

Opportunities and Challenges of a Geodesign Based Platform for Waste Management in the Circular Economy Perspective

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Abstract. In the framework of the circular economy, the operational integration of metabolic flows management and co-planning of waste territories, also defined *wastescapes*, has been implemented by the Geodesign Decision Support Environment (GDSE) platform, a tool developed in the H2020 REPAiR project. The GDSE can be described as a Decision Support System (DSS) to manage metabolic flows in a spatial GIS-based environment. Born as a tool for the resources management in peri-urban areas, the GDSE was also configured as a repository of multiple information. By comparing the main steps of the Geodesign Hub software and the GDSE platform, the paper intends to highlight the results obtained so far from the implementation of the GDSE and the main future development hypotheses. The primary purpose is to integrate wastescapes regeneration with the management of metabolic flows by realising evaluation maps, required by Geodesign Hub software, in the GDSE to trigger a holistic regenerative process for the circular city.

Keywords: Geodesign Decision Support Environment (GDSE) · Geodesign process · Circular economy · Evaluation maps · Wastescapes

1 Introduction

The circular economy is one of the central themes of new sustainable territorial development policies [1–4]. Today cities are mostly complex in terms of tangible and intangible infrastructures, need cyclical planning processes capable of promoting collaboration between the parties concerned to reach a shared agreement. Current tools and processes tend to follow their linearity, and as a result, there is a loss of collective knowledge that would facilitate an efficient and effective planning process at the same time. Moreover, collaboration becomes essential, especially in large-scale planning processes [5]. In this perspective, there is a need to identify which decision-support tools can improve evaluation and planning processes, at different scales [6]. An attempt is being made to screen out current tools and methods that allow integrating collaboration and participation into evaluation and planