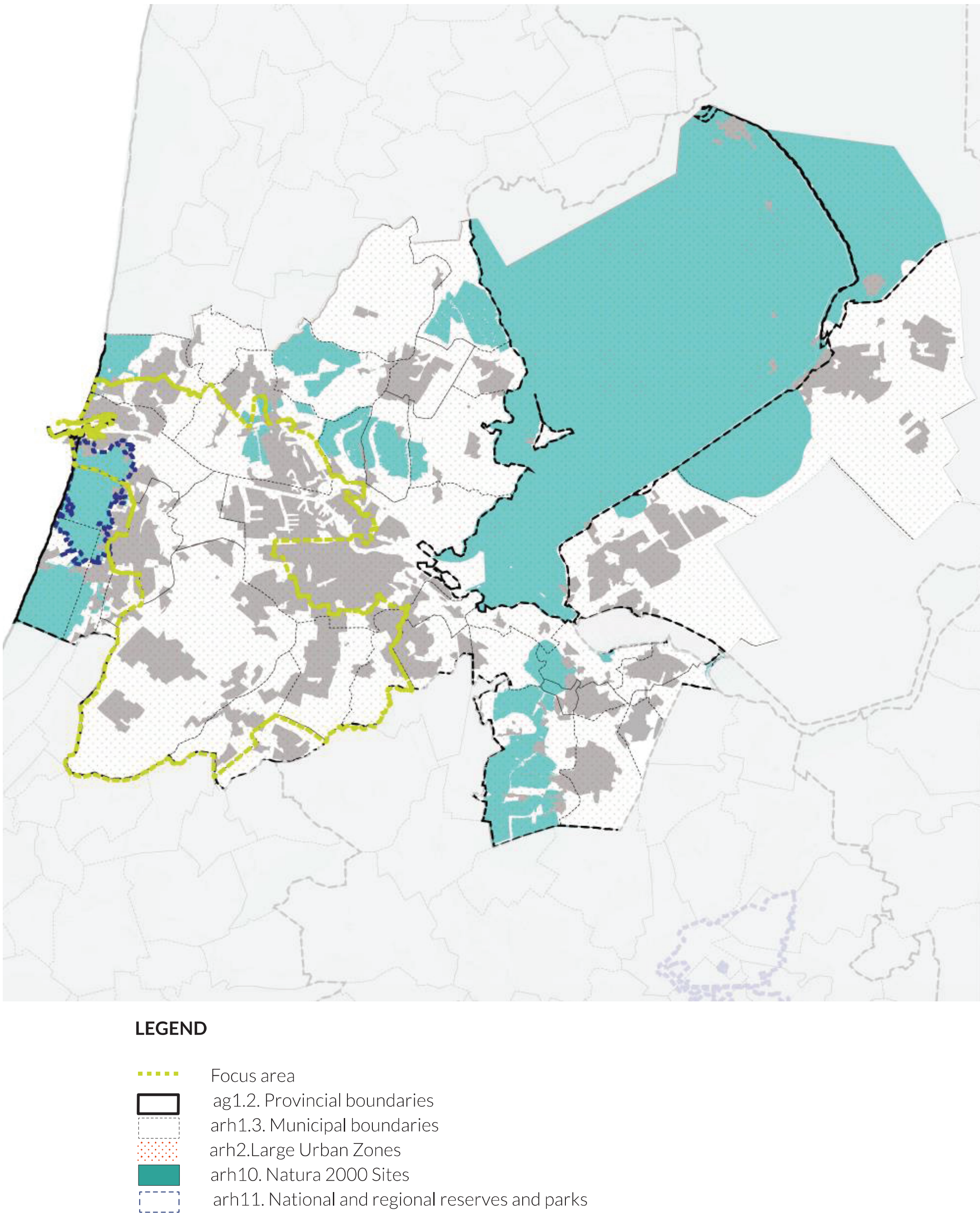

Figure 3. Administrative, demographic and planning issues. Pilot case of Amsterdam. Source: REPAiR (2018c); map by REPAiR TUDelft Team.

Research teams combined this concept with the contextual knowledge developed in PULLS, eventually defining it as a place-based, processual and systemic tool for peri-urban areas. The PULLs must problem-solve and deal with innovation (van de Ven et al., 2009), working in a dimension where the problems and objectives are well defined (as an outcome of the work of the PULLs) but the solutions are yet to be defined.

An eco-innovative strategy has been defined as "an alternative course of action aimed at addressing both the objectives and challenges identified within a PULL and develop a more CE in peri-urban areas" (REPAiR, 2018a, p. 11). Then, a strategy can be composed of a systemic integration of two or more EIS.

The co-creation of EIS in pilot cases has been developed in a contextual process which is the most relevant element of innovation, more than the results themselves (Dente & Coletti, 2011). The definition of EIS follows a circular and multi-scale process. EIS are place-based and depend on local, regional and national policies, as well as managerial ability, economic or financial specificities, and administrative capacity. At the same time, EIS has the ambition to be transferable to other case studies, where the contextual conditions can change. Then, the elementary EIS can be re-assembled in spatial strategies (and streamlining of flows) which are different case by case, since they depend on the local conditions, as the debate in each PULL could clarify throughout the project.

2.5. Steps of Interaction with Stakeholders in the MAN and AMA PULLs

Ten PULL workshops were organised in the MAN. In the first four PULLs, participants included representatives of regional, metropolitan and local governments, policy-makers, waste management administrators, local companies' representatives and researchers. From the fifth PULL event on, social organisations and active citizens were also involved.

In the beginning, PULL events had as their main objective to build a shared knowledge on CE objectives between stakeholders and researchers. Then, they focused on constructing knowledge respectively on organic and construction and demolition waste. During the first PULL events, participants identified critical wastescapes in a collaborative process and they collectively updated the wastescape map and discussed its legend. Later on, the focus was on developing EIS. Thus, participants decided to divide themselves into three worktables. For each worktable, there were a leader, a facilitator and a Regional officer.

An interesting discussion began on the current possibility of funding specific actions. Participants also filled in a form on the proposed actions, identifying who was available to support them and interested in collaborating. The prioritisation of actions was included in the form.

The final PULL events focused on the report on the work that was carried out by local groups and the improvement of the proposed solutions by the research group, stimulated by the visualisation of waste flows through the Geo-Design platform, under construction within the project.

The approach was the same in MAN and AMA. However, in the AMA, a series of three integrated PULL workshops were organised. The workshops focused on first identifying the challenges to a CE in the AMA, second, defining the objectives of the different stakeholders, and finally, developing EIS to respond to objectives and challenges. The fourth PULL workshop was organised as several small workshops, specifically focusing on developing EIS responding to each specific objective that was defined in the earlier workshops.

3. Differences and Similarities between Case Studies: MAN and AMA

3.1. EIS in the MAN and AMA and the Differences in the Approach

Before actually designing EIS, still in the co-exploration phase, challenge trees were used to define challenges and formulate objectives and directions for solutions in both cases. Working in small groups during the PULL workshops (3 to 5 participants) stimulated the participants to come up with concrete solutions.

At the start of the co-design phase, EIS coming from literature or defined by common discussions were presented in PULL events in both pilot cases. Then, both cases started a co-creation process with some differences due to stakeholder's awareness and the challenges emerged in the co-exploration phase.

In the MAN, three worktables focused respectively on three territorial strategies, as a starting point for testing preliminary EIS. Then, the researchers selected solutions to be further developed among the wider number of actions coming from the worktables. The MAN case-study considered the pressure of flows in spatial terms, on general peri-urban landscapes and especially on wastescapes. Furthermore, in order to facilitate interaction among local stakeholders, it was considered useful to work on a sample of the focus area, pointing out on the one hand current critical conditions, and on the other hand actual competences to implement solutions, leading to the development of place-based territorial strategies, in which eco-innovative actions can be distinguished.

In the AMA, EIS were developed for the flows of construction and demolition waste and food waste, and for wastescapes. In the co-exploration phase, the first mapping exercise was done to develop a common understanding of the territory, contributing to the representation model. Henceforth, challenges were defined for developing a CE in the AMA, defining the key resource flows to focus on. Based on this, objectives were developed for implementing CE solutions in the AMA. The objectives were discussed in interviews with AMA stakeholders and in a follow-up PULL workshop.

The results formed input for the representation and the process models. Then, in the co-design phase, the challenges and objectives were further detailed, and draft EIS were developed as a response to the challenges. In this phase, stakeholders were asked to rank the objectives and the expected impact of the developed solutions. Henceforth, in the co-production phase, a set of solutions were selected for further detailing based on the solutions that were developed and their expected impact. In this phase, a series of expert meetings were held, in which EIS were developed to be eventually assessed on sustainability and implemented in the change model. The solutions were detailed to provide input to the impact models, evaluating the efficiency of the EIS.

3.2. Styles of Interaction: MAN and AMA

From the initial survey to the PULL workshops, noted differences in interactions between Amsterdam and Naples emerged. Differences started from the composition of the public taking part in the PULLs to the methodology adopted to build the EIS.

In Amsterdam, participants in the PULLs were essentially experts, researchers, key stakeholders, companies and designers. In Naples, on the contrary, in addition to the public sector and a limited number of companies, many social organisations and civic groups have been involved. These differences led to different strategies in order to achieve the research objectives and the need to adapt the proposed methodologies to facilitate the involvement of the actors and the decision-making process.

The method used for the prioritisation of objectives is Soft Delphi (REPAiR, 2017a), which is productive for a public mainly composed of experts, but hardly applicable in the presence of a mixed public with a high percentage of social groups and organisations.

Amsterdam used questionnaires before and after the PULL workshops in order to assess the effectiveness of the meetings. In Naples, questionnaires were also used to collect information from participants in the PULLs on specific subjects.

The same differences apply to how EIS are developed. In Naples, they have been conceived as site-specific in the PULLs, then studied and improved by researchers, public sector officials and companies. In Amsterdam, after a developing and selection process, solutions were improved and adapted to the Amsterdam focus area. Although through different processes, in both Naples and Amsterdam, spatial analysis, material flow analysis and actor analysis were combined in the design of EIS.

4. Discussion

4.1. From Wastescapes to Regenerative-Scapes

This research applies a metabolic perspective to re-interpret the variety of fragile urban and peri-urban areas in two case studies in Europe, in Naples and Amsterdam. In particular, in the case of Naples, this research investigates the waste flows regarding Construction and Demolition Waste, and Organic Waste. In the case of Amsterdam, the flows of Construction and Demolition Waste and Food Waste are deepened. Furthermore, in both cases, this research studies the spatial effects of waste flows on the landscape, as well as the life cycle of the territories which in some cases can assume the appearance of wastescapes.

In the case of Naples, there was the need to investigate the topics related to the specific waste flows. The latter have been identified separately in separate PULL workshops with experts in the fields. This was also necessary because of the different stakeholders involved which, in the case of Construction and Demolition Waste, are mostly small and medium enterprises, and in the case of the Organic Waste are mostly the Campania Region Authority and the interested municipalities.

Conversely, in the case of Amsterdam, the different flows have been investigated in the same PULL workshop, where different sub-groups were organised in worktables and the experts involved had the opportunity to co-create together with other stakeholders.

In both cases, all of the material flows are intertwined in the landscape, and particularly in what are defined as wastescapes.

Through co-design applied in PULLs, this research allows moving towards a more CE, implemented thanks to new governance models. Wastescapes are the results of the operationalisation of linear urban metabolism. In this context, they can be the places that can host stakeholders when carrying out co-creation initiatives, defining a socio-technical domain.

PULLs activities configure a sort of community metabolism that arises as a vibrant response to the criticality of dissipation and abandonment, proposing innovative forms of urban recycling. The analysis of the spatial configuration and related waste flows started with wastescapes. However, in line with the consideration of waste as a resource, this research aims towards the co-creation of resource-places or regenerative-scapes. The latter are ecosystems, designed to allow the co-evolution of human and nature (Dias, 2015), holding together physical, social and metabolic resources (even wastescapes), in order to re-activate places as resources (Brown et al., 2018).

As in LLs, regenerative design (Mang & Reed, 2012) is a process-oriented approach, learning from experience and practice. Regenerative design works on the balance within natural cycles, integrating environment and anthropic systems. It promotes a new human-human and human-nature relationship as the ultimate driver of analytical and transformational sustainability (Gibbons et al., 2018). This is achieved using innovative technologies aimed at establishing healthier lifestyles and habitats, in coherence with on-going initiatives of the EC towards technological and non-technological eco-innovation.

In REPAiR pilot cases, material flow analysis of waste management and spatial analysis of wastescapes provide a framework to interpret design and guide actions, applying a system of technologies and strategies with relevant stakeholders and local experts. The aim of the PULLs becomes to facilitate a sustainable transition towards better territorial conditions of welfare, liveability, and cooperation with stakeholders. The shift from waste to resources, through the lens of circular metabolism, becomes the tool to re-interpret and carry out strategies and socio-technical tools in order to mitigate the environmental impact of flows.

4.2. Integrating the Recycling of Waste and Wastescapes in the PULLs

In the development of the PULL process, a pre-condition is orienting knowledge co-creation and innovation design: the trust in a public–private–people–partnership where each partner is both competence donor and receiver. At the same time, the cooperation among actors defines specific enabling conditions, supporting the identification of operative tools and envisioning decision-making processes.

The recursion of the process becomes an act of legitimacy for its achievements. Positive feedback builds trust among the participants, while serious problems can be driven out through new collaborative and cooperative processes.

PULLs within the two pilot cases of Amsterdam and Naples run in parallel, in a real ‘learning by doing’ experimentation. Nonetheless, they turned out to be quite different, especially due to the kind of stakeholders involved and their level of awareness about circularity topics. For example, Naples had firstly to overcome institutional mistrust, territorial fragility and spatial injustice before being able to work on the development of EIS. Conversely, Amsterdam could build its experimentations on an already more CE-oriented audience.

Moving towards circularity is urgent for urban planners and decision-makers. Hence, renewing existing technological, socio-political, environmental and economic behaviours and patterns is a necessity. Therefore, when working in LL collaborative environments, such awareness produced different types of responses in various types of contexts and in various categories:

- Products-related innovation, such as the so-called EIS and strategies to implement circularity;
- Process-oriented, such as the development of new decision-making models, collaboratively building interactions and connections within unexpected actors;
- Services-proactive, as the ultimate goal of Co-Decision/Co-Governance phases, the mixing between competences and opportunities, in order to increase circularity feasibility.

5. Conclusion

In the co-creation approach of the PULLs every stakeholder is involved in the definition of EIS and strategies that aim at improving the quality of life that characterises the investigated territories. This integrated approach—which is tailored to each specific case study—based on the principles of circularity, is experimented and tested. The PULLs, as an institutional arena for discussions, can facilitate the relations among institutions, citizens, researchers, enterprises and other stakeholders which will eventually constitute new networks of cooperation that can help overcome institutional lock-in situations.

Generally, in urban LLs, stakeholders are actively involved in the development of services and strategies. Moreover, they are also asked to promote actions in the process of their implementation. However, the implementation phase is out of the scope of the project that this article is based on and is therefore not included in it.

In conclusion, with this research, in the PULLs local teams verified EIS and strategies through the lens of existing public programmes and urban planning policies. In this research, PULLs functioned as an empowering tool for local communities influencing decision-making processes. Their ultimate achievement, when the local condition allows, is to become the public arena where the negotiation at the local, regional, and even national level takes place (Attademo & Formato, 2018). The definition of this ‘public arena’ guides practical intervention, in parallel with the technical work carried out within institutions. This can help to increase the integration between marginalised population segments and encourage responsibility among citizens and associations, also guaranteeing the efficacy of a transparent process.

The PULLs implemented in the two case studies investigated in this article achieved different outcomes in relation to the following aspects: institutional and social innovation; wastescape definition and regeneration; and circularity.

Specifically, in the PULL of Naples, the solutions and strategies proposed within the PULL workshops were strong enough to stimulate the actual implementation of policies and programs which were overlooked for a very long time, leading to institutional innovation. Social innovation was also achieved as citizens were invited to bring their own perspectives on the territory and its challenges to the PULL workshops, discussing them with experts of the field. These perceptions were then interlinked with the know-how and expertise of citizens who work within the project area. Moreover, PULL participants developed a detailed definition of wastescapes, which was improved thanks to the specific knowledge of the citizens and institutions involved in the PULLs. Finally, in Naples the focus on circularity overcame the sectorial discussion on improving the waste management sector for example by developing innovative waste plants that would be able to face emergency phases (see the case of Land of Fire).

Instead, circularity was addressed in a systemic way, also involving the social dimension.

In the case of Amsterdam, the PULL workshops applied co-creation between researchers and professionals from the field. Between the workshops, the researchers worked on refining the results from the previous workshop and preparing input for the new workshop. The identified challenges and the objectives that had been defined in the AMA were complex, requiring the development of solutions that need institutional, social and governance innovation to be implemented. An example of this is Circular Tendering as a solution to implement CE principles in large scale building projects. For the market to implement this solution, new taxation policy is needed that favours the use of existing materials and components and relieves taxes on labour. As such, implementing circularity in the construction sector seemed to require complex strategies, involving to a great extent financial-economic and legal aspects, more than the technical aspects that are focused on by many current projects.

On the other hand, several simple circular solutions were found for organic waste, such as the Bread-to-Beer solution, that would be beneficial for both brewers and bakeries. So, whereas simple solutions could be found for implementing a series of circular solutions, a more complex set of strategies is needed to develop the CE systemically, and to make the social and governance changes that are needed to address the most important challenges of the CE.

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Conflict of Interests

The authors declare no conflict of interest.

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Article

Urban Regions Shifting to Circular Economy: Understanding Challenges for New Ways of Governance

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Abstract
Urban areas account for around 50% of global solid waste generation. In the last decade, the European Union has supported numerous initiatives aiming at reducing waste generation by promoting shifts towards Circular Economy (CE) approaches. Governing this process has become imperative. This article focuses on the results of a governance analysis of six urban regions in Europe involved in the Horizon 2020 project REPAiR. By means of semi-structured interviews, document analysis and workshops with local stakeholders, for each urban area a list of governance challenges which hinder the necessary shift to circularity was drafted. In order to compare the six cases, the various challenges have been categorized using the PESTEL-O method. Results highlight a significant variation in policy contexts and the need for these to evolve by adapting stakeholders' and policy-makers' engagement and diffusing knowledge on CE. Common challenges among the six regions include a lack of an integrated guiding framework (both political and legal), limited awareness among citizens, and technological barriers. All these elements call for a multi-faceted governance approach able to embrace the complexity of the process and comprehensively address the various challenges to completing the shift towards circularity in cities.

Keywords
challenges; circular economy; governance; peri-urban areas; urban region

Issue
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1. Introduction

The need for a shift to a more sustainable way of living is key in recent strategies at European level (European Union [EU], 2017). In order to reach this goal in a comprehensive manner, the process needs to be carefully governed. At this point, several problems and challenges have emerged, due to the relative novelty and complexity of Circular Economy (CE) as a policy field; furthermore, there are still only few studies on governance of CE, particularly at the scale of urban regions (Section 2); and thus requiring a solid methodology (Section 3).

It is argued that an analysis of governance settings and related challenges is necessary to delineate new ways of governance towards circularity. The latter should allow cross-cutting (horizontal) and multi-level (vertical) involvement of various actors in finding answers to challenges posed by CE.

This article attempts to address this knowledge gap by providing guidelines for overcoming barriers and taking advantage of opportunities within governance settings to develop CE thinking on the level of urban regions. These have been developed through an explorative analysis (Section 4) of the first results on governance challenges for CE in six European peri-urban areas, as an output of the ongoing Horizon2020 Project REPAiR. The challenges derived from the six cases are compared, analyzed and discussed in Section 5. Thus, gaps in the current literature on governance of CE in urban regions are addressed. Furthermore, an account is provided on how, at regional scale, stakeholders from different governance fields and levels grapple with those issues.

We argue that the challenges linked to the different and context-specific governance and institutional settings have a significant impact on the effectiveness of resource management processes in observance of the EU goals for CE (Section 6).

2. The Need for Governance Change in Urban Regions

Urban areas are responsible for around 50% of global solid waste generation and between 60% and 80% of greenhouse gas production (Camaren & Swilling, 2012; Chávez et al., 2018). Facing ongoing urbanization, it is also predicted that consumption of goods and services and, as a consequence, the use of resources in cities, will grow in the future (McKinsey Global Institute, 2016).

Over the last decades, various concepts with regard to resource consumption and flows of materials have been developed and discussed. The urban metabolism concept as one of the most comprehensive approaches was first outlined by Wolman in 1965. It aims at understanding the flows into and out of cities and has been adapted several times, with recent approaches trying to further integrate social and economic aspects and to develop proposals on how to (re-)build cities in a more circular way (Kennedy, Pincetl, & Bunje, 2011).

While urban metabolism focused on cities, the concept of CE was conceived as primarily non-spatial as its focus is on the reorganization of enterprises, sectors and the economy. The objective is to close resource loops by recycling waste and reusing materials (Ghisellini, Cialani, & Ulgiati, 2016). The CE approach has been translated into policy recommendations by—among others—the Ellen MacArthur Foundation (2013). Also, building on the CE concept, the EU has adopted strategies—e.g., the Circular Economy Strategy 2017—to make Europe's economy more circular (EU, 2017).

An important step when approaching CE-oriented actions is to determine their setting and the boundaries of their impact. Among the extensive recent literature on the city scale of CE is a suggested approach able to provide a holistic interpretation, allowing a systematic view of problems and objectives (Geng & Doberstein, 2008; Ghisellini et al., 2016). This is said to help in integrating the local/territorial approach, since the main flows of materials are organized in very different ways based on variations in local conditions (European Spatial Planning Observation Network, 2019).

Girardet (2015) attempted to connect the concept of CE with urban development approaches in his regenerative city concept; while Williams (2019) emphasized the deficits of the CE concept with regard to spatial and social questions. Both authors accentuate the necessity of effective governance in the process of applying CE ideas to cities. For sustaining and facilitating such changes, a territorial governance approach which integrates the multi-level and cross-sectoral features of governance must be considered (Schmitt & Van Well, 2016; Van Well & Schmitt, 2016).

Recent studies have examined circular city and CE strategies on the municipal level. Prendeville, Cherim and Bocken (2018) discuss the concept of circular cities by analyzing circular city strategies and their implementation in six cases. They argue that, even though policymakers are interested in circular city strategies to achieve CE in cities, the implementation of these strategies faces limits: policymakers often rely on big economic stakeholders to execute CE in cities, while the development and implementation of these strategies lack an involvement of a broader stakeholder setting. Based on an analysis of CE strategies on the municipal level in 83 cities, Petit-Boix and Leipold (2018) recommend taking into account urban planning in the analysis of CE in cities as it influences many strategies linked to CE. Furthermore, they suggest involving key stakeholders in cities to identify barriers to and opportunities for the implementation of CE strategies.

In this article we consider the aforementioned demand for a better understanding of how CE could be achieved in cities and how CE and circular city approaches could be supported by key stakeholders. While the approaches of the studies of Petit-Boix and Leipold (2018) and Prendeville et al. (2018) focus on cities, we argue in this research that looking at urban regions is the more suitable scale to act for the concretization and spatialization of CE actions (Milligan & O'Keeffe, 2019). Urban regions and especially their peri-urban areas are characterised by a patchwork of dispersed urbanized areas, agricultural land and open spaces. The Directorate General for Regional Policy of the European Commission underlined in *Cities of Tomorrow: Challenges, Visions, Ways Forward* (European Commission, Directorate General for Regional Policy [EC],

2011) the presence of problems such as excessive use of resources and waste production, as well as urban sprawl and extensive land consumption in peri-urban parts of urban regions. This situation is often accompanied by fragmented local governments and planning systems. Nevertheless, while urban regions and notably their peri-urban areas are considered particularly relevant as a source of problems, their spatial configurations offer at the same time a range of possibilities to establish a CE and support sustainable development (EC, 2011; Knieling, Jacuniak-Suda, & Obersteg, 2017).

Looking into the research on climate change and transition, different aspects and issues have been identified to categorize governance processes and challenges (Dewulf, Meijerink, & Runhaar, 2015; Ehnert et al., 2018). Three main dimensions to examine governance challenges can be derived from this research:

(1) Multi-level governance considers the different scales that are involved in governance processes related to the shift of urban regions to CE (from local, regional, national to supranational) and the interactions between these levels;
(2) Cross-sectoral governance considers the involvement of different divisions of the public sector that are connected to circularity, such as waste management, spatial planning, environmental planning and business development;
(3) Multi-actor or quadruple helix governance focuses on the participation actors from public, private (enterprises), science (research institutions) and civil society (NGOs, initiatives) sectors.

These three dimensions were applied in our analysis with the aim to explore and enhance the understanding of the concrete governance challenges in nudging metropolitan urban regions towards a CE approach. A special focus in our research is set on identifying governance challenges where CE is linked to spatial affairs and planning. The research was conducted in six European case studies in the urban regions of Amsterdam, Naples, Ghent, Pécs, Łódź and Hamburg, using the methodology explained in Section three.

3. Methodology

Due to the novelty of the CE topic (Ghisellini et al., 2016), we opted for an exploratory approach describing six selected case studies around Europe to investigate the theoretical aspects derived from an extensive literature research in a real-world context (Yin, 1984/2009). Existing literature has drawn attention to implementation challenges of CE tenets at different levels (Franco, 2017; Petit-Boix & Leipold, 2018; Prendeville et al., 2018). We aim to enrich this discussion by highlighting the cross-cutting—multi-level, multi-sectorial, multi-actors—nature of the implementation of CE actions and their spatial relationships (REPAiR, 2017e). The case study selection was driven by the necessity of identifying common elements in situations characterized by apparent profound social, economic and environmental diversities. Yet it was still following a comparability logic (Kaarbo & Beasley, 1999); exploring the phenomena in all dimensions (Bartlett & Vavrus, 2017). The number of cases was intentionally kept small, allowing “thick description” and adequate analytic depth (Collier, 1993, p. 109; Kaarbo & Beasley, 1999).

Therefore, we primarily constructed a story for each case based on a total of 58 semi-structured interviews and archival sources such as published official documents and media reports. The interviews were conducted in loco with key stakeholders from waste management sector, local and regional authorities, housing companies, and representatives of the private sector (Nilsson, Eklund, & Tyskeng, 2009, pp. 5–6) and using a snowball sampling method which led to the identification of additional stakeholders concerned with the CE topic in the six urban regions (snowball sampling; see Reed et al., 2009). The thus identified stakeholder constellation was considered for direct involvement in several meetings where challenges were addressed and discussed, following the Living Lab format (Advanced Metropolitan Solutions, 2017; REPAiR, 2017c). At least one organizer of these meetings per case study is author of the present article. The challenges produced in these meetings are summarized in Tables 2 to 8.

To allow and facilitate comparison between the case studies, the analytical framework PESTEL (Political, Economic, Social, Technological, Environmental, and Legal) was used. First conceived as a tool for evaluating alternatives within organizations (e.g., Fozer et al., 2017; Song, Sun, & Jin, 2017), the framework has proved to be of significant importance in the field of strategic planning due to its ability to provide a comprehensive overview on different factors, the challenges in our case (Osborne & Brown, 2005; Yüksel, 2012), and simultaneously to highlight possible interdependencies between those (Codagnone & Wimmer, 2007; Mietzner & Reger, 2005). As governance is the focus of the present article, we considered it necessary to add organizational-related challenges as a seventh category for comparison sake.

4. Governance Settings in the Six Urban Areas

This section presents the governance background concerning spatial planning and CE topics in the case areas and provides an insight on the various challenges that a shift to CE requires. Table 1 shows key information for each case, followed by a more detailed description of each case.

4.1. Amsterdam

The Netherlands ranks among the top countries in the EU in terms of waste management (BiPRO, 2012), and has far-going ambitions to develop the country’s econ-

Table 1. Overview of the six focus areas in REPAiR project. Focus area indicates arbitrarily predetermined zones which contain peri-urban features.

Case Study Focus Area	Inhabitants in the Focus Area (number)	Waste Stream Focus
Amsterdam—The Netherlands (several municipalities in Amsterdam Metropolitan Area including Aalsmeer, Haarlemmermeer, Velsen, Zaanstad)	**758 845** (2017)	• Organic waste (OW) • Construction & demolition waste (C&D) • Wastescapes
Naples—Italy (Napoli Est, Casoria, Afragola, Acerra, Casalnuovo, Caivano, Cardito, Crispano, Frattaminore, Volla, Cercola)	**519 425** (2017) • C&D	• OW • Wastescapes
Ghent—Belgium (Ghent-Destelbergen)	**277 065** (2017) *Ghent 259.083* *Destelbergen 17.982*	• OW from households and SME
Hamburg—Germany (Bezirk Altona and Kreis Pinneberg)	**577 734** (2016) *Altona 270 263* *Pinneberg 307 471*	• OW from households and tree nurseries
Łódź—Poland (Łódź, Nowosolna, Głowno, Stryków, Brzeziny, Dmosin, Jeżów and Rogów)	**757990** (2017) *Łódź itself 690 422 (2017)*	• Municipal solid waste -especially OW fraction
Pécs—Hungary (Pécs and 41 municipalities)	**144 188** (2017) *Pécs agglomeration 179 719 (2017)*	• OW • Plastic packaging waste • Residual waste • Wastescapes

omy towards one based on the principles of the CE by 2050 (Ministry of Infrastructure and Environment & Ministry of Economic Affairs, 2016). In addition, the national government has formulated specific CE policies focusing on specific sectors, for instance construction (Rijkswaterstaat & Ministry of Infrastructure and Environment, 2015).

The Amsterdam Metropolitan Area (AMA) can be regarded as one of the frontrunners in moving towards a CE. The AMA spans across the boundaries of two provinces and encompasses the city of Amsterdam and 32 municipalities. For instance, the city of Amsterdam has formulated a circular city policy, which gives direction to public and private decision-making in the metropolitan area (Municipality of Amsterdam, 2016), and the municipality of Haarlemmermeer has the ambition for a transition towards a regional circular society and economy (Bosch, 2015). Moreover, various private actors, including waste management companies, as well as construction companies working on circular development initiatives, formulate their own ambitions.

Some of the key CE objectives for the AMA include: (1) redeveloping the Amsterdam docklands and wastescapes while limiting the amount of construction and demolition waste; (2) reusing the airport wastescapes surrounding, and reducing the food waste from Schiphol airport; and (3) reducing and reusing biowaste from agricultural production in greenhouses and flower trading within the Greenport Aalsmeer area.

Stakeholders identified a variety of specific challenges for reaching the above objectives, including: (1) conflicting interests of stakeholders across and within organizations; (2) lack of awareness of CE solutions and business models, particularly among the business players; (3) organizational fragmentation and lack of regional leadership; and (4) regulatory, financial and behavioral obstacles to learning from and upscaling circular innovations. Both the area-specific, waste-specific, and governance-specific challenges result in ambiguous and complex governance settings in which to promote a CE strategy in the AMA.

4.2. Naples

In Italy integrated waste management started in 2006. Being recent, this measure has been absorbed differently by regional policies, and this is truly evident in southern Italy. In particular, the Campania region has experienced two environmental crises since the mid-nineties, whose effects are still ongoing: the Waste Emergency and the Land of Fires. Both crises arose from government incapacity and the poor governance model in use (REPAiR, 2017d). As a consequence of the socio-ecological decay process, the abandonment and illegal deposit of waste along peri-urban streets and infrastructure has contributed to the proliferation of wastelands. In the case-study area, which extends towards the North-East of Naples up to the town of Acerra, the assemblage of different kinds of wastelands has consequently given shape to wastescapes (REPAiR, 2017a).

What local authorities have to aim at is a multi-level governance through which the CE approach can be applied to both the waste management and the wasteland regeneration (Berruti & Palestino, 2019). In order to achieve this objective, there are some key challenges to face:

(1) the stalemate in the waste management system, for which institutions do not care or even exploit at the different levels. The Regional Authority is playing its decisional power without calibrating rules to local contexts or turning them into effective policies; municipalities are interested in preserving benefits related to the previous waste system and companies selected through political nepotism. Surprisingly, Metropolitan City of Naples has been wrongly excluded from the governance of waste management by the regional law;
(2) the increase of wastelands due to intra-institutional difficulties in overcoming sectoral policies and conflicting powers;
(3) the lack of shared knowledge among institutions and towards citizens;
(4) suspicion, stigmatization and distrust making it difficult to innovate policies and develop new economies.

Promoting the relationship with communities through the co-design of places would be crucial for decision-makers, in order to turn all the fragmented measures and rules into a pluralist strategic vision. It would be also crucial for institutions to sustain proposals coming from local stakeholders that otherwise risk failure.

4.3. Ghent

Flanders has a long history of Waste Management. Since 1981 a combination of instruments and tools has been used to move waste management further up in the waste hierarchy, promoting prevention and material recovery (REPAiR, 2017e). As a result, waste sensitivity is amongst the highest in Europe (REPAiR, 2017b).

The general legal framework for household waste management is determined at Flemish (regional) level, with implementation plans setting priorities, targets and general strategies. Customization at local (municipal) level remains possible, providing that waste management services are accessible to all.

The ongoing ambition to reduce the total amount of (residual) waste necessitates municipalities to look for eco-innovative solutions, in order to further improve resource management. While waste management has been integrated in the city's climate policy and urban planning, the shift to CE is yet to be made. Food waste prevention, local waste treatment and higher valorization of resources remain challenging.

In the case-study area, Vegetables, Fruit, Garden waste (VFG) still represents a considerable amount of the residual waste. Challenging collection conditions (smell, hygiene, volume) for households and waste agencies, label VFG as a difficult waste flow to treat. However, many aspects determine the direct/proactive involvement of households to the separate collection of VFG. Legal obligations and financial incentives are only part of the solution. More compact living forms, changing family units, demographic evolution and new mobility trends all impact waste behavior. They ask for other collection methods than the classic kerbside collection or the collection in recycling parks. The diverse urban fabric calls for a customized approach and cost-benefits must be taken into account to guarantee an accessible service to all. Furthermore, open public space is scarce in the inner city as well as in peri-urban areas, resulting in a strong competition between different policy objectives.

4.4. Hamburg

Germany is widely considered as a frontrunner in dealing with environmental problems (European Environmental Agency, 2009; Wilts, 2016). Since 2012, the Circular Economy Act (Kreislaufwirtschaftsgesetz) guides actions related to waste management issues. The fulfilment of its requirements is the task of the Federal States. However, the interpretation of national regulations might substantially differ between states (REPAiR, 2017e, p. 23). This situation is reflected in spatial planning issues: in Pinneberg County (Schleswig-Holstein), municipalities develop their own spatial plans according to the national strategies without any restriction from the county. Meanwhile in Hamburg, binding plans are drafted at county level (i.e., the districts), as for the District of Altona, revealing a concentration of powers at higher levels. This setting might hinder pursuing CE actions, which call for cooperation between the two different states.

Just as the systems in the two states are distinct, the challenges that are faced have two different aspects. In Hamburg's District of Altona around one third of the bio-waste generated is thrown in the bins for residual waste. This is due in some households to a lack of separate bio-waste bins available and in others to improper disposal behavior, despite the many incentives provided for correct separation (REPAiR, 2017e, p. 31). The residual waste is incinerated, leading to a loss of valuable resources. In the case of Pinneberg, the focus is on the tree nurseries business as this economic activity characterizes the county. The bio-waste that is generated in tree nurseries is often directly incinerated on site, causing emissions that annoy the neighbors. This has led to protests and, jointly with an always increasing housing market pressure, the tree nurseries are at risk of being replaced in order to build new apartments.

Barriers are also present inside each Federal State, between different stakeholders and, sometimes, even within the same institution. As a matter of fact, stakeholders have mentioned the necessity of a more integrated approach between planning and waste management to overcome these challenges and to reach more circularity.

4.5. Łódź

In Poland two regulations are currently in force: one on waste from 2012 (amended in 2015) and the Act of 1996 on maintaining cleanliness and order in municipalities (amended in 2011 and 2014). The authority responsible for organizing waste management is the municipality. Moreover, municipalities' responsibilities comprise ensuring the construction, maintenance and operation of waste treatment infrastructure as well as including all households in the municipal waste management system and providing selective waste collection. Municipal authorities appoint waste collection companies by means of public tender (REPAiR, 2017e).

After various meetings and interviews with local stakeholders, three key challenges related to waste management in Łódź Agglomeration were identified:

(1) Environmental awareness of inhabitants—concerns inadequately low level of socio-ecological awareness, manifested mainly in improper or even lack of waste separation. As a consequence, the amount of waste to be recycled is relatively low;
(2) Legal status—the regulations in force do not ensure high quality of service concerning collection and management of municipal waste. The issue regards the restricted possibility of establishing local recycling centers and meeting requirements of complex environmental procedures in a short time. Establishment of commercial institutions intended for waste management by local authorities is also hampered;
(3) Local government policy—local governments cooperate poorly with each other in implementing objectives of environmental policies. There is a lack of widespread actions to pass on good practices. Local authorities do not stand for lobbying innovative ecological solutions.

The coming years will be decisive to the process of stabilizing the waste collection and management system. A significant role should be played by local self-government associations, which articulate the need for changes and modernization of approaches towards waste management, including enacting legal regulations. However, the successful implementation of CE principles will depend to the greatest extent upon enhancing the environmental awareness of the local population.

4.6. Pécs

Although there have been many remarkable achievements in regard to decreasing waste generation and improving waste management infrastructure, Hungary lacks a visible political intention related to circularity both at national and local levels. Furthermore, there are only few voluntary CE initiatives and projects in the private sector. According to the OECD report for Hungary, a whole-government approach is needed to accelerate towards CE (OECD, 2018). However, starting in 2010, a very strong centralization process within the whole governmental area can be observed, accompanied by the degradation of the independent environmental management system (in all lower decision-making levels). This centralization has resulted in the unavailability of secondary raw materials in the local market for public waste management companies, which led to a weakening in their importance in waste management activities. Because of this, local stakeholders' interest has dropped. A lack of a real iterative process in planning and decision making further complicates matters.

The EU-financed new waste management infrastructure (built in 2016) of the urban region Pécs has caused path dependency in technology in use for the next 20–25 years. As a result of this investment there is door-to-door collection for many materials. However, there are some remaining challenges: the low density of selection islands (collection points) and the lack of solutions for special waste collection and treatment (e.g., discharge the asbestos from the demolition waste).

On the other side of the waste chain, household behavior and attitudes need major improvement. In this case, the challenges in the urban region of Pécs consist of high rate of selectively collectable materials wrongly put in the residual waste (bins); garden waste burning practice of the households (instead of composting); heating with waste in poor families (REPAiR, 2017e).

The generation of wastescapes is related to the main economic development trajectory of Pécs. The three main groups of challenges are the closed mining sites and their spoil-bank, the leftover military sites and the abandoned industrial areas.

5. Comparing Cases

5.1. PESTEL-O Table

In order to understand and compare the main governance challenges to CE among the six cases, Table 2 was constructed using the PESTEL-O method. The next two paragraphs draw out the key common points of the challenges and the discussion of the main findings, respectively.

5.2. Comparison

Similarities can be identified by drawing out the key findings from the table for each category. The rule of thumb used here is that a certain challenge must be present in at least two cases and only the most significant points will be discussed.

Table 2. Governance challenges: Policy/politics.

Amsterdam	Naples	Ghent	Pécs	Łódź	Hamburg
• Lack of consistency in municipal sustainability policies • Lack of regional CE policy formulation and coordination • Silo-mentality within governments and business regarding CE	• Competition among municipalities for leadership on waste management • Lack of policies able to face problems beyond administrative boundaries • Regional policies not calibrated to local contexts	• Long-term and solid cooperation are difficult to built • Integrate CE in urban planning policies • Balancing general regulations with tailor- made solutions	• Lack of real participation of stakeholders • Lack of decentralization of decision-making	• Not enough horizontal municipal cooperation • Difficult cooperation between local authorities and private sector	• Lack of integration of waste management and urban planning policies

Table 3. Governance challenges: Economic/financial.

Amsterdam	Naples	Ghent	Pécs	Łódź	Hamburg
• Banks reluctant in financing CE ventures • Limited awareness of successful CE business models in resource management and planning projects	• European waste management sanctions to be paid • Tendering not respondent to CE processes • Highest waste tax of Italy in the Campania Region	• Financing and up-scaling CE initiatives in a linear economy • Developing circular business model equally sharing burdens and benefits • Dual waste system (house-holds/industrial) hinders waste management optimization	• Local service fees not purposed for refinancing new sectoral investments • Recently centralized secondary raw material market inaccessible to local service providers • Many non-re-cultivated wasted areas needing major investments	• Slow market development for eco-innovative solutions • Lack of business models to improve waste management processes • Difficult process of applying for additional funding for developing innovative solutions	• Incentives for waste separation not clear/high enough

Table 4. Governance challenges: Social/behavioral.

Amsterdam	Naples	Ghent	Pécs	Łódź	Hamburg
• Consumer readiness to pay premiums for circular products • Reliance on business leaders to make the CE transition	• Citizens' distrust of institutions • Suspicion of the quality of organic and C&D waste products • NIMBY Syndrome in local communities	• Engaging households in fighting food waste • Participation (quantity and quality) in separate collection VFG-waste • Citizen's knowledge and support for CE	• Excessive (mainly landfilled, food, plastic packaging) waste • Residual and garden waste burning practice of households	• Limited (ecological) awareness regarding waste burning for heating and waste separation advantages	• Waste topic not included sufficiently in school curricula • Little interest in waste from either landlords or tenants

Table 5. Governance challenges: Technological/infrastructure.

Amsterdam	Naples	Ghent	Pécs	Łódź	Hamburg
• Limited awareness of CE product development among producers	• High percentage of organic waste displacement in Northern Italy's waste treatment plants • Disposal of Eco bales • Lack of recycle points in the peri-urban area	• Improve valorisation of food surpluses from distribution chain • Nuisance related to storage and collection of VFG-waste	• Path dependency of waste management system and planning practice • Low density of waste collection points • Insufficient solutions for special waste collection and treatment (i.e., asbestos)	• Small number of companies with innovative potential • Insufficient waste separation infrastructure (incompatible container size) • Limited capacity for bulky waste storage and waste containers in public space	• Persistency of existing waste technology prevents innovation • Long distances between waste generation and treatment

Table 6. Governance challenges: Environmental.

Amsterdam	Naples	Ghent	Pécs	Łódź	Hamburg
• Presence of polluted or noise-restricted peri-urban wastescapes in port and airport areas	• Abandonment and illegal deposit of waste along peri-urban streets • Deposit of Eco bales in peri-urban areas by Campania Region • Peri-urban assemblages of wastelands	• Environmental impact of waste transport	• Points for separated waste collection frequently becoming wasted areas (illegally dumped litter near the separate collection bins) • No solutions for PLA (polylactic acid) collection, treatment and low level of distribution	• Enhancing the efficiency of waste collection system management aiming at reduction of mixed waste • Locating new waste treatment plants • Suburbanization significantly increases waste management costs	• Bio-waste potential not fully used for biogas production

In relation to policy/politics, key challenges in the various case studies refer to a lack of leadership regarding waste management, the difficulty in formulating integrated waste management and planning policies, and a lack of stakeholder participation and cooperation. The main economic-financial challenges are the lack of tested CE business models and the difficult financing of CE initiatives. Observed social-behavioral challenges include a limited awareness about and engagement of citizens in waste collection, separation and management. The shared technological-infrastructural challenges are insufficient physical space for the collection, storage, separation and recycling points for waste. From an environmental point of view the cases illustrate the existence of wastelands, illegal waste dumping, and unwanted waste burning practices. Legislative challenges are very much case- and context-specific and thus difficult to generalize arbitrarily. Finally, widespread organizational challenges found are knowledge asymmetry and lack of dialogue within (intra-institutional) and between (inter-institutional) organizations.

5.3. Discussion

After pointing out the similarities using the PESTEL-O, now the specificities of governance challenges for each case are highlighted. Though the AMA is one of the frontrunners in moving towards circularity, it lacks common regional strategies and actions in the public sector and coherent actions between the private sector and public institutions. In the metropolitan area of Naples, by contrast, CE works as a rhetorical argument that is rarely ap-

Table 7. Governance challenges: Legal.

Amsterdam	Naples	Ghent	Pécs	Łódź	Hamburg
• Construction tender procedures not adequately adapting CE principles • Unclear legislation on waste ownership • No tax disincentives for companies and households producing waste	• Legal control by EU on regional waste management • Poor measures for implementing CE processes • Redundancy of authorizations for implementing waste plants		• Lack of room to maneuver for local (government) stakeholders	• Privatized collection • Disrespecting environmental protection and waste management legislation • Lack of a well-functioning effective flow monitoring system	• Conflicts between waste management and other uses in public spaces

Table 8. Governance challenges: Organizational.

Amsterdam	Naples	Ghent	Pécs	Łódź	Hamburg
• Lack of regional CE platforms and networks • Risk-avoiding attitude towards CE initiatives in municipalities • Knowledge fragmentation within and asymmetry between organisations (intra- and inter-institutional)	• Slow transition in regional waste management • Organised crime interests in maintaining waste management status quo • Lack of inter-institutional and intra-institutional integration in environmental policies	• Knowledge asymmetry between stakeholders	• Insufficient level/mode of knowledge and information transfer	• Focus on waste recycling, less on design, prevention and reuse • Lack of reliable simulations regarding actual needs for providing waste management infrastructure	• No (or limited) dialogue between different stakeholders and sectors

plied in policies, due to inefficacy of sectoral planning and difficulties in fostering urban metabolism. In Ghent the transition to CE is well advanced, now the focus of local debates is how to upscale and mainstream CE initiatives. As CE is still a relatively new phenomenon in Łódź, there is a lack of cooperation between public authorities especially municipalities as well as between the public sector and enterprises. Furthermore, the citizens' environmental awareness with regard to CE and waste management is not yet very advanced. The Pécs case shows a lack of political interest in circularity and like in Łódź there are only few CE initiatives coming from the civic society. This indifference is worsened by a centralized environmental management system that hinders local actors' involvement. In the Hamburg case, in Pinneberg County the challenge is how to involve the private sector (tree nurseries) in CE activities, while in Hamburg-Altona it is to bridge the gap between urban planning and waste management. The six cases show that, despite being in different stages of shifting towards CE, all of them are facing challenges in the implementation of CE strategies in overcoming sectoral policies and fragmented decision levels.

6. Conclusion

The study examined the necessity of understanding governance challenges in order to support urban regions in successfully shifting towards CE. The broad spectrum of governance challenges has been illustrated based on the case study specific analysis and their categorization according to the PESTEL-O method. According to the three dimensions that were introduced in Section two the following major governance challenges could be highlighted. First, with regard to multi-level governance the examined cases show that while ambitious initiatives for CE do exist in urban regions, the connections between these local and regional initiatives to policies on higher political and administrative levels are lacking. Second, concerning cross-sectoral governance within the public sector the examples from the six urban regions demonstrate a lack of connection of CE strategies with other policy fields especially spatial planning. Another major challenge is the often-missing horizontal cooperation between municipalities. Strategies and activities often remain local, not using the opportunity of promoting CE in larger regional scale. Third, regarding multi-actor or quadruple helix governance: while in some of the examined urban regions many entrepreneurial and civic society initiatives exist that lack coordination and support by the public sector; in other regions still only few activities from the economic sector and citizens can be observed and the public sector is mostly absent in promoting CE.

From a methodological point of view it should be stated that the use of the PESTEL-O method has its limitations. While it is useful for categorization purposes, there is a risk of neglecting the complexity of some of the challenges that cross more than one division.

Although the results of this study are limited due to the fact that the research only comprises qualitative studies in six cases, the need for further and deeper examination of CE implementation challenges in urban regions can be derived from the described findings. Urban planning has the potential to steer CE processes and has a cross-thematic and integrative character which suits the complexity of CE implementation. Further, as we have shown, CE strategies and activities must be further spatialized. The nature of this future role of spatial planning in the realization of CE demands further investigation.

As mentioned before, the presented outcomes derive from an ongoing project, and in future research each of the cases will be examined in-depth. This will allow for the development of more specific implications for policies.

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Conflict of Interests

The authors declare no conflict of interests.

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Article

A Geodesign Decision Support Environment for Integrating Management of Resource Flows in Spatial Planning

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Abstract
Improving waste and resource management entails working on interrelations between different material flows, territories and groups of actors. This calls for new decision support tools for translating the complex information on flows into accessible knowledge usable by stakeholders in the spatial planning process. This article describes an open source tool based on the geodesign approach, which links the co-creation of design proposals together with stakeholders, impact simulations informed by geographic contexts, systems thinking, and digital technology—the Geodesign Decision Support Environment. Though already used for strategic spatial planning, the potential of geodesign for waste management and recycling is yet to be explored. This article draws on empirical evidence from the pioneering application of the tool to promote spatially explicit circular economy strategies in the Amsterdam Metropolitan Area.

Keywords
Amsterdam; circular economy; decision support tools; geodesign; recycling; urban living labs; waste management

Issue
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1. Introduction

With circular economy (CE) becoming a new sustainability paradigm (Geissdoerfer, Savaget, Bocken, & Hultink, 2017), strategies to reduce waste generation through better resource management have been climbing up the policy and planning agendas in numerous cities and regions. Improving waste and resource management entails understanding the interrelations between different material flows (e.g., organic waste, construction and demolition waste, plastics), 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). This entails an increased complexity of interdependencies, relations and impacts of new kinds of circular processes and interventions that need to be considered in the decision-making process. Such complexity calls for new Spatial Decision Support Systems (SDSS) for translating the intricate information on material flows and related actors into accessible knowledge that could be used by stakeholders in the spatial planning process. SDSS typically combines tools from participatory Geographic Information Systems (GIS) with decision support tools, which have the capacity to animate and clarify discussions between stakeholders rather than just representing optimal results (de Wit, Brink, Bregt, & Velde, 2009).

The geodesign approach is a widely used methodology for exploring and addressing complex territorial challenges in different geographical scales while cooperating with stakeholders in an iterative and bottom-up manner (Li & Milburn, 2016). Therefore, geodesign emerges as a suitable methodology for supporting planning for the CE. However, to date, it has hardly been applied in the development of territorial strategies for reducing the generation of waste and closing the loops of material flows. Given the above-mentioned complexity and the importance of material flows in this field, the application requires modifying the methodology in order to integrate methods and technologies suitable for exploring the volumes and geographies of material flows, life cycle of materials and governance analyses. Technological innovation and rapidly increasing computational power, new means of sharing data and information and digital literacy, have a great potential to be effectively deployed in the pursuit of sustainability (Retief, Bond, Pope, Morrison-Saunders, & King, 2016). The tool proposed in this article, along with its underlying methodology, addresses this challenge by integrating geodesign with the Urban Living Labs (ULLs) approach (e.g., Steen & van Bueren, 2017). ULLs are becoming increasingly popular for engaging citizens and key stakeholders in the process of knowledge co-creation and co-design of experimental solutions to urban challenges in a real-life context. While geodesign is already used for strategic spatial planning, its potential for waste management and CE is yet to be explored. This article explores whether and how geodesign can be used to improve waste and resource management. It also describes a web-based open source tool that adapts geodesign for the purpose of spatial diagnosis and elaborates on territorial and systemic eco-innovative strategies toward a CE through the Geodesign Decision Support Environment (GDSE).

Section 2 outlines the theoretical background for the GDSE and builds on recent geodesign and living lab approaches and technology implementations in the field of spatial planning. Section 3 describes the geodesign-based GDSE methodology to support collaborative resource flow management. The methodology is applied within an ongoing living lab aimed at improving waste and recycling management in the Amsterdam Metropolitan Area (AMA; Section 4). Finally, conclusions on the usefulness and limitations of the GDSE are provided in Section 5.

2. Theoretical Background

CE is primarily driven by the agreements between multiple actors to share resources, materials and infrastructure for as long as their physical properties allow. This increases the pool of stakeholders that could act together, which may create collective strategies to achieve higher benefits to everyone's interests. Mathematical models could theoretically be used to optimize the total sum of individual, environmental, social and economic benefits. However, in practice, modelling such a system accurately is too complicated. This type of modelling requires the integration of technology and analytical methods with new collaborative approaches for spatial decision-making. We propose an approach that builds on three elements: current technological advances and related analytical methods, the geodesign framework, and the ULL approach as a methodological environment for stakeholder involvement.

2.1. Technology and Analysis Methods

GIS are not only used for cartographic analysis but are increasingly being used for building narratives, qualitative storytelling and within synthesis approaches with the goal for equity and justice (Sui, 2015). Although the usefulness of GIS in all stages of impact assessments have already been recognized (e.g., Eedy, 1995), it is still seldomly applied in sustainability assessments (e.g., Sholarin & Awange, 2015). SDSS are used to help address similar ill-defined problems and are defined as interactive, computer-based systems designed to support a group of users in achieving higher effectiveness in decision-making on spatial issues (Malczewski, 1999). They are meant to support rather than to replace human judgements, and improve the effectiveness rather than the efficiency of a process (Uran & Janssen, 2003). Thus, they are intended to be advisory units that are more capable to digest large amounts of data and can perform quick computations. Decision-making tends to entail social and political conflicts while also relating to values that reflect cultural, historical and social norms that are deemed acceptable by a community (Jones & Morrison-Saunders, 2016). This is crucial for spatial planning and waste management, which are (1) connected to specific geographical contexts with intrinsic cultural, historical and social values, and (2) directly affect the environment and the society in a given territory.

Currently, the most common combination of methods for assessing the impacts of potential resource flow changes includes Material Flow Analysis (MFA) and Life Cycle Assessment (LCA; e.g., Guinée, 2002). MFA is a systematic assessment of the flows and stocks of materials within a system that is defined in a space and time (Brunner & Rechberger, 2016) and provides a system understanding of a particular state of resource flows. MFA is typically applied in the built environment (e.g., Crawford, 2011). Although MFA studies have always had explicit spatial and temporal boundaries (e.g., Stephan & Athanassiadis, 2017), what happens within those limits is rather considered as a black box, where materials flow from inputs to outputs through various stocks and processes. These flows and processes are not typically described in great detail spatially, except with a few attempted studies. For example, Roy, Curry and Ellis (2014) spatially allocated construction material flows within administrative units of Kildare County, Ireland. Wallsten (2015) used the context of hibernating the stock of subsurface urban infrastructure to demonstrate how social science approaches can provide hands-on advice for private and local actors involved in material recycling. Vivanco, Ventosa and Durany (2012) developed a model for material and spatial characterization of waste flows, which included indicators that were potentially useful for assessing key policy strategies for waste management and the minimization of transport by locating adequate facilities. Even though there have been existing attempts to introduce a spatial dimension into the MFA methodology, the spatial granularity is very coarse and its usefulness in decision-making has not been validated as of yet.

LCA is used to assess environmental, social and economic impacts of products or services through all the stages of their lifetime in comparison to a baseline scenario (Taelman, Tonini, Wandl, & Dewulf, 2018). LCA intends to support decision-making and therefore, the involvement of decision-makers throughout the entire study is crucial in order to avoid issues addressed by the study that may differ from those that the decision-makers deem as important. Depending on the situation, it may be relevant to include other stakeholders that may be affected by or can influence the consequences of the decision (Weidema, 2000). Failure to involve stakeholders may result in controversies or may hamper the implementation of the suggested environmental improvements. Hence, decision-making in spatial planning and resource management should not be top-down and should include local stakeholders, especially if they are the ones most affected by the decisions made. Although LCA is mostly used for environmental impacts, it may also include several impact categories, such as social or economic impacts (Jeswani, Azapagic, Schepelmann, & Ritthoff, 2010). LCA also aims to include as many substances and compounds, which is required to provide a full impact assessment. The method is widely accepted and standardized in ISO 14040 (Technical Committee ISO, 2019). However, conducting an LCA requires an extensive amount of time and data that is not often available. Moreover, communicating the results usually requires an expert audience (Elia, Gnoni, & Tornese, 2017). This is not in line with typical geodesign workshops that would last only a few days. Thus, the integration of geodesign with living labs prolongs the study period and allows the use of more advanced impact assessment methods.

2.2. Geodesign

Geodesign has emerged as a relevant concept for furthering the development of enhanced SDSS. The use of SDSS for policymaking has changed over the last decades, which can be reflected by an increased role of public participation in combination with collaborative approaches (Keenan & Jankowski, 2019). The increasingly apparent multi-stakeholder nature of policymaking has led to the recent development of SDSS that aim to address group decision-making (Jankowski, 2009). In parallel, many participatory approaches for spatial decision-making emerged, which require more collaborative tools and methodologies (Li & Milburn, 2016). Geodesign is a leading methodology to support spatial planning as it tightly couples the creation of design proposals with impact simulations informed by geographical context (Steinitz, 2012), and ensures a close collaboration between the stakeholders and decision-makers throughout the entire process that starts at problem identification and finishes at proposed interventions. Specifically, geodesign offers a framework that facilitates collaboration in iterative spatial decision processes involving future spatial interventions in a geographic study area. Figure 1 illustrates the structure of this framework.

The process involves three iterative feedback loops, which aim to (1) understand, scope, and model a geographic study area, (2) specify methods to operationalize the process, and (3) carry out the geodesign process tasks. Each iteration addresses a set of six questions, each of which is answered by specific models. The framework represents the collaboration as the interaction required between four types of stakeholders: the people of the place, geography-oriented natural and social sciences experts, design and planning professionals, and their IT technologists.

2.3. Urban Living Labs

There are multiple ways to involve the affected people into the planning process. The International Association of Public Participation (IAP2) has devised a spectrum that explains the different levels of public participation (Figure 2). As seen from this spectrum, merely involving the public into the planning process does not mean that their tacit knowledge and community preferences are used to improve the planning process. SDSS are being used on the full range of the spectrum—from acting as information systems to empowering the stakeholders to become the decision-makers. Living labs constitute an effective method for incorporating innovation and technology into participatory and multidisciplinary planning processes.

According to the European Network of Living Labs (ENoLL), living labs can be regarded as "user-centered, open innovation ecosystems based on a systematic user co-creation approach in public–private–people partnerships, integrating research and innovation processes in real-life communities and settings" (ENoLL, 2019). ULLs are comprised of physical and virtual environments, in which public-private-people partnerships experiment with an iterative method to jointly develop innovations (i.e., co-creation) that include the involvement of end-users and aim at identifying and addressing ur-

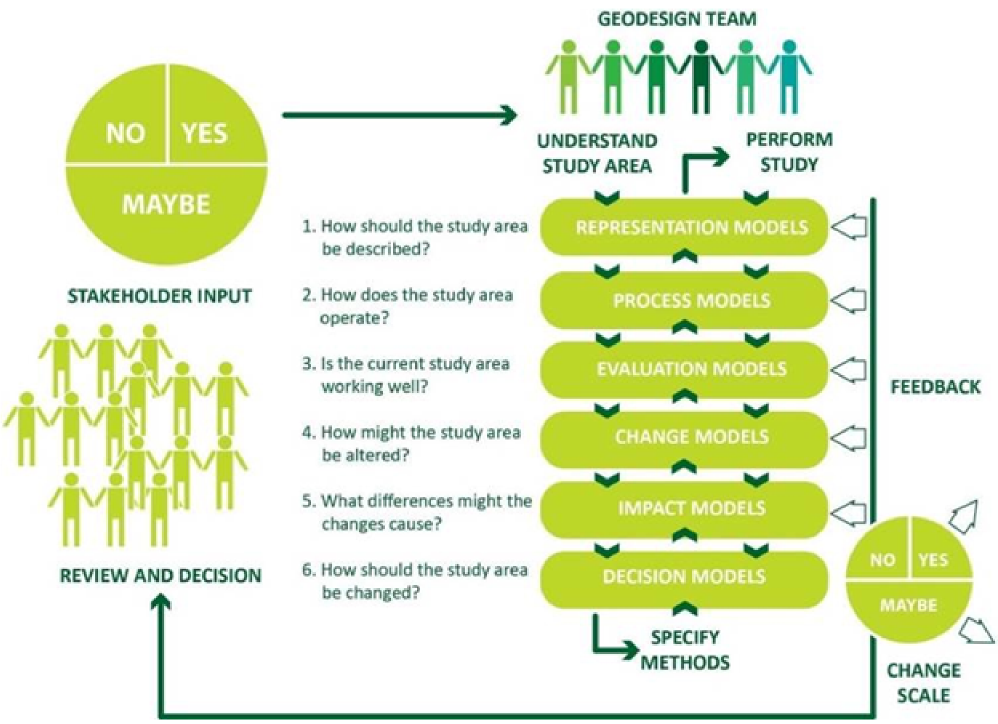

Figure 1. Geodesign framework (Steinitz, 2012). Graphic by author Libera Amenta.

INCREASING IMPACT ON THE DECISION

	INFORM	CONSULT	INVOLVE	COLLABORATE	EMPOWER
PUBLIC PARTICIPATION GOAL	To provide the public with balanced and objective information to assist them in understanding the problem, alternatives, opportunities and/or solutions.	To obtain public feedback on analysis, alternatives and/or decisions.	To work directly with the public throughout the process to ensure that public concerns and aspirations are consistently understood and considered.	To partner with the public in each aspect of the decision including the development of alternatives and the identification of the preferred solution.	To place final decision making in the hands of the public.
PROMISE TO THE PUBLIC	We will keep you informed.	We will keep you informed, listen to and acknowledge concerns and aspirations, and provide feedback on how public input influenced the decision.	We will work with you to ensure that your concerns and aspirations are directly reflected in the alternatives developed and provide feedback on how public input influenced the decision.	We will look to you for advice and innovation in formulating solutions and incorporate your advice and recommendations into the decisions to the maximum extent possible.	We will implement what you decide.

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Figure 2. Spectrum of public participation (IAP2, 2019).

ban sustainability challenges. Main characteristics of an ULL are geographical embeddedness, experimentation and learning, participation and user involvement, leadership and ownership, and evaluation and refinement (Voytenko, Mccormick, Evans, & Schliwa, 2016). The ENoLL approach is based on the quadruple helix model of partnership, which categorizes actors as the government, industry, the public and academia, who work together to generate innovative solutions in a process involving five phases, namely co-exploring, co-design, co-production, co-decision, and co-governance (ENoLL, 2019).

3. Integrating Geodesign, Living Labs and Technology

This article argues that collaboration between actors within an iterative geodesign process with feedback loops plays a central role alongside innovation and the implementation of new technology, which can be facilitated through a living lab approach. The integration between geodesign, the living lab approach, GIS, MFA and LCA into a single support environment (Figure 3) allows for the following innovations:

(1) MFA in a geographical context: via a new method of Activity-Based Spatial Material Flow Analysis (AS-MFA; Resource Management in Peri-Urban Areas [REPAiR], 2017) by geo-locating activities and actors involved in resource flows;
(2) Visualization of resource flows: via AS-MFA data analysis and visualization tools in order to gain insights into the current status quo at early stages of the solution creation process rather than only at the stage of evaluation;
(3) Simulation of proposed changes: applying the solutions as simulations of changes in the overall mapped resource flow network;
(4) LCA for impact assessment: using the AS-MFA data to describe the LCA baseline scenario and the simulated resource flow network of proposed strategies.

The GDSE provides an environment to support the collaborative efforts towards improving resource management and thus enhancing the transition towards CE. It incorporates all the relevant methodologies identified in the theoretical framework and provides both the researchers and the stakeholders with an overall structure and tools. The environment consists of software, hardware and processware.

3.1. Software

The GDSE is a core product of an ongoing EU-funded research project called REPAiR. It features an open source prototype web application that supports both the decision-making process and the research that is required for each of the five steps to guide the living lab process for a study area (Figure 4), available on the project's website. REPAiR aims to implement the GDSE in living labs in six European metropolitan areas to develop place-based eco-innovative spatial development strategies that aims to have a quantitative reduction of waste flows in the peri-urban areas (REPAiR, 2019b). Within REPAiR, a GDSE-related eco-innovative strategy is understood as:

> An alternative course of actions aimed at addressing the objectives identified within a Peri-Urban Living Lab (PULL) for developing a more CE in peri-urban areas, which can be composed of a systemic integration of *two or more* elementary actions, namely eco-innovative solutions (EIS). (REPAiR, 2018a)

To facilitate the ease of reading, from this point forward, "eco-innovative solutions" will also be referred to as either "solutions" or "EIS", while eco-innovative strategies will also be referred to as "strategies".

While designed and tested for the specific purposes of the REPAiR case studies, the GDSE is meant to be easily reusable, which is one of the guiding principles of the software development process. Thus, the GDSE is built with free and open source components and has an open license. All versions of the source code are available on a public GitHub repository (https://github.com/MaxBo/REPAiR-Web). Figure 5 shows the current backend integration of various components into a single platform that supports a range of functions: data management and storage, data visualization, stakeholder input, simulation and assessment of alternatives, and connection to an external LCA assessment.

Data storage and management is done via the Open Science Framework (https://osf.io). GeoServer

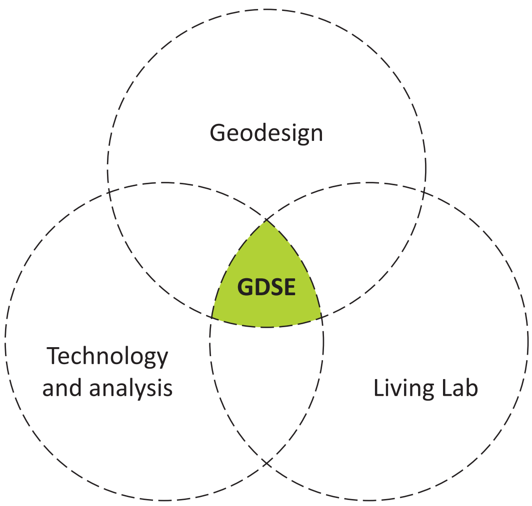

Figure 3. Integrating geodesign and living lab methodologies together with existing technology and analysis methods for the resource flow management into a single support environment, i.e., the GDSE. Source: authors.

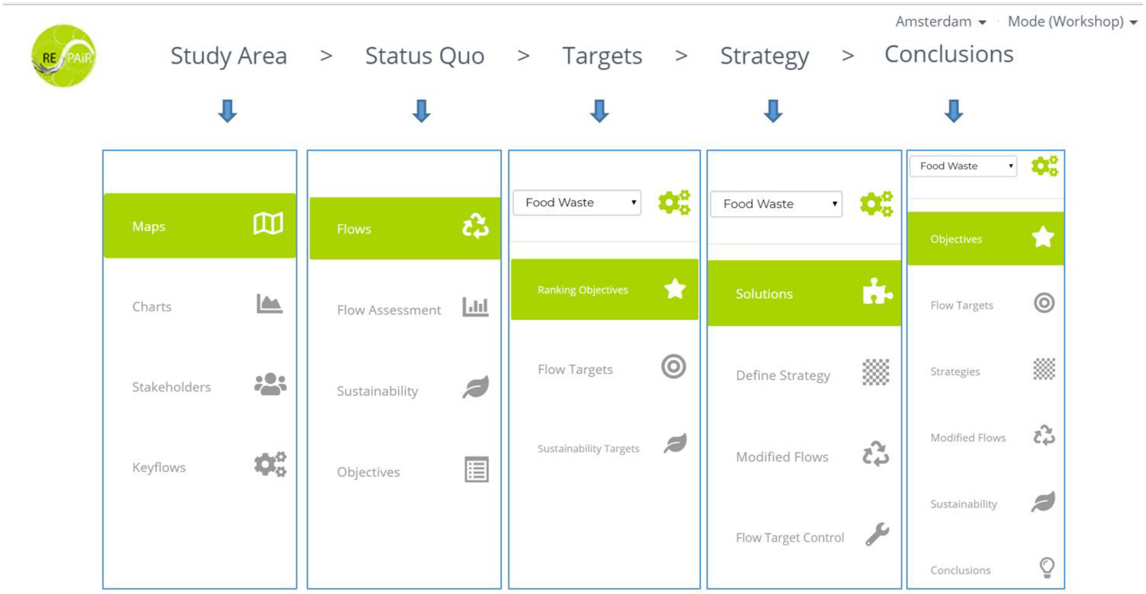

Figure 4. Screenshot of the GDSE showing its main five steps (top) and specific side menus (REPAiR, 2018b).

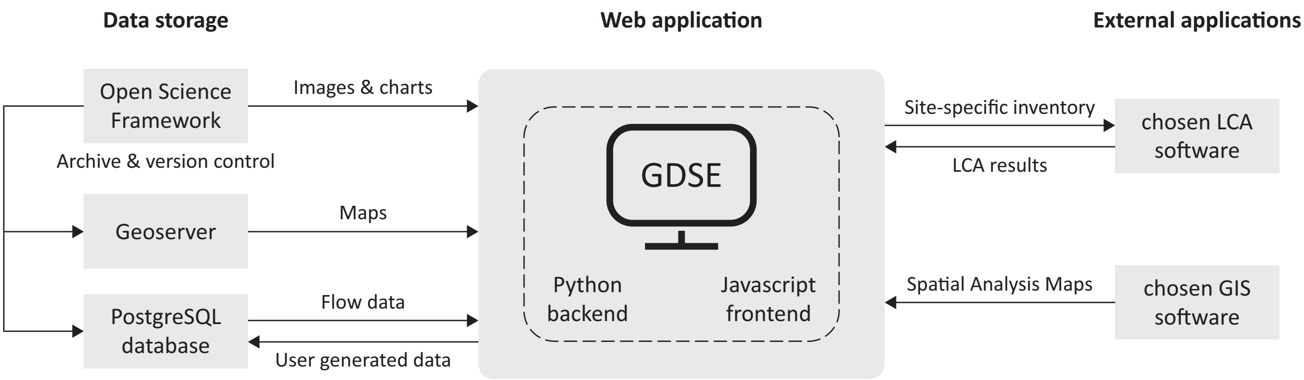

Figure 5. Integrating open source components into a single GDSE. Source: authors.

(http://geoserver.org) is used to publish and host spatial data layers, as web feature services, incorporated and visualized in the GDSE, which are externally prepared using QGIS (https://qgis.org). All the AS-MFA data used for the analysis and assessment are stored in a PostgreSQL object-relational database (https://www.postgresql.org). LCA is conducted externally. All outputs are displayed in the GDSE. Vagrant (https://www.vagrantup.com) is used for providing a reproducible, operating system which is independent of the software environment setup.

Two main roles that are supported by the GDSE are the *researcher* and the *stakeholder* (Table 1). A researcher (or a group of researchers) is responsible for organizing the geodesign process, finding and involving the relevant stakeholders, collecting, preparing, uploading and selecting relevant data, performing impact assessment, preparing and holding the interactive workshop sessions, collecting stakeholder input from those sessions for use in subsequent ones. A stakeholder (or a group of stakeholders) uses the system at workshop sessions, which are facilitated and moderated by researchers. The GDSE provides different functions within two separate environments for the previously described roles: the *setup* mode and the *workshop* mode.

3.2. Hardware

The GDSE hardware component features interactive touch-enabled screens to facilitate workshop communication in two ways: (1) between users and the GDSE software (tools and support information), and (2) dialogue between the users. The touch tables (Figure 6) can easily be switched between horizontal or vertical mode, depending on the purpose (group discussions or presentations).

3.3. Processware

The processware involves a series of interconnected workshops and the guidelines on how to organize these workshops. These are part of the REPAiR's PULLs (REPAiR, 2019a). A PULL workshop is a meeting in which stakeholders from the field of waste and resource management

Table 1. Steps and capabilities of the GDSE in Setup mode (only accessible for researchers) and Workshop mode (used by the stakeholders).

GDSE step	Setup mode (researcher)	Workshop mode (stakeholder)
Study area	Data entry Upload and choose relevant maps and charts Describe all stakeholders	Explore available maps and charts Get acquainted with the pool of stakeholders Get acquainted with the key flow-specific information
	Choose and describe waste key flows to be analyzed in further steps	
Status quo	Prepare and upload Material Flow data Prepare relevant visualizations	Explore MFA data using filters, maps and diagrams Explore flow related sustainability indicators based on the MFA data
	Define flow indicators Define challenges and objectives Choose relevant impacts and scope for the sustainability assessment	
Targets		Rank objectives
	Choose target year	
Strategy	Define solutions and how they affect flows	Choose solutions and their spatial implementation area as combined strategies Explore how the strategies affect flows Control if and how the targets have been achieved Weigh sustainability indicators
	Develop solutions	
Conclusions	Define which users (small groups) should be included into the evaluation of the conclusions	Read the generated summary of the whole geodesign process

Figure 6. Use of touch tables at GDSE workshop sessions in horizontal (left) or vertical mode (right). Photos: author Marcin Dąbrowski.

gather to discuss waste management issues related to the future use of an area or region. Stakeholders work together in small groups of 2 to 6 participants, with each group using the GDSE on a touch table in a co-design process of solutions that together make up CE strategies. PULL workshops typically follow the Charrette System's five-part format (Lennertz & Lutzenhiser, 2006):

(1) Pre-workshop survey + introduction and goals;
(2) Support information + GDSE demonstration;
(3) Division in small groups and (cross-group) touch table assignment using the GDSE;
(4) Presentation of results;
(5) Plenary session and discussion/post-workshop survey.

A REPAiR PULL features four types of workshops, which are categorized according to the first four phases of the REPAiR co-creation process in living labs: co-exploring, co-design, co-production, and co-decision (REPAiR, 2018a). The fifth phase, 'co-governance' does not involve PULL workshops.

3.3.1. Co-Exploration Workshop

This workshop takes place at the end of the co-exploration PULL phase and aims at:

(1) Developing a common understanding of the territory, including the mapping of wasted landscapes, or wastescapes (Amenta & van Timmeren, 2018), and stakeholders;
(2) Categorizing and defining the main CE challenges and objectives.

Table 2 shows the process leading to the workshop. The first two geodesign questions are addressed with the help of GIS and MFA. This involves mapping the region, defining the stakeholders and experts, and selecting and mapping key material flows.

The GDSE is used to show and interactively discuss the study area and its status quo (maps, charts, stakeholders and key flows), and thereby help to construct a common knowledge among local research teams and other participants of the PULL. Moreover, the GDSE supports groups of stakeholders to jointly define challenges and objectives as well as think about paths for developing eco-innovative strategies. Concretely, spatial and social analyses, as well as material flows and stocks are displayed and discussed using interactive maps and Sankey diagrams linked to these maps.

The process model relates to the dynamics of the system and is meant to represent the material flows within the chosen temporal and spatial scope. Therefore, the first task is identifying a key flow (e.g., organic waste, construction and demolition waste, electronic waste) for further investigation. The key flow is chosen during a collaborative process according to the criteria defined by the stakeholders. As explained in Section 2.1, MFA is typically used for detailed analyses of resource flows. The GDSE does not only incorporate a standard MFA method but also connects it with a geographical context. By introducing a new AS-MFA method (REPAiR, 2017) while geographically locating activities and actors involved in the resource flows, this enables further (iterative) identification of stakeholders and experts for potential strategies.

3.3.2. Co-Design Workshop

This workshop takes place at the end of the PULL phase co-design. Its main aims are:

(1) Identifying, mapping and visualizing key activities and actors in the value chains that should be included in the discussion and development of eco-innovative solutions;
(2) Identifying specific CE challenges in the study area;
(3) Identifying and mapping actor networks for each individual eco-innovative solutions development.

Table 3 shows how the GDSE supports this phase. Geodesign questions 3 and 4 are addressed with the help of GIS, LCA and MFA. This involves visualizing current ma-

Table 2. Addressing geodesign questions at PULL phase co-exploration.

LIVING LAB PHASE		GEODESIGN STEP	TECHNOLOGY AND ANALYSIS	AIMS AND RESULTS
1	**Co-Exploration**	**Representation Model** *How should the study area be described?*	GIS	Definition and mapping of Region—Focus, and Sample Areas
				Definition and mapping of Wastescapes
				Definition of stakeholders and experts
		Process Model *How does the study area operate?*	MFA & GIS	Selection of key resource flows
				Definition and mapping of material flows and waste management system

Table 3. Addressing geodesign questions at PULL phase co-design.

LIVING LAB PHASE		GEODESIGN STEP	TECHNOLOGY AND ANALYSIS	AIMS AND RESULTS
2	**Co-Design**	**Evaluation Model** *Is the current study area working well?*	GIS & LCA	Sustainability assessment of the status quo
				Assessment of the status quo's resource flow circularity
		Change Model *How might the study area be modified?*	MFA	Definition and common understanding of what constitutes an EIS
				Characteristics and effect of EIS on the process model

terial flows and actors (e.g., companies) in the area based on their commercial activity. The GDSE stores the developed solutions, their descriptions and also the selection of the potential actors involved.

The third geodesign question ("is the current study area working well?") refers to an assessment of the status quo or baseline scenario that allows for future comparisons with the proposed strategies (alternative future scenarios). The GDSE evaluates the status quo in terms of flow indicators based on the MFA data and a sustainability assessment. Flow indicators are first identified using existing literature (Zhang, Yang, & Yu, 2009) and then are selected through a collaborative process by the stakeholders during a co-design workshop. REPAiR defines an initial list of flow indicators, which includes flow amounts (for each material or their combination, e.g., vegetal waste vs. separate vegetables and fruits), flow structure (e.g., percentage of renewable material in each flow), flow intensity (e.g., amount of flow consumed/conducted per person), flow efficiency (relationship between economic factors and each material flow), and flow density (material consumption/conduction to sustain urban development) (REPAiR, 2019a). To undertake the sustainability assessment of the status quo for the study area, the REPAiR team has developed a framework for conducting a sustainability assessment on four impact categories (Taelman et al., 2018). This framework will be used to assess the impacts of developed eco-innovative strategies at later stages of the PULL.

3.3.3. Co-Production Workshop

This workshop takes place at the end of the PULL phase co-production and aims to attain:

(1) The ranking of objectives per decision-maker group;
(2) A set of flow targets the group wants to achieve;
(3) One strategy per small group and key flow.

Table 4 illustrates how GDSE addresses geodesign questions 4 and 5 with the help of GIS and MFA. The third phase aims to develop one eco-innovative strategy per small group and key flow to address the objectives previously defined in earlier workshops. Each small group will select several solutions, which will together make up their eco-innovative strategy.

Co-production workshops focus mainly on the development of eco-innovative strategies, expert knowledge on specific eco-innovative solutions that make up the strategies, and relative importance of sustainability indicators, which are based on the LCA methodology and which measure the various impacts of the strategies developed. Main outcomes of this workshop are ranked CE objectives, weights of the sustainability indicators, selected eco-innovative solutions and developed eco-innovative strategies. Multicriteria (MCA) methods support the comparisons of impacts of the strategies on sustainability.

3.3.4. Co-Decision Workshop

This workshop takes place at the end of the PULL phase co-decision and aims to reach a common understanding of:

(1) The differences and similarities between the ranked objectives per stakeholder small groups;
(2) The flow indicators that were used for setting targets for specific objectives;
(3) The differences and similarities between the strategies implemented in terms of the related solutions, across stakeholder groups, and locations of EIS implementations;
(4) How the specific processes in the value chain of the key flows contribute to the different impacts, in particular to the extent to which the developed strategies modify the key flows and meet the various target sets;
(5) Potential sustainability assessments of the strategies developed by individual small groups;
(6) Agreements and disagreements (i.e. consensus level) on objectives, targets, related strategies and where the selected EIS have been implemented for all key flows.

Table 4. Addressing geodesign questions at the PULL phase of co-production.

LIVING LAB PHASE	GEODESIGN STEP	TECHNOLOGY AND ANALYSIS	AIMS AND RESULTS
3 Co-Production	**Change Model** *How might the study area be modified?*	GIS & MCA	EIS and Eco-Innovative stategies Expert meetings on EIS
	Decision Model *How should the study area be changed?*	MCA	Relating EIS to objectives
			Ranking of objectives
			Pairwise comparison of the relative importance of sustainability indicators
			Defining the targets

Table 5 shows how the GDSE supports the co-decision phase. The last two geodesign questions are addressed with the help of LCA, and flow assessment calculations. The main outcomes are a concrete plan with detailed implementation actions for each eco-innovative strategy, a list of actors and stakeholders to collaborate in the implementation of each specific strategy, a timeline for actual implementation of each strategy and the corresponding EIS.

The assessment of proposed strategies is done using two methodologies: LCA and the assessment of flow changes. While the flow changes are assessed in real time during the workshop, the LCA is performed after the workshop by LCA practitioners. This is due to the complexity of the LCA as well as the current lack of software interoperability.

Assessing flow changes is done by comparing the status quo flow indicator set during the co-design phase with the anticipated changes introduced by the strategies in the co-production phase. Once a combination of solutions and their implementation areas are chosen by the workshop participants, a flow calculation algorithm redistributes the flows in between the economic activities, keeping the overall mass balance of the affected flows consistent. The algorithm hypothetically distributes the total surplus or shortfalls within an economic activity in between all the actors present in a chosen geographical area of implementation. That way, the flow changes are reflected in the chosen indicators and their values can be compared with the targets that were set up in the co-production phase.

At the time of writing this article, some modules of the GDSE are not yet fully operational. However, the GDSE has already been used in the workshops described in this article, which have been held in parallel to the GDSE development process. The GDSE is designed with help of intended end-users, in line with the living lab approach, in which end-users test and provide constant feedback on the support tools. This is also in line with the recommendations of Uran and Janssen (2003) that SDSS should be developed to serve their intended purpose instead of those of the study team. The next section presents the application of the GDSE methodology to an Amsterdam case study.

3.4. The Amsterdam Peri-Urban Living Lab

The GDSE methodology is tested and applied as part of the ongoing living lab of the AMA, which encompasses the city of Amsterdam, the provinces North Holland and Flevoland. This is comprised of 32 municipalities, and a total population of over 2.4 million inhabitants. With an area of 539 km^2, the AMA focus area (Figure 7) is located in the peri-urban areas in the west and south west of the AMA and constitutes a pilot case study of REPAiR.

Yearly household waste data was gathered for the AMA. The datasets came from the CBS, Statistics Netherlands. Waste data for companies was retrieved via the Dutch register for electronic waste notifications and communication of the National Contact Point for Waste (Dutch acronym: LMA), which describes the supply, composition and processing of company/industrial waste in the Netherlands. Both datasets describe waste flows for the year 2016. This data is entered by the collectors and managed by the government and contains information on the type of waste (Eural code), waste generator (e.g., name and location of the company), and waste collector (name and location of waste treatment), and the type of waste treatment.

4. Using a GDSE for Co-Developing Eco-Innovative CE Strategies in Amsterdam

The first four phases of the PULL process in the AMA involved four types of workshops, namely co-exploration, co-design, co-production, and co-decision (REPAiR, 2018a). At the time of writing this article, the GDSE had been used at the first three phases of the ongoing PULL process in the AMA. Three PULL workshops have thus been organized with local governments and

Table 5. Addressing geodesign questions at the PULL phase co-decision.

LIVING LAB PHASE	GEODESIGN STEP	TECHNOLOGY AND ANALYSIS	AIMS AND RESULTS
4 Co-Decision	**Impact Model** *What differences might the change cause?*	LCA, Flow assessment calculation	Sustainability and flow assessment of Eco-Innovative Strategies
			Aggregation of sustainability indicators according to given weights into impact categories
	Decision Model *How should the study area be changed?*		Designing rules of system
			Establishing and documenting the agreements and conflicts between differente interests and groups of decision makes
			Triggering future local development and supporting decision-making processes

Figure 7. Location of the AMA and its focus area.

policy makers, local business representatives, international partners of the REPAiR project consortium, and the PULL hosting team. This section presents results from these workshops.

4.1. Results: Co-Exploration

The workshop aimed to define key waste and resource management challenges in the study area by the means of:

(1) Verifying challenges already identified in previous interviews with stakeholders and literature review;
(2) Adding new challenges if required or needed;
(3) Developing challenges to a detailed level along with suggested solution paths.

The first step was to share with the participants relevant information on the AMA, which was collected, categorized and uploaded to the GDSE by the PULL team using the GDSE setup mode. Then the stakeholders were required to discuss and modify (i.e., validate, correct, remove, complement) all the information where deemed necessary. This information included (1) maps of the focus area (topographic and related to resource and waste management), (2) relevant charts with the first list of circularity challenges of the area, and (3) the first list of main stakeholders of the PULL process. "Challenge trees" were used as the main materials to present CE challenges in the AMA to stakeholders both in an A3 article format and digitally in the GDSE. Each branch on a challenge tree (Figure 8, right panel) represents one main challenge for the AMA, and each sub-branch represents specific challenges for a particular main challenge branch. Above each challenge branch, there are two fringes, each containing a question for the participants. The questions were: "what if we do this? (where and who should be involved?)" and "what should be assessed?". Participants were asked to provide feedback on each challenge tree by suggesting modifications and inserting sticky notes for each fringe. The results were directly fed into the GDSE (Figure 8). The main workshop outcomes included a categorized list of CE AMA challenges along with possible solution paths.

4.2. Results: Co-Design

The main objective of this workshop was to develop initial sketches of eco-innovative solutions towards CE in the AMA, based on the CE objectives identified in a previous workshop. The specific workshop aims were to:

(1) Verify and rank the identified objectives with the selected stakeholders;
(2) Develop initial sketches for how to meet the objectives, developing preliminary sets of EIS that follow a common GDSE-friendly template.

The output from the previous co-exploration workshop (CE challenges) was used as input for this workshop. "Solution sheets" were used as main materials to communicate eco-innovative solutions to participants, and to describe solutions using a common template. A solution sheet (Figure 9) was an A3-formatted sheet that contained specific information about a solution. A sheet contained three panels, namely solution card (containing main characteristics, category and description), CE dia-

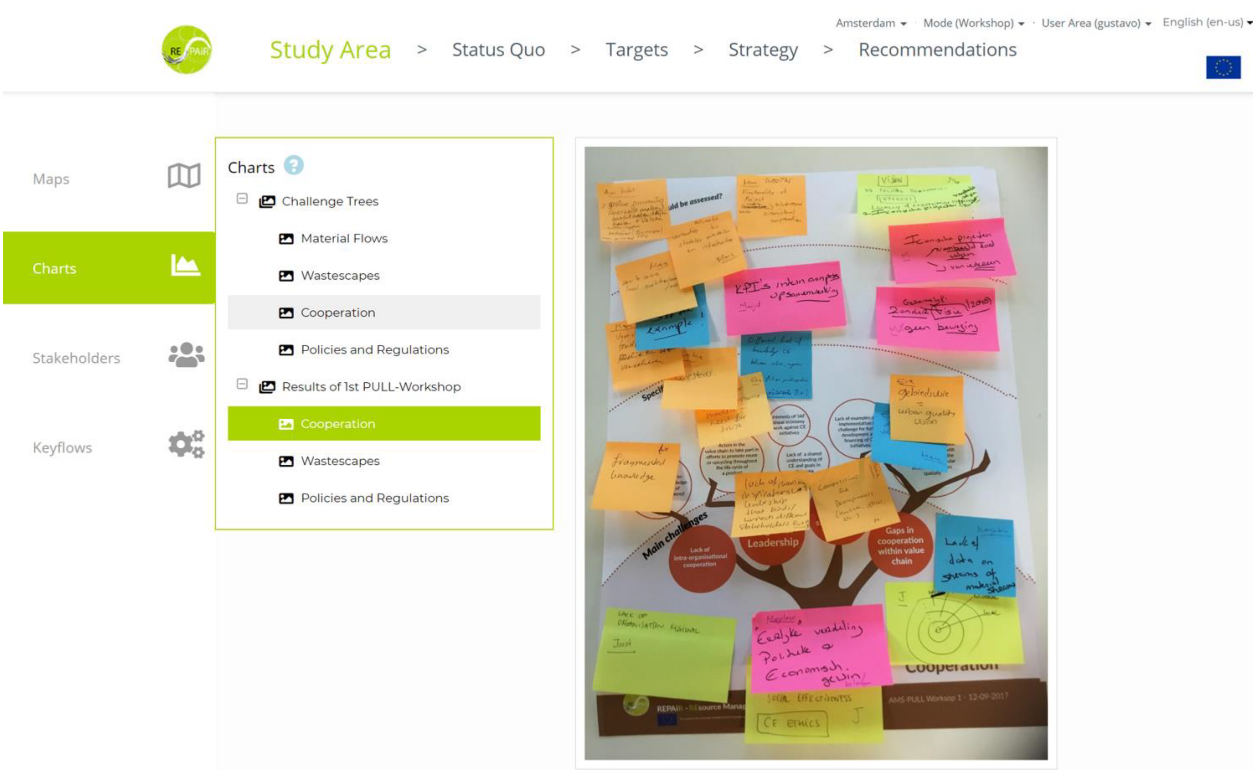

Figure 8. The use of the GDSE helped stakeholders describe the focus area based on particular topics. The CE challenges in the AMA were overlaid with feedback from participants of the co-exploration workshop, were then are uploaded to the GDSE.

gram of the solution, system diagram with activities and flows in the solutions. Participants were asked to review, complete the sheet and suggest how to modify the solution (Figure 9). The main workshop outcome was a catalogue of solutions that addressed the ranked CE objectives in the AMA. The solutions in this catalogue were digitized and directly fed into the GDSE to make the solutions available for ensuing PULL workshops.

4.3. Results: Co-Design/Co-Production

The third PULL workshop was the most recent and was categorized as part of both the co-design and co-production phase. It aimed at further developing the solutions discussed in the previous workshop. The workshop included three parallel sessions, each focusing on one key flow category: food waste, wastescapes, and construction and demolition waste. A GDSE-enabled touch table was available for each session (Figure 10). The GDSE was used to provide support information on flows, solutions, activities, and actors. The participants were asked to work on one session table at a time and to select solutions for further development. Specific main goals of the workshop were to:

(1) Co-develop EIS, following a GDSE-friendly template, based on an EIS initial set;
(2) Match EIS with CE objectives.

New solution sheets were used as materials. The GDSE was used as main software tool on three touch tables to help users retrieve information concerning the solutions they were discussing and working on.

Stakeholders used the GDSE to analyze possible actors and existing waste streams related to the eco-innovative solutions they worked on. Figures 11 and 12 illustrate how the stakeholders used the GDSE to map actors relevant to a food waste EIS, and to visualize waste streams connected to this EIS.

The main outcome of this workshop was the updated EIS catalogue for the AMA. Through a research by design approach, together with local stakeholders, young designers and students of industrial ecology, architecture, urbanism, and with the help of the GDSE, 27 eco-innovative solutions were developed on the basis of aspects, such as relevance for practice, possible areas for further EIS implementation, actors to be involved, business model to implement, and potential policy changes. Figure 13 shows an example of one eco-innovative solution: mycelium blocks for wastescapes modelled in the GDSE. The CE diagrams are displayed for this solution: at the current linear state (on the left) and a new proposed, more circular, value chain (on the right). Actors involved in this solution can also be retrieved in an interactive map. The EIS catalogue has been uploaded to the GDSE and will be used by participants of subsequent co-production and co-design workshops to support the process of combining EIS into strategies.

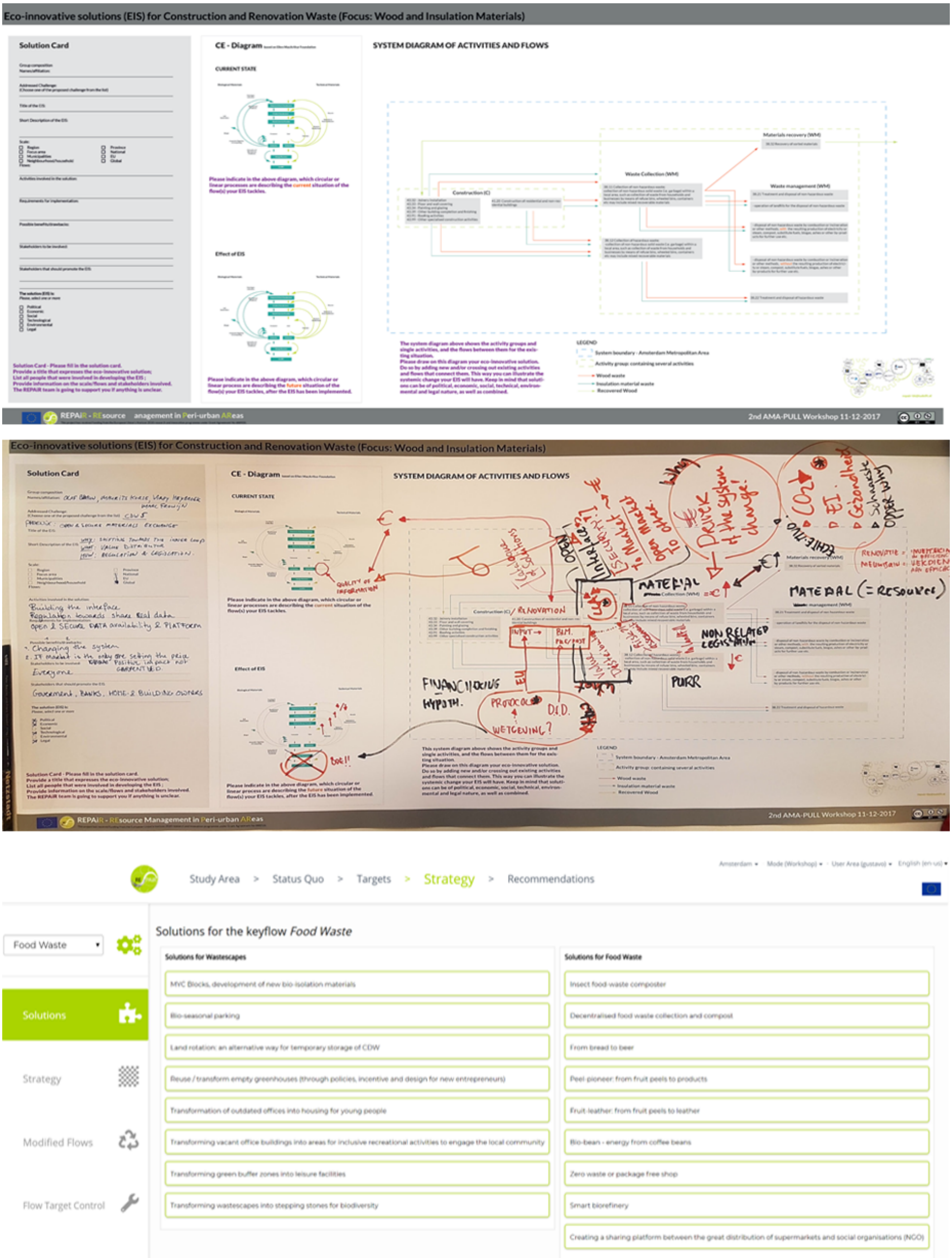

Figure 9. Eco-innovative solution sheet, showing three parts: the solution card, the CE diagram, and the system diagram (top). The same solution was completed with additional feedback from stakeholders (middle). On the bottom, the solution plus feedback was uploaded to the GDSE.

Figure 10. The GDSE runs on three touch tables (outlines are highlighted in light blue), with each one supporting the work of one of the three small groups of participants. Photo: author Marcin Dąbrowski.

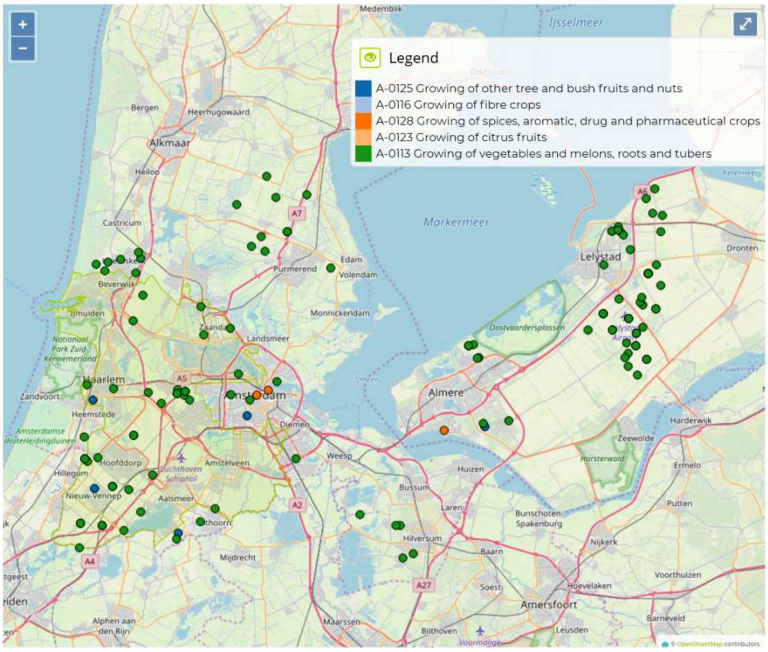

Figure 11. Workshop participants used the GDSE to visualize locations of potential actors involved in growing vegetables and fruits in the focus area that can be involved in the EIS based on the selection of activities made by the participants.

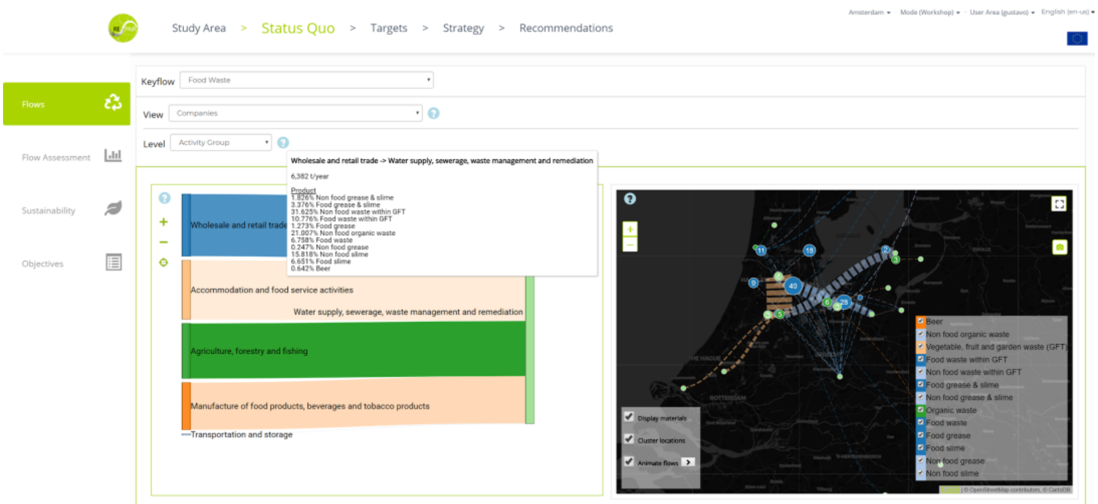

Figure 12. Stakeholders used the GDSE to explore the area's status quo by visualizing flows per activity group as seen in the Sankey diagram (left) and as a flow map (right) of existing related food waste streams (grouped by materials) deemed relevant by the stakeholder during the workshop. Both visualizations are linked, i.e., each Sankey flow correspond to one or more flows on the map. Material flow composition is shown on each Sankey flow (left) and on color-coded on the map (right).

Figure 13. The solution "mycelium blocks" for building bio-isolation materials as modelled in the GDSE.

4.4. Effectiveness of PULL workshops

Surveys were conducted before and after the workshops. Pre-workshop surveys contained questions about the participants' workshop expectations, general expertise and interest in eco-innovative solutions. The surveys were completed by an average of 19 workshop participants, whose backgrounds included human geography, urban design, architecture, and MSc students in Architecture, Industrial Ecology and Urbanism. They rated their own expertise/interest in EIS as 6.4 on a 1–10 scale. Post-workshop surveys contained questions on their experience and specific aspects of workshop effectiveness (Table 6). In general, participants gave good ratings to all workshops, and in particular, the third workshop had the highest rating for average effectiveness and for specific workshop features.

The next steps for the PULL in the AMA will involve further operational EIS development that resulted from this workshop towards more detailed solutions that can be represented, assessed and compared iteratively in the GDSE. Dedicated PULL meetings will be held separately for each material flow investigated, and will host smaller groups of stakeholders who are experts in the different material flows in order to further detail the EIS in the GDSE. Stakeholders will be asked to jointly define, and interactively modify strategies for specific key flows by combining one or more implementations of solutions (Figure 14). The GDSE will provide real-time feedback on the impacts of strategies on flow changes and sustainability indicators (Figures 15 and 16).

5. Conclusions

To address the question of whether and how geodesign can be used to improve waste and resource management, this article proposes a geodesign-based tool for supporting a collaborative process of developing eco-innovative strategies to advance CE in peri-urban areas. Geodesign can provide a helpful framework for improving waste and resource management, which is evident by the observations and outcomes of the PULL workshops, and the positive reactions of the participants in the surveys. In fact, geodesign allows for a structured and comprehensive organization of the process and diagnosis of challenges, design and selection of solutions, and

Table 6. PULL workshop ratings. Values in bold denote maximum. Underlined values denote minimum.

Feature	Workshop 1	Workshop 2	Workshop 3
Content	7.89	7.79	**8.18**
Design	**8.22**	7.58	7.68
GDSE and support aids	7.56	7.32	**7.84**
Facilitation and pace	8.11	7.89	**8.34**
Personal goals	7.13	**7.89**	7.53
Results attained	**8.00**	7.74	7.84
Average effectiveness	7.82	7.70	**7.88**

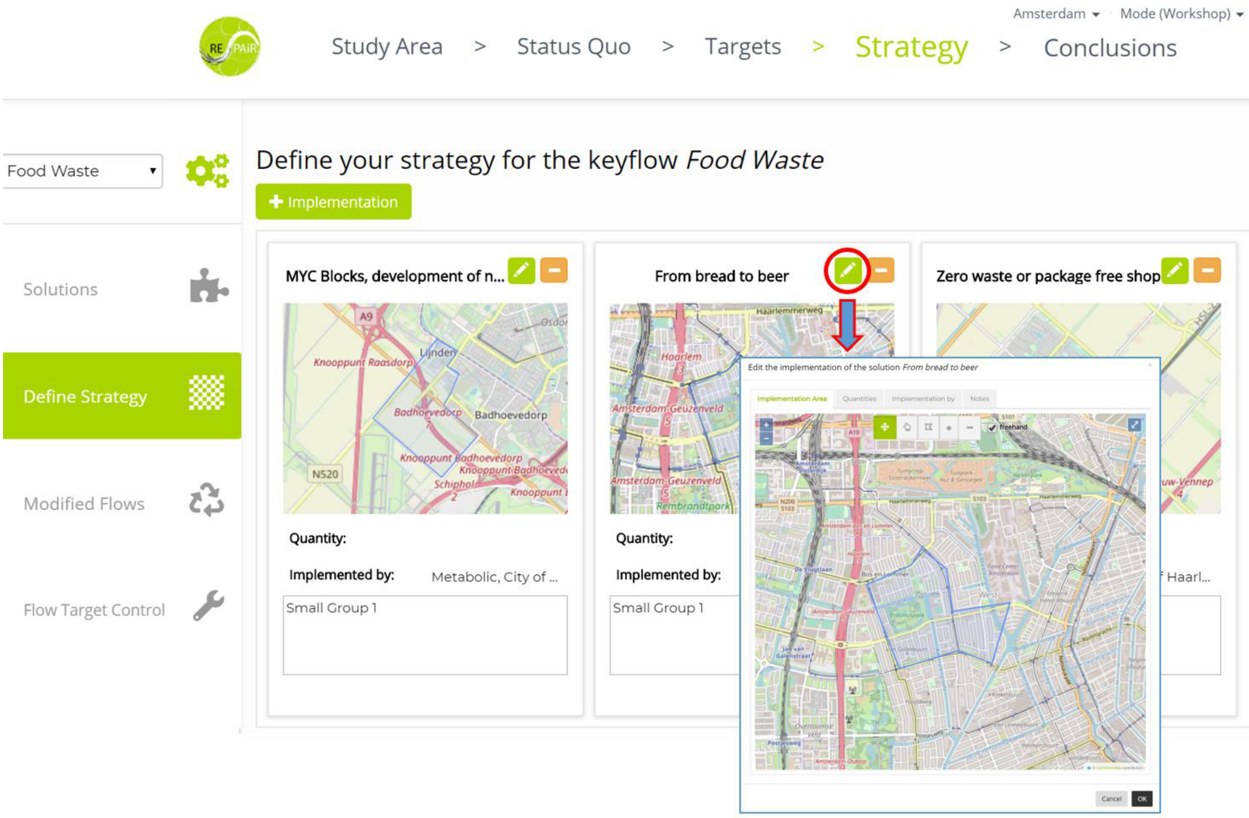

Figure 14. GDSE screenshot showing a strategy for key flow "food waste", which is composed of three solutions, each with their own area of application and list of actors implementing them. Any solution in the strategy can be edited in a separate pop-up window (e.g., EIS "from bread to beer" in the strategy shown here).

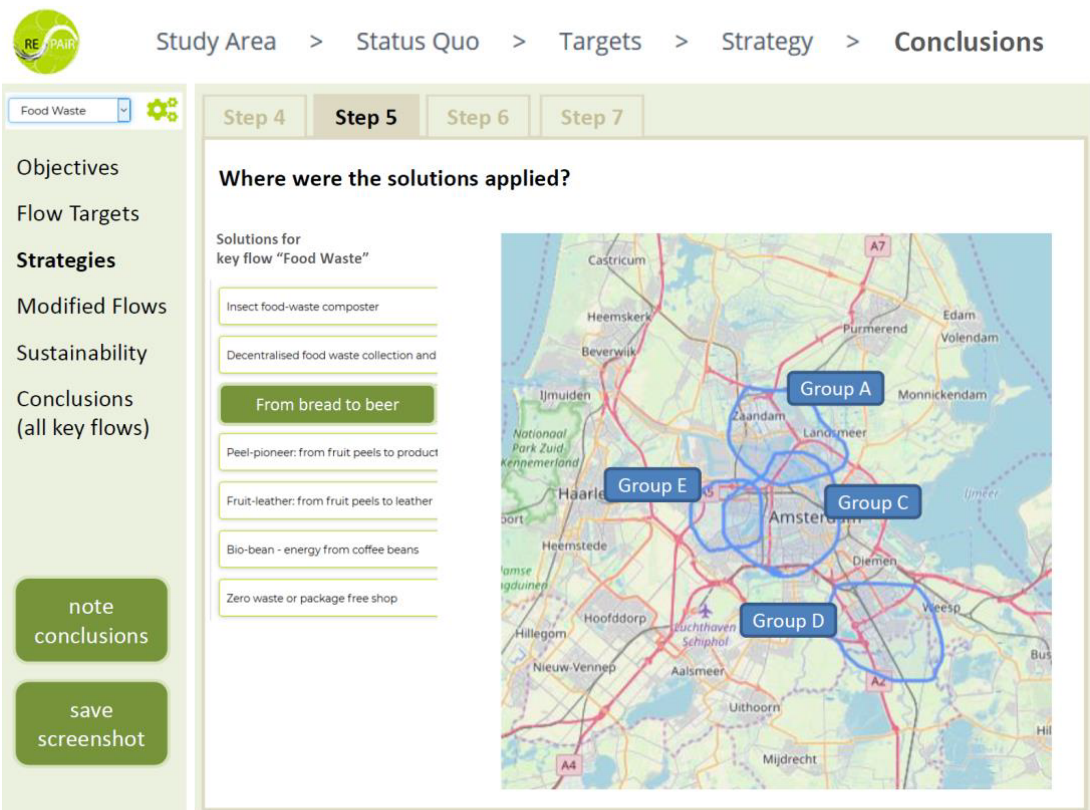

Figure 15. GDSE showing locations of implementations of EIS "from bread to beer", as drawn by the small groups A, C, D, and E.

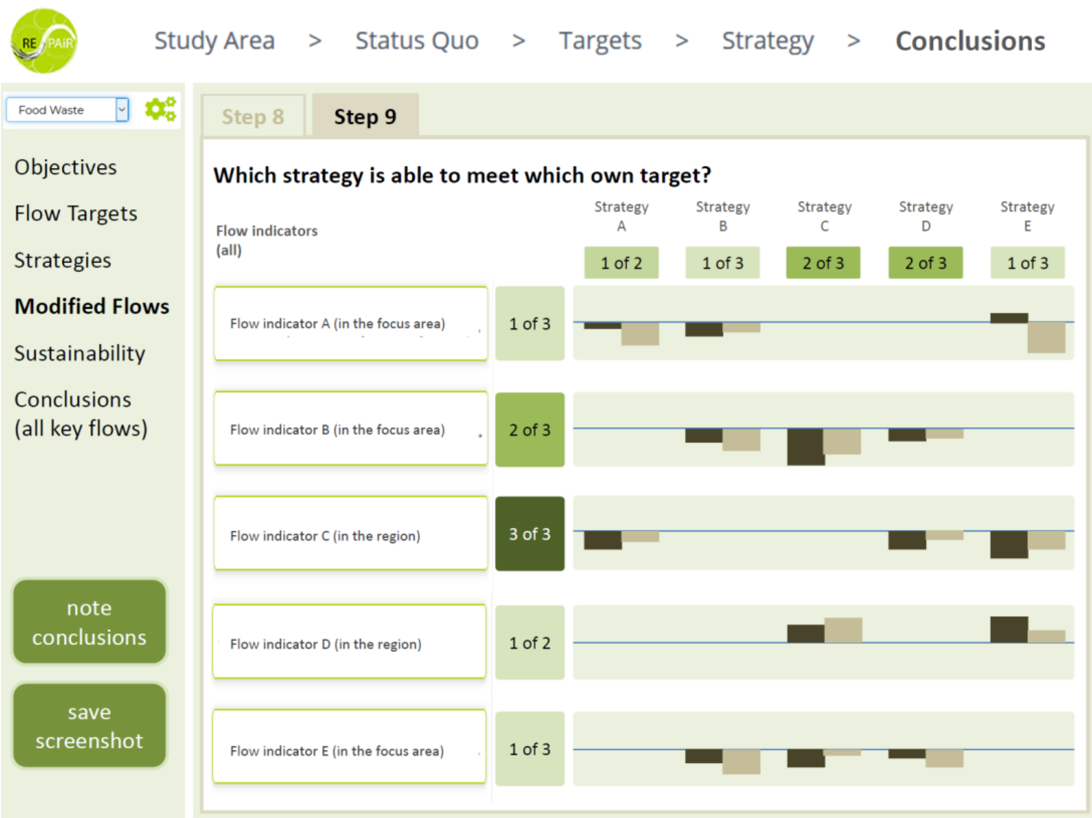

Figure 16. The GDSE comparing impacts of strategies (A, B, C, D, E) in terms of flow assessment targets. A green color ramp is used to indicate the fraction of targets met, where dark green indicates a big fraction and light green for a small fraction.

decision-making on strategies for a given territory with close stakeholder involvement. In addition, the GDSE integrates spatial data on material flows and related actors, which are presented in a visual and accessible way and ensures a sound and accessible evidence base in the participatory process.

In order to address several limitations of geodesign, the GDSE integrates human creativity into a digital interface with complex spatial and metabolic analysis methods in the participatory context of living labs. This allows for informed coordination of waste management activities in space and evidence-based co-design of innovative and spatial solutions with stakeholders. This integration anchors the geodesign process in ongoing experimentations in study areas and enables a continuous engagement of stakeholders in the analysis, building on relatively simple visualization of complex data on material flows in space, and in the co-design of innovative circular solutions. Geodesign thinking enables the process of adding a spatial dimension to typically non-spatial analysis methods (e.g., MFA). Moreover, as the stakeholders argued, the GDSE's key advantage is the ability to make the exploration, design and decision-making process transparent to the participants.

Naturally, there are limitations to the GDSE approach. Firstly, even though the potential of the GDSE to support participatory development of spatial waste and resource management strategies has been demonstrated and validated by the stakeholders involved, the tool is still work in progress. The strategies developed so far with the GDSE have not yet been taken up and implemented by the Amsterdam region stakeholders.

Secondly, the GDSE's capacity to assist in the analysis phase and spatial visualization of material flows depends on the availability of data. Likewise, the quality of data is a critical concern for the GDSE's ability to model the impacts of the strategies co-created with stakeholders. While a robust dataset on material flows was available in the Amsterdam pilot case study, considerable efforts were needed to collect and feed the data into the GDSE and the availability of such data cannot be taken for granted in all regional contexts.

Thirdly, given the complexity and uncertainty involved in enacting CE strategies, a successful GDSE application in the living labs critically depends on the ability to attract and retain the engagement of not only key territorial stakeholders along the entire value chain, but also experts with specific technical knowledge on both the processes and technologies envisaged in the co-designed strategies. Considering the busy agendas of some stakeholders, this proves challenging in practice, as they need to commit and allocate precious time to repeated interactions in the living lab over several months, which cannot be taken for granted. Thus, future GDSE applications require developing robust procedures for identifying the most relevant and knowledgeable stakeholders and keeping them involved in the process. Successful implementations in living lab workshop requires the involvement of an experienced moderator.

Fourth, while the GDSE allows for the estimation of the impacts of strategies co-designed in the living lab, there is a considerable amount of uncertainty about their actual real-life effects. This highlights the need for monitoring the outcomes of the decision-making process facilitated by the GDSE and the implementation of the strategies developed. Integrating monitoring measures within the proposed approach would allow for validation and the creation of a scope for an iterative learning process among the stakeholders. Overcoming these limitations will require further development and testing of the tool as well as scrutiny of the implementation of the strategies developed using the GDSE in a longer temporal perspective.

To conclude, the GDSE-urban-living-lab combination provides a relational space including stakeholders in a structured process in a specific location, spanning over a longer time period, allowing for a more sustained process of co-exploration of the status quo, co-creation of knowledge, and co-production of solutions and strategies. This long-term iterative engagement between stakeholders not only empowers them but also enables a more in-depth analysis for a better integration of various strands of knowledge, while building on inputs from research at each iteration. An open source GDSE facilitates the implementation of innovation in a living lab. The GDSE is developed in cooperation with end-users, which facilitates not only continuous tailoring of the tool based on end-user feedback, but also a smoother adaptation of this open source tool to other case studies, or in a different living lab setting. Future work will focus on a comparative analysis of GDSE applications in different regional settings.

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Conflict of Interests

The authors declare no conflict of interests.

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Article

Transferring Circular Economy Solutions across Differentiated Territories: Understanding and Overcoming the Barriers for Knowledge Transfer

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Abstract
"Learning from abroad" is a widely recognised and used means to innovate and improve strategies and policies implemented by regions and cities. However, literature on knowledge transfer and related concepts, such as policy transfer, policy mobility or lesson-drawing, highlights the limitations of this process, especially when it entails the simple transfer of (best) practices from "place A" to "place B". Such a transfer may lead to suboptimal solutions particularly when the imported practices concern complex phenomena, involving networks of multiple actors and relying on place-specific dynamics. Departing from this critique, the article sheds light on the process of knowledge transfer in the field of circular economy, taking place between the two metropolitan regions of Amsterdam and Naples. This process is guided by an innovative methodology based on a network of (peri-urban) living labs generating eco-innovative solutions for using material waste and wastescapes as a resource in peri-urban areas. Using participant observation in knowledge transfer workshops, stakeholder interviews and surveys, it investigates how the process of co-creation of knowledge in the relational space of the networked living labs takes place thanks to the participation of stakeholders from both regions. This in turn allows for drawing conclusions on what barriers are encountered in such knowledge transfer, what makes solutions transferable across different contexts, and, finally, how the solutions are adapted as they travel from one place to another.

Keywords
Amsterdam; circular economy; eco-innovative solutions; knowledge transfer; living labs; Naples; policy mobility; policy transfer; policy translation

Issue
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1. Introduction

Transfer of knowledge, policies or "best practices" from different territories aimed at addressing policy challenges, has become a standard feature of contemporary policy-making. Urban planners and decision-makers seeking solutions to local problems abroad and striving to learn from foreign experiences to improve domestic policies is widespread (Healey & Upton, 2010), even if this process is riddled with uncertainty regarding the fit of a foreign solution in the recipient context (Dolowitz & Marsh, 2000). In fact, despite the differences between the "sender" and "recipient" contexts, foreign experience can provide a useful source of inspiration, cautionary tales, ideas, understanding or concrete measures, which can enrich the spectrum of possibilities and the knowledge pool available to decision-makers.

Knowledge transfer from abroad is particularly relevant in the case of new kinds of policies and solutions, where there may be little "home-grown" experience, as is the case with eco-innovative strategies and solutions for promoting a circular economy. A circular economy can be defined as a "regenerative system in which resource input and waste emission and energy leakage are minimised by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling" (Geissdoerfer, Savaget, Bocken, & Hultink, 2017, p. 759).

This concept is taken up in a growing number of policies and strategies of national, regional and local governments; however, it is far from being a mature policy field. Moreover, there is little experience and knowledge of its implementation in spatial strategies. There is, therefore, a strong interest among policy-makers and planners in learning from international experiences in this field, while there has been no research to date on the transfer of knowledge in this emerging policy field across differentiated territorial contexts.

Knowledge transfer, however, is a process riddled with uncertainty and difficulties. As highlighted in the literature on inter-organisational knowledge transfer (e.g., Argote & Fahrenkopf, 2016), and the bodies of theory and knowledge on the related concepts of policy transfer (e.g., Dolowitz & Marsh, 2000), policy translation (e.g., Stone, 2012), or learning from best practice (e.g., Stead, 2012), transferring policy solutions from abroad can lead to policy failure at home. Therefore, from the practice perspective, there is a need for careful consideration of the context in which the original solutions emerge and of how they can be adapted to the recipient context. There is, however, a research gap concerning: (1) the transferability of solutions between contexts, and (2) the understanding of how solutions are adapted and morphed as they are grafted from one place to another.

Against this background, the article strives to address the above gaps and answer following three research questions: (1) What are the barriers for transfer of circular economy solutions across different regions? (2) What makes solutions transferable between differentiated regional contexts? (3) How do solutions change and adapt in the process of transfer?

To address these questions, the article draws on novel empirical material from the knowledge transfer process on spatial solutions for promoting circular economy between two contrasted European metropolitan regions (Amsterdam Metropolitan Area [AMA] and the Naples Metropolitan Area), experimenting with eco-innovative solutions (EIS) for circular resources management. The process is unique insofar as it takes place within a network of six living labs (Steen & van Bueren, 2017), bringing together stakeholders to co-explore circularity challenges and co-create spatial solutions to promote circular economy in a real-world context. Living labs are "user-centred, open innovation ecosystems based on a systematic user co-creation approach in public–private–people partnerships, integrating research and innovation processes in real-life communities and settings" (ENoLL, 2019). In the case of this research, the living labs located in different urban regions also provide a "networked laboratory" for studying and promoting knowledge transfer. The empirical material on which this article builds, collected through participant observation within living lab workshops, interviews and surveys with the living labs participants, offers unique insight into this topic.

The remainder of the article is organised as follows: Section 2 offers a review and critique of knowledge transfer and related concepts. Then, on that basis, the methodology for the article is outlined in Section 3. This is followed by the empirical section unpacking the knowledge transfer process between the regions of Amsterdam and Naples in Section 4. Finally, the concluding Section 5 summarises and discusses the findings, draws lessons for practice and outlines avenues for further investigation.

2. Knowledge Transfer: How to Make It Work?

Knowledge transfer is a term which originated in organisation studies, where it was used to study how knowledge 'travels' between firms and contributes to innovation processes. According to Argote and Ingram (2000, p. 151): "Knowledge transfer in organisations is the process through which one unit (e.g., group, department, or division) is affected by the experience of another". Knowledge transfer is conditioned by structural network features like the strength of the ties between the actors and their stability, but also cognitive characteristics like shared goals or trust between them (Inkpen & Tsang, 2005). It is collaboration, open communication, and trust between the actors involved that support effective knowledge transfer. As such, partnering between organisations is a means to achieve this (Bellini, Aarseth, & Hosseini, 2016). However, there remains a major gap in the literature on knowledge transfer insofar as it struggles to explain how organisations identify what is relevant and suitable to transfer (Argote & Fahrenkopf, 2016). Moreover, it is worth stressing that knowledge transfer across differentiated contexts "implies the transformation of both the target context and knowledge content…through processes of translation, negotiation and bargaining among actors" (Yakhlef, 2007, p. 44). Thus, knowledge content is modified as it 'travels'. In this study, the emphasis is thus on understanding how EISs for a circular economy are adapted to the recipient context in the process of transfer.

The concept of 'policy transfer' (Dolowitz & Marsh, 2000), related to knowledge transfer, also informs this study. Policy transfer explores "how policies, administrative arrangements, institutions and ideas in one political setting (past or present) are used in the development of policies, administrative arrangements, institutions and ideas in another political setting" (Dolowitz & Marsh, 2000, p. 5). Transfer, however, may lead to policy failure when it is done without adaptation to recipient context or there is a lack of structural conditions, knowledge or resources to make it work. In a similar vein, Evans (2009) was also interested in what could make policy transfer unsuccessful and conceptualised the potential obstacles for this process, distinguishing cognitive barriers (related to, e.g., a shallow understanding of the practice transferred), environmental barriers (related to the process of transfer, e.g., lack of platforms for transfer) and public opinion barriers (opposing transfer). In this study, specific barriers for transfer of solutions for a circular economy are explored.

The policy transfer literature, while being extremely influential, has been criticised for disregarding how practices and norms are changed and adapted to the local context during the adoption process (Stone, 2012), as well as the question of what is actually transferred and why (Howlett & Rayner, 2008). Beyond this research gap, there is also little recognition of the problems associated with the circulation of best practice without due consideration of its suitability for the recipient context. In fact, lack of knowledge on how such best practice emerged, what other options that were pondered, which process that lead to this and its possible failures or u-turns creates a risk of misinformed transfer and ultimately failure of the adopted solutions (Stead, 2012). Some policies are so deeply embedded in the peculiar national legal, political, or social systems that they are simply not transferable (Stone, 2012).

This led to a growing interest in 'policy translation' (see Stone, 2012), as opposed to transfer as a simple linear copy-paste process from 'place A' to 'place B'. Thus, in the process of translation of a foreign practice to the local 'language', hybridisation and learning processes take place, which in turn can lead to the emergence of new policy meanings and a significant departure from the original imported policy. This can have the merit of resulting in "a more coherent transfer of ideas, policies and practices" (Stone, 2012, p. 488). In parallel, geographers have been exploring the process of 'policy mobility', which is concerned with the linking global circuits of policy knowledge to local policy practice, politics, and actors and exploring what happens along the way as the policies are transferred from place to place (e.g., McCann, 2011). The emphasis here is on policy mobility networks, while recognising the importance of spatial nodes in which these networks are anchored.

Building on the notion of policy translation, this study focuses on exploring how EIS for achieving circularity are translated to best fit into the recipient context (see Stone, 2012). It also explores how the process of transfer is moored in a set of networked living labs providing a platform for collaboration between stakeholders from different territories (see Bellini et al., 2016) and establishing socio-spatial nodes where transfer takes place, solutions emerge, hybridise and morph as they 'travel'. The latter endeavour is loosely inspired by policy mobility literature (e.g., Peck, 2011; Temenos & McCann, 2013), borrowing the notion of international networks being moored in space and applying it describe the network of the living labs as part of the REPAIR project, in which the knowledge transfer activities unfolded, albeit without deeply engaging with this strand of the literature.[1]

3. Methodology: Living Labs as a Knowledge Transfer Platform

The use of living labs for user-centric innovative planning processes (see van Geenhuizen, 2018) began in Europe circa 2000 (see, e.g., Lepik, Krigul, & Terk, 2010; REPAiR, 2017). The concept has since then been widely applied to foster urban experimentation across Europe and the world (Steen & van Bueren, 2017), providing a methodology for fostering open innovation and knowledge co-creation (Lepik et al., 2010). Living labs bring users/consumers/citizens into the system of innovation, thereby leveraging on a larger mass of ideas, knowledge and experiences (Eriksson, Niitamo, Kulkki, & Hribernik, 2006, p. 1). In the Horizon 2020 REPAiR project, on which this article builds, Peri-Urban Living Labs (PULLs) were set up across six European regions[2] to engage stakeholders in co-creation of circular economy solutions for these regions. The stakeholders in each of the regions were selected by the project consortium partners based on the waste management topics and material flows investigated in the given case. Thus, stakeholders included a range of experts dealing with the said topics and flows from for-profit, non-profit, university sectors were identified by the researchers running each living lab and were invited to the workshops. The participation activities of stakeholders varied across workshops and case study regions, albeit within the framework of the predefined methodologies for the living labs and for knowledge transfer events within them. Some of the stakeholders were involved in all of the workshops, while the participation of others was less regular. Experts from other case study regions also take part both in the early phase of each PULL process and later in so-called 'knowledge transfer events'. The role of these foreign stakeholders is crucial because during the early phase of co-creation process they can work in their own experience and ideas

[1] Policy mobilities literature typically takes a critical stance on these processes, pointing to contested questions regarding the interest and agendas of the actors involved in policy mobility, whereas the researchers conducting this study were directly involved in the transfer process as part of a major research consortium, seeking to explore how to make the transfer of solutions across the participating regions more strategic and purposeful.

[2] For the REPAiR project, six peri-urban areas have been chosen in order to allow a comparison of (three) different urban scales with similar (e.g., in recycling rate) and different challenges (e.g., dominancy of organic versus C&D waste flows). In every phase of the project—including the PULLs' organisation and the knowledge transfer events—a two-step approach has been applied. After the test of tasks in the work packages in the two (similar) pilot regions (AMA and the Naples Metropolitan Area) tasks were conducted in the follow-up regions (Ghent, Łódź, Hamburg and Pécs). In this article, however, we are focusing only on the knowledge transfer between the two pilot regions. For more on REPAIR methodology see: http://h2020repair.eu/about-repair/project-methodology

from their region into the discussion. They also play a vital role in the said knowledge transfer events. Besides explaining the EIS (EC, 2011, 2012) from their regions to be transferred, the 'sender stakeholder' can explain the socio-cultural, geographical, historical background of the region in which the EIS emerged. Moreover, the discussion on adaptations to the EIS required for its transfer can result in important feedback and lessons on how to further improve the original solution. Therefore, the PULLs network offers fertile soil for knowledge transfer because such labs are widely recognised as successful instruments for accelerating innovation in a real-world context, co-creating and improving innovative ideas for different case study areas (REPAiR, 2017). Furthermore, PULLs support effective knowledge transfer as they provide a platform for partnering between stakeholders from different regions (cf. Bellini et al., 2016).

By allowing for appreciation of both the sender and recipient contexts, this method responds to the call for more culturally and socially-constructed perspectives on learning across national boundaries (Dolowitz & Marsh, 2012; McCann & Ward, 2012), while spatialising the process of knowledge transfer by connecting it to PULLs' effort to design solutions for given territories. Thus, knowledge transfer via PULLs is moored to specific spatial nodes in the six peri-urban regions. It is in those nodes that solutions and implementation strategies are generated and transferred across cases (Figure 1), with translation to fit another context taking place (cf. Stone, 2012).

During the knowledge transfer events, a discussion was facilitated by moderators from both the sender and recipient regions and structured around a prepared template sheet outlining the eco-innovative solution to be transferred (see Figure 2) and its key constituent elements (e.g., waste flow, location, stakeholders involved, etc.). Thanks to the sheet—to be filled within the PULL workshops—and explanations provided by the sender region participants, the recipient region participants gained insight into the transferred solution and the context in which it emerged. Participants were asked to discuss and summarise, in written form, answers to questions to explore the scope and possibilities for transferring a given solution. The recipient region stakeholders were thus asked about the transferability of the EIS in general, the best locations for implementing the EIS, the barriers for transfer (based on their preliminary experiences and knowledge about the milieu of the recipient region), the adaptations needed and the local actors who should be involved in the implementation (Figure 2).

Data for this study was collected through participatory observation (participatory rapid assessment; cf. Russel, 2006) of the operation of the PULLs and knowledge transfer events. Instead of recording voice or audio, which would be difficult to analyse due to multiple languages (e.g., local language and English) being used at knowledge transfer events across the different PULLs, we relied on the descriptive recording of observations "under natural conditions" (Kumar, 2014). Hence, besides the questions in the knowledge transfer sheet (Figure 2) for the participatory observation, we elaborated a sheet for the observers (in the case study areas). In this sheet, observers were asked to categorise the stakeholders based on their affiliation (13 types), describe their dominant behaviour (rational or emotional), the attributes of the leading person of the group, the overall attitudes of the group towards the problem raised by the guest stakeholder (EIS sender), the types of barriers to transfer, the degree of transferability, the adaptations to EIS

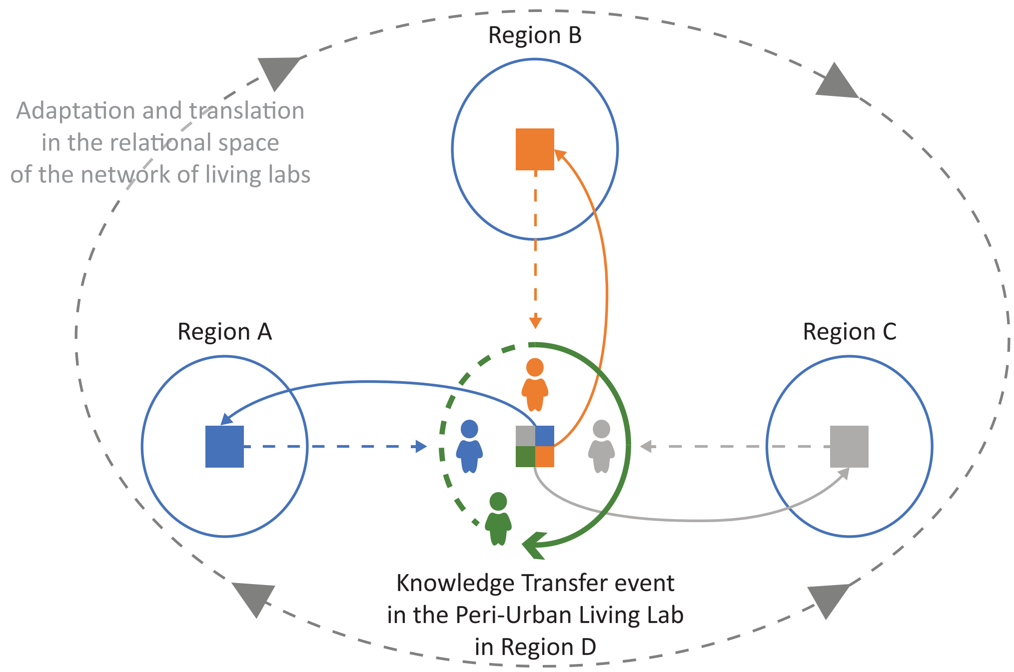

Figure 1. Co-creation and mobility of EIS in a network of living labs. Source: authors.

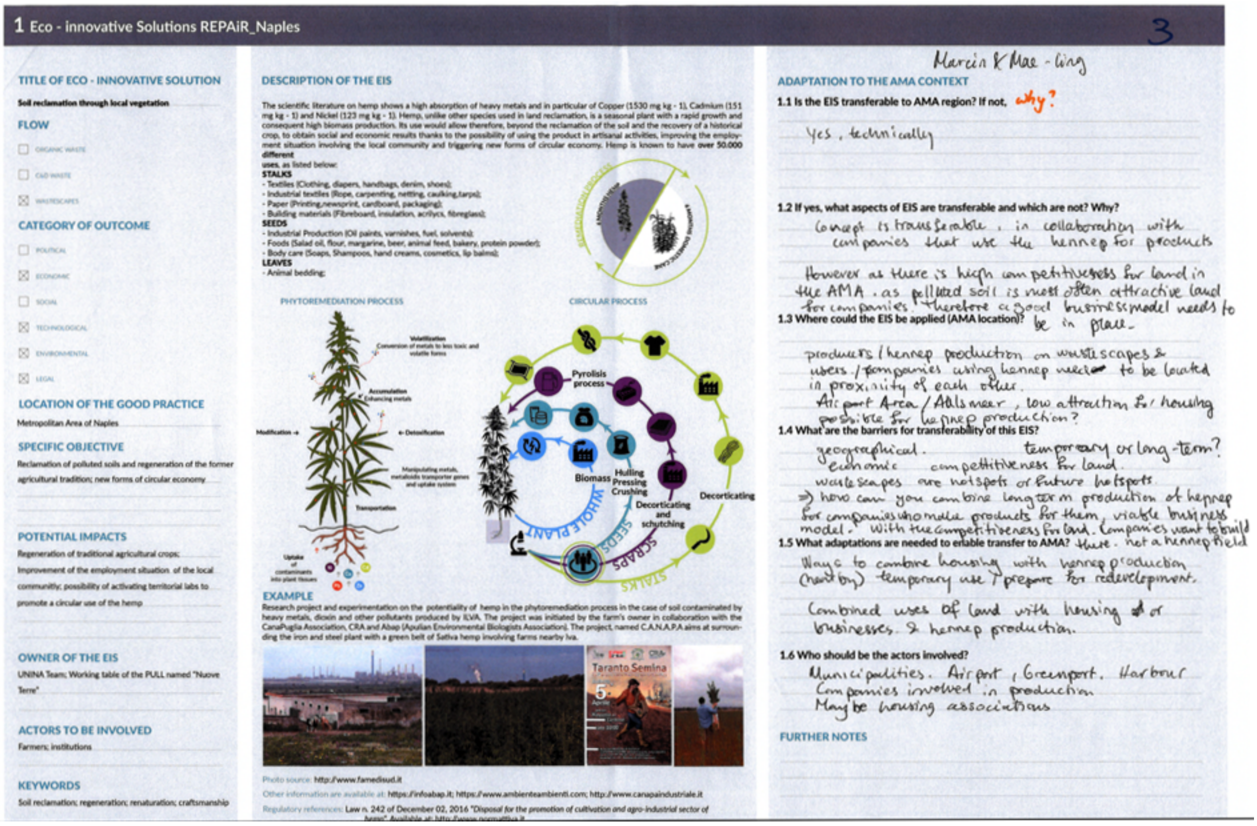

Figure 2. Example of a knowledge transfer sheet template for testing the EIS transferability, used in living lab workshops. Source: REPAIR project team.

proposed, the use of available time, etc. These all allowed for identifying the main peculiarities of knowledge transfer, analysing the dialogue and exchange of knowledge between stakeholders with a different territorial, disciplinary and socio-cultural background. The study entailed observation of interactions in a network of living labs unfolding over a period of about two years, giving enough time for relations of trust to emerge between the participants and allowing for exploring how the solutions emerged, travelled and morphed in the processes. Moreover, PULL workshops (in the two pilot cases) started and ended with a short questionnaire filled in by participants, including questions on the process of the knowledge transfer, the preferred knowledge transfer channels (e.g., study visit, webinar, workshops), and the evaluation of the PULL as a knowledge transfer channel. Finally, a short semi-structured follow-up Skype interviews were also conducted with visiting participants in order to gain further insights into the transferability of the solutions in the recipient regions and experiences of the process of transfer of knowledge in the PULLs.

4. Unpacking the Knowledge Transfer Process

Using the methods described above, the research aimed to reveal how knowledge (EIS in this case) can be transferred and adapted. It is important to note here, however, that the study did not scrutinise the implementation of the transferred solutions, but rather focused on proposed sets of solutions designed in the Naples and Amsterdam PULLs and transferred between them. The transfer, hence, was intended to contribute to the work of each of those living labs and to the catalogues of EIS co-produced in them with the regional stakeholders. Investigation of the later possible implementation of the transferred solutions remains beyond the scope of the project on which this article draws.

It should also be stressed that both PULLs had a specific focus in terms of material flows and spatial conditions to consider in the solutions and strategies developed. Firstly, the spatial structures for which the EIS are developed can include wastescapes (underused/abandoned/polluted lands typically due to former industrial activities hosted, pollution and formal/informal waste dumping, proximity of infrastructures, etc.; see Amenta & van Timmeren, 2018). Secondly, the EIS regard the flows of construction and demolition waste (C&DW), which is the waste material that is produced through demolition processes and/or can be used in the construction of buildings and infrastructure, and organic waste flow.

4.1. EIS to Be Transferred

Knowledge transfer events were held both in Amsterdam, in 2018, and in Naples, in 2019. For each of them, stakeholders from the other region were invited to take part and brought with them a selection of EISs from their region. Since the EIS catalogues from each region (REPAiR, 2018a, 2018b) included several types of EISs focusing on several flows (e.g., organic waste, C&DW, wastescapes), stakeholders in each region were asked to pre-select EISs able to address similar challenges that were identified in the earlier phase of their PULLs. EIS were pre-selected by the research teams from both regions on the basis of match of material flows and challenges to be addressed in both cases. Thus, the process of transfer from Naples to Amsterdam is illustrated with the cases of two EISs. The first one is entitled "RECALL: REmediation by Cultivating Areas in Living Landscapes" (henceforth mentioned as the RECALL solution), aiming at promoting the reclamation and eventually the reuse of polluted wastescapes through bioremediation of soil. This is done using hemp and other relevant crops (see REPAiR, 2018a). This solution tackles wastescapes, as well as the C&DW flow. The original solution developed for the Naples region attempts to address the massive problem with polluted land remaining vacant or underused because of polluted soil (often due to illegal dumping of hazardous waste). The solution taps into the artisanal traditions of manufacturing a variety of products from hemp fibres (e.g., cloth, string) and the high capacity of hemp to extract heavy metal pollutants from soil. The process would make the polluted wastescapes suitable for reuse for residential or other compatible uses, while creating scope for recreating a traditional industry and creating jobs. The second EIS, called "REC.OVER: Free Eco-Lab for Construction and Demolition Waste Reuse" (henceforth mentioned as the REC.OVER solution), entailed creating a storage, sorting and marketplace facility for C&DW, reusing a wastescape and providing individuals and small companies to deposit waste anonymously and for free (to tackle illegal dumping in Naples). The materials collected are classified according to a material passport and made available for purchase to local builders, while spreading knowledge on circular construction processes and creating new job opportunities.

The transfer from Amsterdam to Naples is illustrated by two examples of solutions for wastescape regeneration (REPAiR, 2018b), which were deemed the most transferable by the Naples PULL stakeholders: "Transformation of Wastescapes into Stepping Stones for Biodiversity" and "Transformation of Green Buffer Zones into Areas for Leisure Activities". They both aimed to reuse buffer zones of infrastructures in circular and creative ways for improving the quality of life in periurban areas, where large scale infrastructures can represent a threat for the environment and biodiversity (EEA European Environment Agency, 2017).

The first EIS aimed at reusing the underused areas within buffer zones of large infrastructure networks to increase their ecological value and biodiversity. In this way, plants and animals could use these 'sequential patches'. Conversely, the second solution is meant for people, that could find alternative areas for recreation in the buffer zones of highways or railways.

4.2. Understanding the Barriers to Knowledge Transfer

Based on a systematic literature review, several types of barriers for knowledge transfer were identified and later verified through research on the process of knowledge transfer between Amsterdam and Naples PULLs. Besides language ('dummy' barrier), the disciplinary background of transfer actors, geographical features of the regions involved, socio-cultural, socio-economic, socio-political, or legal differences, governance/decision-making background, and level of technological development were identified as factors that can influence the transferability of circular EIS (REPAiR, 2018c). This typology of barriers to knowledge transfer is summarised below (Table 1).

4.2.1. Naples to Amsterdam

In the case of the transfer of the RECALL solution from Naples to Amsterdam, the workshops' participants identified the main geographical and socio-economic barriers: the scarcity of land and huge competition and demand for land for new developments in the AMA. The AMA has a substantial amount of polluted wastescapes, mainly in the port of Amsterdam terrain. However, land scarcity and huge demand for land for development limit the scope for application of soil bioremediation with hemp or other crops, unless it would be connected to other metabolic flows (for instance construction and demolition materials), broadening the economic appeal of the solution. Other more immediate uses for the wastescapes, like housing development or expansion of the Schiphol airport, with pollution removed simply by scraping off the layer of polluted land and dumping it elsewhere, may be economically more viable.

Major socio-cultural and socio-economic barriers were identified for the transfer of the REC.OVER solution from Naples to Amsterdam. The original EIS was designed to incentivise individuals to renovate their property or small building companies to avoid illegally dumping of C&DW on the streets or in other open spaces, and instead bring it anonymously to the proposed collection points. The problem of illegal dumping is hardly present in the AMA, while the construction sector operates differently, with little individual activity and well-organised system of disposal, collection and recycling of C&DW.

4.2.2. Amsterdam to Naples

The two solutions for valorising underused buffer zones from Amsterdam to Naples can easily be transferred, even if some barriers were identified. Firstly, for the solution where buffer zones are upgraded by the increase of biodiversity, the main issue was the availability of budget

Table 1. Typology of barriers for knowledge transfer. Source: Adapted from REPAiR (2018c), building on Evans (2009), Heinelt et al. (2006), Marino, Parotta and Pozzoli (2016) and Schumacher (2015).

Barrier	How it hinders transferability of EIS
Language	Difficult mutual understanding in knowledge transfer events and EIS descriptions
Disciplinary background	Difficult communication between transfer actors with social science and engineering or design background
Geography (of metabolic flows)	The difference between geographical circumstances affects metabolic flows and applicability of solutions
Socio-cultural	Differences in waste sensitivity, environmental culture, and other socio-cultural specificities may make stakeholders non-receptive to some solutions
Socio-economic differences	A higher level of economic development tends to be related to more advanced environmental culture; pragmatically, more wealthy regions are able to dedicate more resources to innovation in circularity
Other socio-political phenomena	Public opposition to the transfer of foreign policies may block transfer
Legal aspects	A discrepancy in legislation between two of the two contexts may prevent implementation of an imported solution
Governance and decision-making	Divergent governance arrangements may undermine the implementation of an imported solution
Technological aspects	When the recipient region is at a lower stage of development of circular technologies transfer is hindered

to maintain these areas (a socio-economic barrier) and the inherent regulations (a legal barrier). However, as stakeholders argued, using biologist expert(s) in the implementation of the solution would allow the overcoming of these barriers easily. Another legal barrier identified was the lack of clarity on the ownership of these areas, even if they are generally publicly owned.

The solution for the transformation of buffer zones for leisure activities faced more substantial legal barriers, mainly related to access and safety (e.g., safety of leisure activities next to highways). The original EIS aimed at activities such as cycling, however, the programme for the use of such buffer zones for leisure would need to be determined to conform with the legal requirements in the Naples region. In the Italian context, generally, access to such buffer zones is restricted for people on safety grounds. This barrier was deemed difficult to overcome. Moreover, a further barrier identified was socio-cultural: cycling as a leisure activity is much less popular in the Naples context than it is in Amsterdam.

4.3. Transferability of Solutions

4.3.1. Naples to Amsterdam

Concerning transferability of the RECALL solution, the Amsterdam stakeholders involved in the workshops generally saw it as highly transferable, since soil remediation is also needed for polluted land around Amsterdam, especially in the port area. In both regions, the traditions of manufacturing products from hemp fibres are also present. The barriers identified were deemed surmountable. Practically, the entire solution was considered transferable, albeit with some extensions and adaptations to fit the local context and connect it to construction materials flow. Importantly, this connection to the C&DW flow increased the potential of the solution to trigger innovation by linking wastescape regeneration to circular construction. Consequently, the EIS was added to the catalogue of solutions for the AMA.

Conversely, the REC.OVER solution was deemed hardly transferable due to the magnitude of the barriers identified. Since the original solution was largely context-specific, only some of the ideas behind this EIS were deemed transferable (e.g., providing support for handling C&DW by individuals and support for informal waste collection from individuals engaged in small-scale construction work).

4.3.2. Amsterdam to Naples

The Neapolitan stakeholders agreed that both solutions for buffer zones from Amsterdam were generally transferable to the Neapolitan case in their entirety because neither of them relied on specific territorial features of the AMA. Furthermore, buffer zones around infrastructures can be found practically in every regional context. However, the solution aimed at leisure activities was deemed much less transferable due to the importance of the legal barriers described above. Moreover, it was hard to imagine the activities proposed in the original EIS in the Neapolitan case. In fact, the EIS was based on the Dutch socio-cultural context and the huge popularity of cycling and ubiquity of bicycle paths for leisure and commuting. Conversely, cycling in the Neapolitan culture is not yet as deeply rooted as in the Netherlands.

4.4. Adaptation of Solutions

4.4.1. Naples to Amsterdam

Stakeholders identified a range of far-reaching adaptations transforming the RECALL solution to fit the AMA context, which departed substantially from the original solution. First, the metabolic focus of the solution was expanded to include manufacturing of hemp-based construction materials (e.g., hempcrete blocks combining chalk and hemp fibres), offering excellent isolation capacity and suitable for constructing and insulating warehouses or data centres (pollutants in fibres preclude use for housing). That reflected, on the one hand, the high importance of C&DW flow in the Amsterdam region, and, on the other hand, the on-going spatial and industrial trends in the region, namely the growing demand for (circular) construction materials in the wake of the expected massive urban expansion (and the ambitions of the Municipality of Amsterdam to develop new urban areas following circularity principles) and the emergence of new clusters of economic activity (data centres). Interestingly, this expansion of the goals and scope of the solution was also later partly taken up by the Naples PULL to enhance the original EIS, connecting it to the C&DW flow.

Second, stakeholders proposed to consider various approaches to remediation depending on the demand for land in a particular area. In a nutshell, in cases where there was high pressure on land needed for imminent development, a layer of soil could be stripped down and transported to a wastescape in a more remote location where development is likely to happen later, allowing for redevelopment of the wastescapes in the short term. There, remediation process with crops (adapted to pollution type) would take place, making those more remote wastescapes suitable for later development. Finally, to further broaden the potential support for the solution, proposals were made to combine hemp-based soil remediation with recreation activities or renewable energy production. This could be supplemented by a strategy entailing periodic rotation of hemp production on a given plot with solar energy harvesting, which could muster the support of renewable energy production cooperatives.

The stakeholders identified the Amsterdam port area as the most suitable space for deploying the solution. Also, while the traditional industry actors (hemp products) were critical for the original solution, in its Amsterdam-adapted version, producers of construction materials, builders and developers became important stakeholders, alongside *grondbanken* (soil banks), municipal institutions dealing with assessment and classification of batches of land based on environmental quality and with the logistics of soil flows to and from soil depots.

In the case of the REC.OVER solution, assuming that only some elements of this EIS could be implemented in the AMA context, it was proposed to consider a network of neighbourhood collection points and to use digital support tools to provide accurate and real-time information on the material available for reuse. Due to low transferability, however, the solution ended up not being included in the AMA catalogue of EIS.

4.4.2. Amsterdam to Naples

Adaptations deemed necessary to implement both solutions for buffer zones (e.g., in the industrial areas or in the motorway junctions) in Naples were not major as such, however, a process of translation also took place. First, adaptation was the combination of both solutions into one comprehensive solution for valorising buffer zones in a complementary and differentiated way, reflecting the spatial and legal restrictions. Since access to buffer zones located immediately next to transport infrastructure is not possible in the Italian legal context (for safety reasons), it was proposed to focus on creating spaces for biodiversity in the restricted access areas, while opting for leisure-oriented transformation of wastescapes close but not immediately adjacent to transport infrastructures where access restrictions did not apply.

Second, on the basis of spatial analysis of the potential areas for the transformation of buffer zones adjacent to infrastructure, the stakeholders stressed the necessity to create stronger connections among these fragmented buffer areas since they should ensure continuity for the passage of animals (e.g., connection to larger regional green networks). Stakeholders also agreed that with the involvement of biodiversity experts this should be easily manageable, as they would ensure the selection of suitable species compatible with the infrastructures.

Finally, it was proposed to integrate these solutions with the solutions proposed for the reuse of organic waste and C&DW which foresees the reuse of compost and inert construction material for the creation of new soils for reshaping and regeneration of the landscape. The scope and goals of the original solutions from the Amsterdam PULL were thus also expanded. This expansion made the transferred solutions go beyond the original goal of wastescape regeneration, connecting to other waste flows in a systemic way. It was proposed, namely, to reuse a combination of C&DW (as construction material) and organic waste (as compost) acquired through other EIS developed in the Naples PULL to develop new dynamic landscapes in the buffer zones, for instance creation of hills that would diversify the existing landscape, while providing space for biodiversity, recreation as well as a sound barrier for the transport infrastructure.

5. Conclusions

The article explored the process of knowledge transfer between Amsterdam and Naples, taking place within a network of living labs set up to develop experimental solutions and regional strategies for circular economy and better resource management. This unique setting offered an opportunity to: (1) explore the barriers encountered, (2) assess the degree of transferability of solutions, and (3) investigate how the solutions changed as they "travelled" through the relational space of the networked living labs.

Some of the solutions covered were highly transferable in their entirety and with only minor adaptations, while others were much less suitable for transfer due to significant contextual barriers. A typology of barriers for transfer of spatial solutions for a circular economy was elaborated and empirically tested, responding to the calls for a better understanding of the practicalities of knowledge transfer (e.g., Argote & Fahrenkopf, 2016), especially in an emerging policy area like circular economy.

The typology of barriers was applied to the scrutiny of the process of transfer of a selection of eco-innovative territorial solutions for circular economy between Amsterdam and Naples. The most prominent barriers, as observed in our cases, were geographic (e.g., scarcity of land), socio-economic (e.g., pressures on land development, availability of funding), socio-cultural (e.g., presence or absence of illegal dumping practices, cycling culture) and legal (e.g., lack of suitable regulations or presence of regulations preventing deployment of a solution). While the geographical and socio-economic barriers were surmountable—provided that the solutions were 'translated' to fit the local context better—the socio-cultural and legal barriers proved more difficult to overcome and limited the transferability of solutions. Naturally, the set of such barriers will vary from case to case, but the typology proposed can be applied in other cases as a first step towards assessing the transferability of solutions across places and the consideration of adaptations needed for a solution to work in the recipient context.

Applied to the Amsterdam-Naples knowledge transfer, the barriers identified pointed to the need for more or less wide-ranging adaptations of the solutions, from cases where transfer was deemed impossible due to the magnitude of the socio-cultural barriers, as in the case of the Naples solution for tackling illegal dumping of construction waste; to cases where a process of far-reaching adaptation took place, largely transforming the original goals and modalities of the solution, as for instance with the transfer of the Neapolitan solution for soil remediation with hemp to Amsterdam region or that of solutions for buffer zones transferred from Amsterdam to Naples. The adaptations proposed to make imported solutions work in the recipient context were co-developed by the stakeholders from the recipient region, with participation and feedback from stakeholders from the sender region, to: (1) ensure contextual appropriateness, (2) broaden the impacts, and (3) the potential support for the solution among wider stakeholder groups. Thus, the article provided an empirical illustration of the process of policy translation, as advocated by Stone (2012), in which solutions are not mechanistically grafted, but rather redesigned in this process.

One of the key observations made is that transferability is high if a solution does not rely on place-specific characteristics of the sender region, but rather builds on resources, practices and territorial features that are present in the recipient region, too. That said, substantial differences between the sender and recipient context do not preclude transfer per se, but rather point to the need for using the original solution as a basis or inspiration to develop an almost entirely new solution, building on the original idea but substantially departing from it, by rethinking and/or expanding its goals and focus. In such cases, knowledge transfer is less about transferring a solution 'from place A to place B' and more about using a solution from 'place A' (and in our case, also the feedback from the stakeholders from 'place A') as an inspiration for learning and co-design of an innovative solution for 'place B'.

Finally, the article sheds light on the process of adaptation of the solutions transferred and the role of the networked living labs as socio-spatial nodes for knowledge transfer. The inter-connected living labs, set up to co-design circular economy solutions with regional stakeholders in Amsterdam and Naples, anchored the knowledge transfer process in a parallel process of policy innovation in both regions, addressing similar challenges and using similar methodology. The labs provided a relational and physical space for interactions between stakeholders from the two regions. This allowed for a relatively deep understanding of both contexts and the solutions emerging from them, facilitated by the stakeholders from the sender regions. It also facilitated the building of shared understanding among the stakeholders from both regions. This made the transfer process not only more strategic but also more creative, learning-oriented, prompting outside-the-box thinking and being more likely to lead to the successful implementation of the solutions based on the knowledge co-created through interaction between stakeholders from different contexts. Thus, the networked living labs as a knowledge transfer method allowed for reflexivity, as opposed to one-way learning channels or transfer process with limited feedback opportunities. This allows for jointly finding ways to overcome transfer barriers and avoiding the pitfalls of ill-informed copy-pasting of 'best practices' from abroad (see Stead, 2012).

A caveat is that the solutions studied were pre-selected from a larger catalogue elaborated in each region in order to minimise the potential barriers. Thanks to this pre-selection, and the repeated interactions between the stakeholders, the transfer process was fruitful, despite the initial scepticism of the stakeholders involved about the purpose of transferring solutions between such vastly different regions. Another caveat is that the transfer took place in a 'controlled environment' whereby the transfer activities were institutionalised in a network of living lab experiments as part of a large international research project. This created scope for applying a pre-determined methodology for the transfer events and nudging the participants to ponder specific questions about barriers, transferability and adaptation of solutions. However, the process relied heavily on the substantial financial and organisational resources deployed as part of the project, which may not be available in other situations. This experiment, however, allowed for organising a detailed participant observation of this process, collecting unique insights on the above questions from the interactions with and between real-world regional stakeholders from two European regions. This, in turn, allowed for experimentation and drawing a number of lessons for theory and practice, as described above. Moreover, the study provides a template for the process of knowledge transfer between territories which could be deployed in the context of various events and networks oriented towards knowledge exchange between urban and regional practitioners (e.g., international city networks, study visits, territorial cooperation and/or city twinning activities).

Future research could apply this method to facilitate the transfer of knowledge between other regions and cities, possibly also covering on other aspects of sustainable urban and regional development and, ideally, examining how the solutions transferred were ultimately implemented on the ground. Such research would validate the potential of networks of living labs as a knowledge transfer device shown in this study.

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Conflict of Interests

The authors declare no conflict of interests.

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Article

The Circular Economy Concept in Design Education: Enhancing Understanding and Innovation by Means of Situated Learning

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Abstract
The concept of circular economy (CE) is high on the agenda of many planning agencies in European countries. It has also become a prominent issue in European academic education institutions. It is expected that spatial planning and design can support and add the spatial quality dimension of such a transition towards CE. However, incorporating the concept of CE in an integrative manner in urban design and planning courses is challenging because of its metabolic and complex nature. This article presents the first results of integrating design-teaching activities at a faculty of architecture with an H2020-financed research project. The integration of research and design education provided the students with a situated and indeed transdisciplinary learning environment. Students understood that they needed to address challenges from a systemic perspective rather early in the design process, meaning to understand what the relations between different subsystems and their spatial structures are. Furthermore, the experiment provided evidence that the eco-innovative solutions developed by the students are seen as an effective option to achieve objectives for a transition towards CE by stakeholders.

Keywords
Amsterdam Metropolitan Area; circular economy; design education; situated learning; urban design

Issue
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1. Introduction

The Circular Economy (CE) concept is high on the agenda of planning agencies in cities and regions across European countries. It has also become a prominent issue in academic education at several European schools. It is expected that spatial planning and design can add the spatial quality dimension of a transition towards CE. To achieve this and equip present and future urbanists with the knowledge and skills required to fulfil this expectation, adaptations of current teaching practices must be implemented. As Dehaene (2018) stated, the challenges that are related to “water, energy, nutrient and soil cycles, as well as localised food production, are rather new to urbanists, who traditionally focus on housing and mobility’’.

Furthermore, it also requires a critical consideration and further development of concepts that are normally at the core of CE strategies, with a focus on closed-loop industrial symbiosis and the development of CE business cases and circular service-based economies. We agree with Williams (2019) that “the current conceptualisation for the CE is inadequate when applied to a city" or region. She identified five crucial issues of this inadequateness: (1) the fact that the city, contrary to industrial processes, is a complex, self-organising system, where economy is an important factor, but not the dominant one; (2) the focus of CE approaches on the production side of the value chain and the underrepresentation of the need for sustainable consumption patterns as crucial aspect for the transition towards a CE; (3) the exclusion of land as a resource although it is one of the most valuable resources of regions; (4) the neglecting of infrastructure, both as a resource, but also as an instrument to steer circular policies; and (5) that the dominant approach ignores the importance of different scales for closing resource loops. One way to overcome these inadequacies is to better integrate (van der Leer, van Timmeren, & Wandl, 2018) and further develop principles of CE with regional planning and design, plans, and policies.

However, this requires an integration of expertise on resource flows and industrial processes in the practice of spatial planning and design and calls for transdisciplinary learning approaches in urban and regional design education. This is a general challenge in the field of Urbanism also concerning other issues with urgent societal relevance, like climate adaptation. The TU Delft-led Horizon 2020 project REPAiR—Resource Management in Peri-Urban Areas, which has the core aim to integrate spatial development and resource flow management, provided the possibility to develop, test, and assess adapted ways of teaching and situated learning. This happened in two courses that are both included in the MSc programme of the Faculty of Architecture and the Built Environment: one compulsory design studio and one elective design course. This article reports on the first two years of this pilot, answering the following two research questions:

(1) What teaching activities have been developed and implemented to provide knowledge and skills, and to what extent has this integration of CE and design education been understood by students, and further contributed to innovative solutions for the transition towards CE?
(2) To what extent were the proposals developed by the students appreciated by the stakeholders?

The questions were answered by conducting a case study on two MSc courses during the academic years of 2017 and 2018. The case study is built up in three sections, which also structure the remainder of this article.

First, there is a description of the courses and how they were adapted. Second, an analysis of the students' results by the course coordinators answering the following questions:

(1) Did students integrate multiple concepts?
(2) Did students develop a spatial understanding of resource flows?
(3) Did the students understand the physical footprint and impact on the spatial quality of the linear as well as a proposed CE?
(4) Were students able to describe, understand, and propose an alteration to systemic relationships?

Third, the validation of the outcome of the teaching experiments, using the feedback received from questionnaires distributed by student organisations, tutors' meetings and interviews with stakeholders, as well as regional stakeholder feedback collected by the REPAiR project during the Peri-urban living lab process conducted in the Amsterdam Metropolitan Area (AMA).

2. Integration of Research into Design Education

Inspired by the idea of enhancing regional collaboration in education, highlighted in the Strategic Agenda for Higher Education and Research (2015–2025, published by the Dutch Ministry of Education, Culture and Science in 2015), there is an increasing ambition in Urbanism education at Delft University of Technology to collaborate with research projects to offer rich learning environments. The aim of the integration of research and education is twofold. From the research projects perspective, the integration of student education should allow to test the research methods and find innovative solutions for the research projects' main outcome. From the education perspective, the connection to an on-going research project should provide state-of-the-art knowledge and insight into scientific research and provide transdisciplinary learning environments.

However, there are challenges to achieving such integration. The aim of the research is to develop beyond the state of the art, while education focuses on transferring the state-of-the-art knowledge. Moreover, the field of circularity is complex and its integration in the equally complex field of spatial design raises the level of difficulty for the students and even the teachers, let alone that fact that the CE field is still in development and, teachers need to transfer knowledge that is still dynamic.

These challenges were overcome in the design education by collaborating with researchers, who are at the forefront of knowledge generation and transfer, as well as integrating the teaching activities in the living labs established by the research project. In this way, a learning environment with the support of the established regional and sectoral stakeholders in practice is provided. This is a "situated learning" environment that provides chances for students to participate in the "community of practice" (Lave & Wenger, 1991), which has its relevance to design education (Lawson & Dorst, 2009). What can be expected includes: (1) an enhanced problem definition and assignment of the course through early consultation of societal partners, resulting in more relevant student work; (2) a more structured and substantial participation of societal partners in education, resulting in more exchange between students, researchers and societal partners; and (3) an enhanced valorisation of student work via partner institutes, resulting in more publication and active engagement of students in societal debate.

In situated learning, students play a role not as a passive audience, but as inventors and advocates of best practices (de Hei, 2016; Schweitzer, Howard, & Doran, 2008). Such an approach seeks innovation in Urbanism education by better preparing students for the collaboration and negotiation involved in their future professions. To achieve this goal, as pointed out by Müller, Tjallingii and Canters (2005), a transdisciplinary context that reflects real-life settings should complement disciplinary specialisation. Settings resembling "urban living labs" (Steen & Van Bueren, 2017) are particularly required in regional design education because they reflect the, at times, contested multi-actor setting of the practice.

The following sections explain how the situated learning environment was set up for two courses, the learning outcomes concerning the issue of integrating aspects of different fields of expertise and the assessment of student projects by the stakeholders.

3. Adapting Urbanism Education

Urbanism is concerned with understanding the spatial organisation and dynamics of the built environment and inventing new ways to maintain spatial quality and equality. Urbanism is a scientific design education, characterised by the interaction between thinking (analysis and reflection) and doing (the speculative/intuitive imagination of spatial interventions). Starting with the spring Semester 2017, the integration of CE as a topic was tested in two urbanism courses in a situated learning environment:

(1) MSc course "Spatial Strategies for the Global Metropolis", an obligatory annual course of the MSc Urbanism programme that integrated CE in 2017 and 2018, each with about 75 students;
(2) MSc course "Geodesign for a Circular Economy in Urban Regions", an elective course open to students of different MSc programmes that ran in 2017 and 2018, each with about 15 students.

Common adaptations to both courses were that the students were introduced to a definition of CE, which already included aspects of spatial quality and spatial development, and therefore went beyond definitions they might have been familiar with:

> Circular Economy (REPAiR-specific): An economy that accommodates resources to flow through human-made and natural systems in renewable ways, creating or retaining value through "slowed, closed or narrowed loops/flows", rather than rapidly destructing value through the creation of waste. This value can manifest itself in monetary principles as well as other social, ecological or economic principles, taking account of potential trade-offs. Important in this notion is the establishment of production-consumption-use systems built on restorative resources in optimal flows. By optimal flows, it is implied that cycles are closed or connected in spatially and temporally favourable conditions, i.e., where and when is most appropriate (highest possible value, possibly via cascading loops). Moreover, changes in one part of the system should not incite negative externalities. Of particular interest for REPAiR in this respect are the impacts on spatial quality. From that perspective, REPAiR also takes the notion of wastescapes (open spaces as well as built urban form) into consideration. (Geldermans & Taelman, 2016)

Moreover, students were introduced to two resource flows that were previously identified as key flows by the local stakeholders: food waste, and construction and demolition waste. The following subsections provide, for both courses respectively, a general description of the course followed by the manner in which the courses addressed the challenges defined above.

3.1. Urbanism MSC Course "Spatial Strategies for the Global Metropolis"

Regional design is the core theme of the third quarter of the MSc Urbanism curriculum and deals with promoting solutions to long-term challenges in a given Dutch regional context. It emphasises on a comprehensive, evidence-informed understanding of regional spatial structures and development trends, as well as an understanding of interrelations between design, planning, and politics. The design process leads to two products, a spatial vision and the development strategy. Since 2017, this course has been conducted in collaboration with the REPAiR project, focusing on regional design for the AMA, and stimulating its transition towards a CE.

The learning goals of the course remain the same each year, but when integrating the course with the REPAiR project, some of the learning goals have been more specifically oriented towards the theme of CE. Students are expected to show, in their regional design proposals, a deep understanding of CE and its spatial implications. By the end of the course, students are expected to be able to (1) understand the complexity, multi-scalarity, and uncertainty of regional spatial development; (2) consider the limitations that these conditions set to regional planning and design; and (3) formulate and argue for a comprehensive regional vision. Students were expected to conduct systematic analyses on material flows at the regional scale and identify the spatial implications of such flows and the societal relevance of the CE concepts. As output, the students formulate an innovative vision, which comprehensively integrates correlated development and normative goals.

The Research and Design Studio is the core activity of this course. Students conduct a regional design in groups of 4 to 5 students, supervised by two tutors with complementary expertise on planning, design, and CE. As the duration of the course is only 10 weeks, and the level of complexity involved is very high, predefined themes are provided to guide the studio work: reuse of land, energy, water, and waste. Supporting course elements are an integral part of the studio, providing knowledge about theories and methods of regional analysis and design with lectures and workshops. Furthermore, the REPAiR team developed two half-day workshops, which were integrated into education. The first one—week 2—was intending to educate the students in an urban metabolism-based method for system analysis and system design. This method is based on the Netzstadt approach (Baccini & Oswald, 2008) and combines urban morphological as well as urban physiological methods to understand which spatial systems and their potential adaptations in a region are crucial to support the CE transition. The second one—week 6—introduced the students to a multi-size (micro, meso, macro), multi-geoscale (processes located at different geographical scales), and multidisciplinary sustainability assessment framework (Taelman, Tonini, Wandl, & Dewulf, 2018) for assessing and further developing their spatial strategy.

Additionally, the REPAiR team provided a lecture for the opening session, which introduced the basic concepts and theories behind CE as well as the global and regional circularity gap to emphasise the urgency of the CE transition. This input was complemented by lectures from planning practitioners—weeks 3 and 4—who shared their experience with CE projects. The students received stakeholder feedback twice during the course: at the midterm presentation, when the students presented their vision, and during the final review, when the students presented the spatial development strategy.

Equally important was to prepare and educate the teachers. The aim was not to make them CE experts, but rather to bring them up to date with CE challenges and CE related planning policies and initiatives within the AMA. This was achieved in a one-afternoon session, where key literature and policy documents were discussed. The teachers were also assured that in case of specific CE-related questions, the REPAiR mentors would be available for extra mentoring of student groups. Figure 1 shows a timeline of the activities that took place for the duration of the course.

3.2. Elective Course: Geodesign for CE in Urban Regions

This elective course was newly designed as a transdisciplinary course that tests methods developed within the research project under controlled and simplified circumstances and uses the creative potential of design students to inform research activities in the Peri-Urban Living Labs (PULL). The course was attended by students following four different MSc programmes: urbanism, architecture, landscape architecture, and industrial ecology.

The course methodology builds upon the geodesign framework (Figure 2) of Steinitz (2012), which consists of three iterations of six questions and models that together are used to understand the study area, to develop methods for the study, and to perform the study (Figure 3). The course focuses on the third iteration to perform the study, which in this case means to develop and evaluate an eco-innovative solution (EIS) to support the transition towards a CE in the AMA. The students were introduced to the results of the first and second iteration, which were achieved by the REPAiR research team and the local stakeholders within a living lab environment (Russo et al., 2016). This means that the students were working within clearly defined methodological boundaries and a defined decision model.

The course is organised into three parts: introduction, study, and iteration (Figure 3). Additionally, the students take part in a workshop in one of the other case study areas of the REPAiR project. The introduction during the first weeks was used to familiarise the students

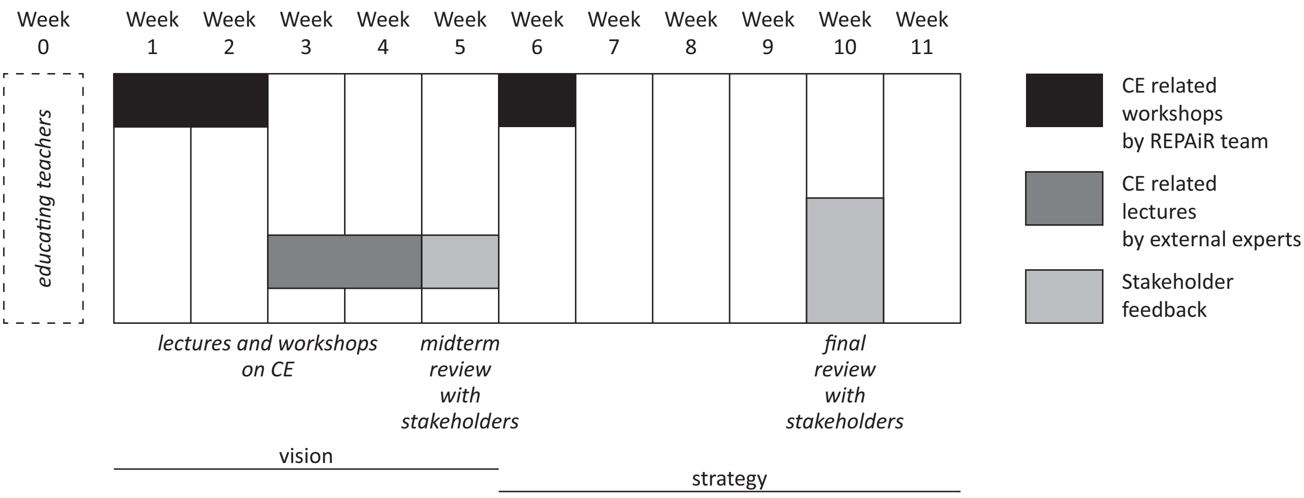

Figure 1. The simplified timeline of the Spatial Strategies for the Global Metropolis course illustrating the CE related input and stakeholder interaction.

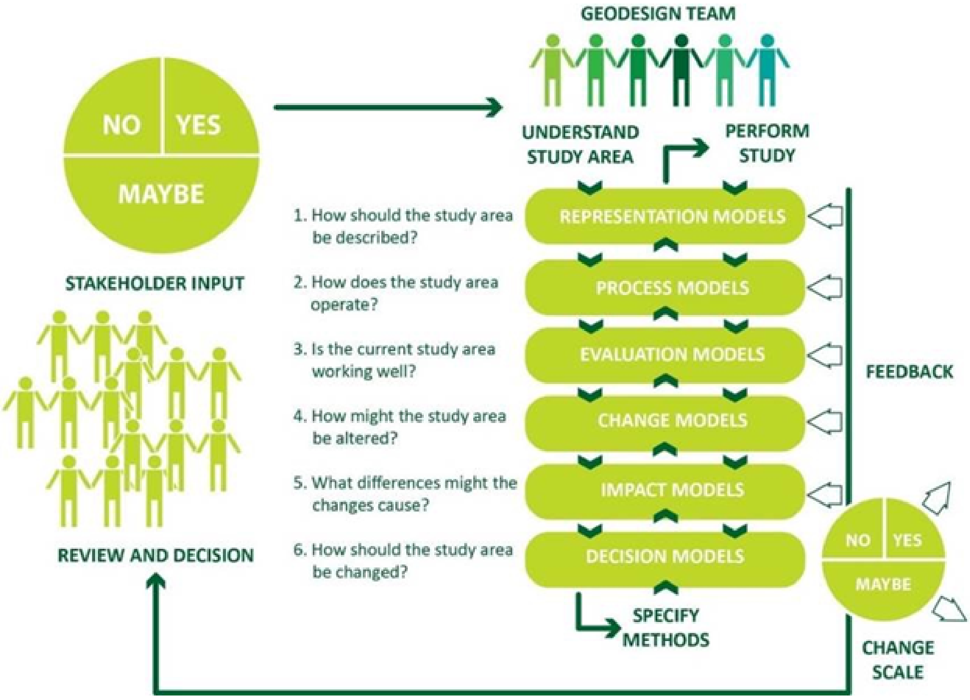

Figure 2. The structure of the geodesign framework of Steinitz (2012). Graphics by REPAiR researcher Libera Amenta.

with: (1) the basic concepts used during the course—CE, geodesign, EIS; (2) the case study area—the AMA; (3) the key flows identified by the stakeholders—construction and demolition waste, and food waste; and (4) the challenges defined by the stakeholders for the key flows. At the end of the week, the students had to formulate the first idea of one EIS. Based on this idea, the students were grouped in teams of three, always including one urbanism, one industrial ecology, and one architecture or landscape architecture student in each group. In this way, the interdisciplinary aspect was simulated.

The study phase extended over week 2 to 6. Each week, the students were introduced to: (1) one model of the adapted geodesign framework; (2) theoretical background; and (3) methods and tools they should use. In week 2, students were introduced to GIS supported system analyses and systemic design methods. In week 3, the input focused on urban metabolism-based sustainability assessment and related indicators. The students then directly applied their acquired knowledge by creating a first version of the respective model, adjusted to their EIS. Two to three teachers were present, supporting the students with methodological and conceptual help. Each step concluded with a group presentation and discussion.

The iteration phase took place over the last three weeks of the course. The students updated their EIS and the related models based on their findings from the

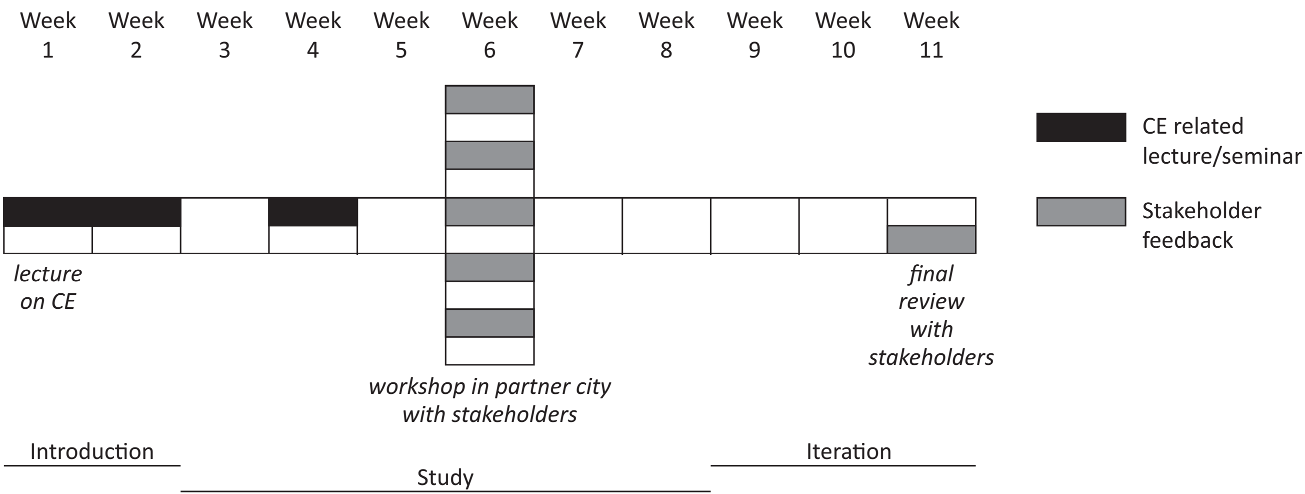

Figure 3. The simplified timeline of the course "Geodesign for a Circular Economy in Urban Regions" illustrating the CE related input and stakeholder interaction.

previous phase and discussions with stakeholders or researchers from the REPAiR team. The iteration phase was interrupted by a week-long workshop in one of the other case study areas of the REPAiR project. These workshops were organised with the Università degli Studi di Napoli Federico II, in 2017, and the HafenCity University, in 2018. In the workshops, students from all three faculties worked together to quickly develop urban design proposals answering challenges and solution paths that were formulated and developed in the local living labs. The aim of these workshops was twofold, on the one hand, to make the students aware of the limitations of the transferability of EIS, but to understand on the other hand that the methods the students learned helped them to accelerate their design process. Moreover, students from foreign universities provided the living labs with an external perspective on local challenges.

The final week of the course was used to prepare a poster presentation. The presentation was used to give feedback to the students based on the course learning goals, but also to engage in a discussion on the overall findings of the REPAiR project. The poster format made it easy to show and discuss the results in later meetings with local stakeholders of the project.

During the course, it was important to define the meaning of eco-innovation in design terms and solutions together with the students. The awareness of moving towards circularity has raised the necessity to modify and renew existing technological production and socio-political, environmental, and economic behavioural patterns. Such awareness is developing alternative types of responses, the so-called solutions and strategies, to make the shift towards circularity.

The EIS is defined as an alternative course of action encompassing decisions on the following aspects (EC, 2011; Remoy, Furlan et al., 2018):

(1) The development and implementation of new materials, technologies, or processes in connection with the development of sustainable economic activities, or adding new activities in value chains with the modification of the status of the current waste management systems, and the resource flows, also capable of modifying the spatial configuration of peri-urban areas;
(2) The modification of existing policies and governance, or new policy/governance developments;
(3) The definition of spatial and environmental design proposals. These solutions will potentially lead to the modification of existing flows of materials, development of new flows and processes, and/or change the spatial design of areas, as well as generate change in the behaviour of stakeholders and inhabitants.

Strategies and solutions towards eco-innovation are normally used in the context of complex problems. Different disciplines have reflected upon alternative approaches related to different parts of the problem-solving process. Engineering disciplines are used to optimise processes when both solutions and objectives are well defined, while designers usually work in contexts where neither of those is well defined, using design to reveal new possibilities. In this light, the proposals of the students are situated within the innovation realm, where problems and objectives were defined within the Living Lab workshops but the solution was not (Figure 4).

4. Discussion of Outcomes

In total, around 200 students participated in the two courses. The following subsection discusses exemplary student results to answer the research question: To what extent has this integration of CE and design education been understood by students, and further contributed to innovative solutions?

In doing so, we assess the results according to the following aspects:

(1) Did students integrate multiple concepts?
(2) Did students develop a spatial understanding of resource flows?

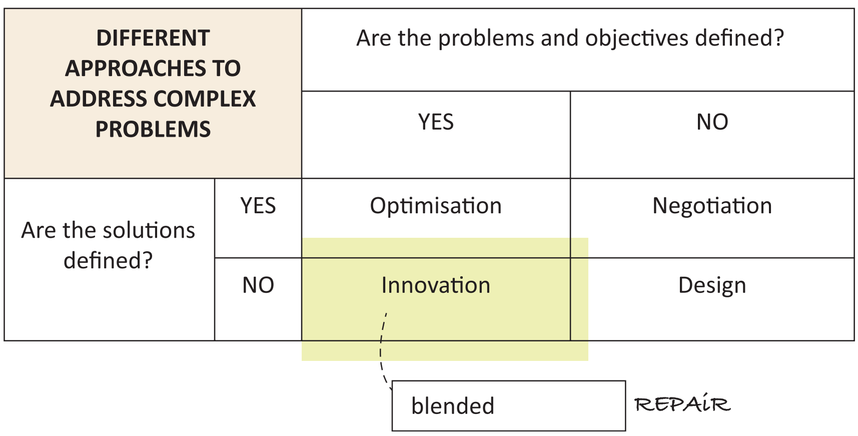

Figure 4. Different approaches to address complex problems based on van de Ven et al. (2009).

(3) Did the students understand the physical footprint and impact on the spatial quality of the linear as well as a proposed CE?
(4) Were students able to describe, understand, and propose an alteration to systemic relationships?

A summary of the student results is publicly available via the REPAiR project webpage (http://h2020repair.eu/project-results/research-design-studio; http://h2020repair.eu/wp-content/uploads/2019/03/Deliverable-5.2-Catalogue-of-solutions-and-strategies-for-Amsterdam.pdf)

4.1. Urbanism MSc Course "Spatial Strategies for the Global Metropolis"

As described above, students participating in the regional design studio "Spatial Strategies for the Global Metropolis" were asked to use the concept of CE for the design of a spatial vision and development strategy for AMA. Observations on students' understanding of the concept and their ability to use it to formulate innovative regional design solutions are summarised below. Particular attention is paid to how students' performances were fostered by involving expert knowledge gained during the REPAiR project. Observations draw on an assessment of specifically the 2018 round of the studio. Table 1 lists the titles of students' projects and gives outline information on the CE themes addressed. There were also findings resulting from the experience acquired during earlier rounds of the studio (where the CE concept has not played a role), as well as expert knowledge about regional design.

Students participating in the "Spatial Strategies for the Global Metropolis" studio are expected to ground designs in a comprehensive, evidence-informed understanding of regional spatial structures and development trends. To achieve this goal while using the CE concept, they were asked to conduct a flow analysis during the first stage of their studio work. Outcomes of the analyses indicate that it was relatively easy for students to grasp spatial flows when they were related to the ma-

Table 1. The scope of students' projects.

Title student project	CE topic
Clockwork AMA. Integrating tourism in the CE model by transforming wastescapes	Re-use of land
Closing Loop—Opening up society. Creating an inclusive CE for household electronics in AMA	Electronic household waste chains
Food Island. Building a resilient food system for AMA.	Organic (food) waste chains
Modularama. How modularisation in construction industries can contribute to more social cohesion	Construction and demolition waste chains
Amsterdam's Hill-Sphere(s). Implementing the polycentric model through circular wasted landscapes	Re-use of land;
Float to Circularity. Connecting human needs with the material flows in the AMA region	Re-use of land; Construction and demolition waste chains; Organic (food) waste chains;
Food Roots. Connecting people and food in a circular agri-food production landscape	Organic (food) waste chains
I am De·n·city. Using density to increase liveability	Organic (food) waste chains
The Agronomic Renaissance. Towards a fairer and circular agro-food system in the AMA	Organic (food) waste chains
AMA, Balanced. A renewable energy network as a driver for a sustainable peripheral development	Renewable energy
Redefining Logistics. How public transport can circularise the flows of goods and services in the AMA	Household waste
AMA Activated. Harvesting residual streams to drive peripheral development	Renewable energy and food production
The Food Connoisseur. Creating a highly efficient circular foodscape built on global-local synergies	Organic (food) waste chains
Collaborative Commons Scapes. Shifting the AMA system towards a prosuming mindset	Sharing economy; solid household waste
AMA—Towards Collective Energy. Increasing social justice in a decentralised energy system	Renewable energy

terial flows of goods. More complication arose from applying such analysis to the re-use of land and water. In these realms, students struggled in particular with consolidating the CE concept with existing approaches to sustainability, such as urban regeneration and the redevelopment of brownfield sites. Besides understanding their principal logic, students were also asked to map a ‘spatial footprint’ of current linear and, in the future, more circular waste chains. A broad range of student groups engaged with food and organic waste cycles. This indicates that they found it manageable to identify the spatial implications of a CE in case current linear chains already have a high spatial impact. Finding the spatial expressions of circular construction and demolition waste chains—a chain that is spatially delimited to a few locations—proved most challenging. Few projects discussed these expressions, and if they did so, the discussions concerned indirect outcomes of reformed cycles, e.g., concerning socio-economic relations or new types of housing.

During the initial phase of the studio, apart from analysing flows, students were asked to identify important existing regional spatial structures. The combination of CE-inspired and more traditional analyses—focused on, e.g., transport infrastructure, socio-economic characteristics, and open space—has led to innovative insights into spatial opportunities for a CE in some cases. One project has, for example, associated a concentration of derelict land around a former military defence line in the AMA, with re-use of land strategy that is fostered by tourism. Another project used existing socio-economic structures (including vocational schools) to inform a more circular use of electronic household waste. Innovation that stems from combining types of analyses is also reflected in re-occurring discussions on decentralisation in students’ projects. Finding appropriate planning scales is an important task of regional design. Projects overall demonstrate that the CE concept has led to deeper thinking about a richer set of dependencies in regions and has thus led to new insights regarding the need to up- or down-scale development strategies.

Regional design engages with interdependencies in complex spatial systems. Regional design education, therefore, seeks to train students to deal with a large amount of information comprehensively. When comparing the 2018 students’ projects with results from earlier rounds of the studio, it appears that a particular contribution of the CE concept lies in enhanced ‘system thinking’. The initial flow analysis forced students to identify specific problems within a broader problem field during an early stage of their project work. The positioning of a distinct problem within a wider system also allowed them to better sustain an argument that ties their vision to their development strategy. Excellent student groups succeeded in supporting an argument with quantitative evidence. CE experts have also perceived the visualisation of students’ projects as an innovation.

4.2. Geodesign for CE in Urban Regions

As described in Section 3.2, the students in this course modelled different EIS in an urban region, assessing their sustainability impact and using their findings to respond to the complex problems of urban development, encouraging the dialogue between disciplines and allowing a crossover of ideas. The developed EIS proposed a modification of existing value chains, the development of new products, services, and related flows and processes and the spatial configuration and functions of parts of the metropolitan area.

Notably, although using the same methodology, some groups started with a territorially defined challenge, such as the negative environmental and spatial impacts of the parking lots around Schiphol Airport, while others started from a waste flow, such as the large amounts of plastic waste in hospitals. All EIS developed by the students integrated flow as well as territorial aspects. It varies, however, in how far they considered spatial quality in their sustainability assessment. Table 2 briefly describes a selection of EIS, including the territorial and flow aspects tackled, as well as the complexity of disciplinary integration.

The differentiation in the type and quality of the resulting EIS allows us to formulate three main observations on students’ understanding of the CE concept and consequently their ability to design EIS.

Firstly, both the complexity and the innovative character of almost all the EIS show how interdisciplinary research and collaboration provided a substantial benefit to the outcomes and the learning process. Students were able to translate their disciplinary perspective and methods into simple concepts while being open to ideas from others. As affirmed by Bridle, Vrieling, Cardillo, Araya and Hinojosa (2013), this willingness and aptitude provide face-to-face exchange and encounters fostering effective communication.

Secondly, each solution simultaneously addresses one or more issues, tackling specific parts of the waste flows in a holistic way, such as the building insulation material, organic food waste stream, and underused spaces. By developing EIS, students acquired a systematic design approach in a ‘learning-by-doing’ way. This approach allowed them to consider the effects of the interaction of different systems by focusing on larger-scale dynamics and observing their spatial effect. For instance, in the case of the MYC block solution, students propose to develop a biodegradable insulation material made out of fibres and mycelium fungi and based on already existing patents. Although the solution in itself is not new, the innovative character lies in the local production of fibres like reeds on unused (waste)land alongside specific canals in the AMA. A secondary systemic effect of this cultivation is the prevention of the salinization and subsidence of agricultural land, currently affecting parts of the AMA (OECD, 2017).

Table 2. EIS, their territorial and flow aspect, and the complexity of their integration.

Title	Territorial aspect(s)	Flow aspect(s)	Complexity of integration
Bio-seasonal parking; transforming seasonally underused car parks of the International Amsterdam Airport Schiphol into productive landscapes	Low spatial quality and negative effects on the ecological connectivity of large parking lots.	Food waste used as secondary raw material for the production of biodegradable asphalt alternatives	Product development to agricultural practices and spatial design of parking areas.
Mycelium (MYC) Blocks; new bio-isolation materials made out of plant fibres and fungi	Need for sustainable insulation material for the refurbishment of post-war neighbourhoods; Use of salinated and polluted areas for the growth of fibres.	Bio-based insulation material, agricultural wastewater cycle and food waste cycle	Product design, value chain design, and integration of spatial quality into environmental considerations
Enzymatic fuel cell; using neighbourhood extension project to store energy in public space	Multifunctional use of public spaces	Energy and food waste	Technology readiness assessment and spatial quality of its application on the neighbourhood scale
Greening up the city: a new solution for regenerative green facades	Negative environmental, health, and spatial impact of areas with a high level of impermeable surfaces	Organic waste for bioplastic production	Product development and building and planning regulations
Food Waste Insect Protein; Biowaste collectors with insect larvae to provide local farming fodder	Neighbourhood as an ideal collection scale for collecting food waste	Use insects to cycle food (waste) and provide nearby farms with animal fodder	Healthy and safe product development and collection strategy
Hospital bioplastic; Circular use of plastics in hospitals	The regional network of hospitals, waste processing facilities, and bioplastic production	Plastic recycling with specific material requirements	Chemical processes and geographic network analysis

If some solutions initially addressed circularity at the product level, others began by observing the spatial dynamics and territorial effects of a linear economy. The bio-seasonal parking EIS reflects on how to reclaim underused parking lots near the Schiphol airport. Students began by designing a biodegradable membrane that can substitute the conventional bitumen and secondly a specific urban structure of the car park to guarantee the water infiltration and avoid oil percolation. In this way, the solution allows to have temporary parking areas during specific months and to grow crops in the remaining months.

Eventually, through the development of EIS, students reflected on the partial implication of CE. From the results, it was clear that some students had had difficulties in understanding land as a resource and urban territories as ecosystems, going beyond the idea of space as a support for allocating products and functions. The limitation experienced by the students underlines the argument expressed by Williams (2019) regarding the inadequacy of the current conceptualisation of CE when applied to urban territories: "a circular city is about a great deal more than creating a CE and circular business models within the urban context. It is about the regeneration and renewal of complex urban ecosystems" (Williams, 2019, p. 15).

5. Validation of Study Outcomes by Students and Stakeholders of the CE Transition

Collaboration between university and practice is not new to design education. However, such collaboration is often dependent on a certain number of highly-motivated professionals. Very often, a structural perspective on regional collaboration in education is lacking (Ministry of Education, Culture and Science, 2015). In these two cases, the parties collaborating in the courses through the REPAiR project have a more collective motivation to, on the one hand, make a broader use of the knowledge available for students; on the other hand, to seek innovation via the interaction amongst students, teachers, and stakeholders who are involved in practice in the region. From the perspective of knowledge generation, students and teachers in the university are also seen as stakeholders in the region, contributing to its transition towards a CE. To validate the outcome of the teaching experiments, the authors collected feedback from all parties involved in such a situated learning environment. Due to the different settings of the two courses, the feedback was collected through various channels, including questionnaires distributed by student organisations, tutors' meetings, and interviews with stakeholders.

5.1. Feedback from Students, Teachers and Practitioners on the Regional Design Course

Every year, when the course is finished, questionnaires are distributed by the Urbanism student association POLIS to evaluate teaching quality. For this article, we used the reports of the past two years (2017 and 2018), when the collaboration with the REPAiR project was implemented.

In response to how did the lectures and workshops support or improve your understanding of the concept of flows and circular economy within a region, feedback shows that the workshop given by the REPAiR team on material flow analysis provided great help to students to break the CE concept down. However, students felt that such knowledge and skills are very basic or general. It would be more helpful if experts of respective flows (energy, waste, water, and so on) could give in-depth lectures. Or in other words, expertise from other disciplines is needed to facilitate real interdisciplinary work.

CE was a new topic for both tutors and students. Generally speaking, students liked to deal with a topic that they had not studied before and learnt a great deal from this topic, especially how it can be reflected in spatial visions and strategies. However, some students found the focus on CE to be a bit demanding.

5.2. Stakeholder Evaluation of the EIS Developed by the Students During the Geodesign for a CE in Urban Regions Course

On 18 September 2018, a PULL workshop was held in Amsterdam with 19 stakeholders. One part was dedicated to further develop EIS for the AMA. The EIS developed by the students in the geodesign course was used as one of the input sources (see Table 2). Other solutions were based on literature studies and pilot projects, or co-developed by the stakeholders themselves in earlier workshops.

Participants of the workshop included local authorities, policymakers, local business representatives, and international partners of the REPAiR consortium. The EIS were co-developed in separate worktables. The workshop participants were asked to select a draft solution and continue to develop that solution towards a more detailed and implementable solution. In a post-workshop survey, the participants were asked questions regarding their perception of the usefulness of the EIS developed in the workshop with regards to the CE objectives in the AMA. The participants were asked to rate the likelihood of the EIS, which they helped co-develop in the workshop, to help address the specific objectives for each CE topic in the AMA. For each CE objective in the AMA, participants rated the impact of each co-developed EIS from 1 to 5, with 1 being "very likely to address the objective" and 5 being "very unlikely to address the objective".

Detailed results of the questionnaire are reported in Remoy, Arciniegas et al. (2018).

The results can be summarised as follows:

(1) Concerning the objectives related to the redevelopment of wastescapes, the students' EIS were assessed as either "very likely" or "neutral" to contribute to the objectives. For some objectives like the redevelopment of wastescapes around Schiphol, the student EIS scored best. For the objective of creating trust and collaboration among stakeholders, the student EIS scored worst. The average value of non-student EIS overall objectives was 2.37, the best value was 1.89, and the worst was 3.10. The best student EIS score was 1.67, the worst 3.20, and the average 2.36;
(2) Concerning the objectives related to the food waste value chain, the student EIS were assessed as rather likely to contribute to the objectives. The average value of non-student EIS overall objectives was 2.31; the best value was 1.50 the worst 3.1. The best students EIS score was 1.50, the worst 2.0, and the average 1.87. The students' EIS were for neither objective the best nor worst scoring EIS;
(3) Concerning the objectives related to the construction and demolition waste value chain, the student EIS were assessed as "very" to "rather likely" to contribute to the objectives. The average value of non-student EIS overall objectives was 2.35. The best value was 1.00, the worst 4.00. The best student EIS score was 1.00, the worst 2.59, and the average 1.86. The students' EIS were for neither objective the best nor worst scoring EIS;
(4) To summarise, the EIS developed by the students during the course were seen at least as likely to contribute to addressing the defined challenges as those EIS that were co-developed by stakeholders in the area. Furthermore, most of the student solutions were considered more likely to contribute to the solutions than solutions based on pilot and literature studies from other places.

6. Discussion and Conclusions

In order to use the CE concept for a regional design, students had to integrate the concept with other, more traditional regional-design approaches to influencing the morphology of regional urbanisation and socio-economic functional relations, for instance. In most cases, students facilitated the CE concept through the association, or 'sampling', of classical and new themes. Outcomes of these combinations can be considered inspirational. Few projects, however, reached a deeper level of conceptual integration, expressed in verifiable interdependencies between issues from thematic fields.

In this context, it is important to consider the little time the students had to develop their projects (10 weeks). REPAiR experts tutoring student groups and providing extra workshops enhanced the quality of the projects, and the rich material in terms of policy documents (visions, agendas, and reports) supported the practical application of the CE concept.

The integration of the courses into the living lab activities had significant advantages. First, the students started with objectives formulated by real stakeholders, with the usual issues that they are often very vague and sometimes contradicting. A further advantage was that the students also had the possibility to present and discuss their results with the stakeholders during living lab workshops. This means that, specifically in the Geodesign course, the integration of research and design education provided the students with a situated and indeed transdisciplinary learning environment. The fact that the course is an elective course with a low number of students from different MSc programmes supported this learning effect. Achieving the same in a core course of a single MSc programme with a large number of students from one programme only is probably much more difficult and would require a rather radical redesign of several master programmes, which may take longer than externally funded on-going research projects.

One clear effect of the integration of the CE concept into teaching was that the students understood that they needed to address challenges from a systemic perspective rather early into the design process. They had to understand and distinguish the relations between different subsystems and their spatial structures. The students were faster than usual to relate specific and local problems of the linear economy within the wider economic and spatial system. This led to design proposals that went beyond problem-fixing at specific locations towards design proposals that discussed transitions and disruption and the role of regional structures and stakeholders within these processes.

A crucial outcome for regional planning and design practice and research was that the students' work amplified the need to work with scales and to reconsider the definition of a region. This working with scales is crucial for regional planning, where functional relations, predominantly commuting patterns, are often used to define borders of regions while ignoring flow relations that go beyond those limits. It is equally important for lifecycle-based sustainability assessments, which are often based on functional units that refer to administrative areas, such as municipality boundaries. Furthermore, it is a crucial shortcoming to ignore the complexity of the territorial metabolism of urban regions.

Finally, we are compelled to state that the integration of research and education was staff-intensive and thus required a higher teacher-to-student ratio than usual. Moreover, it asked for a high level of engagement and flexibility of the teaching staff. This engagement is a vital aspect when aiming to integrate research and education, considering that many universities in Europe are under financial pressure and that teaching loads are on the rise. Therefore, when aiming at the integration of research and design education, it is crucial that, at the time of writing a research proposal, budget and time requirements of staff involvement are already considered in the budget planning. Furthermore, teaching schedules are rather rigid and often defined a year in advance, which also needs consideration in the research design. It is absolutely advantageous if already existing courses have a clear structure, precisely defined learning goals, and required products that fit the research questions and the tasks of the research projects.

Moreover, clear transparency towards the students is important. Students need to be made aware that both the lectures they attend and the materials they receive constitute work in progress, and that the staff that provides workshops and feedback are not primarily trained as teachers. Students also need to be made aware of the ethical aspects of participating in a research project, such as how to deal with confidential data or working with results that are not yet published by the research team. The same holds for the researchers, who have to be ethical when using student work in further research activities and publications, and conscious that the grades of the students cannot be dependent on the value their work has for the research project, but rather on the general learning goals of the course.

If the above is considered well in advance then, according to our experience, the following aspects are crucial for successful integration: making sure that the teachers who are not experts in the added field of expertise are informed and educated in a way that they are comfortable enough to do their job; providing both additional workshops and lectures from the research team as well as stakeholder involvement in a structured way and at times when it fits naturally in the design process followed by the students; and finally, evaluating the course process and outcomes through feedback from students, teachers, and stakeholders, critically reflecting on these evaluations, and adapting the course if necessary.

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Conflict of Interests

The authors declare no conflict of interests.

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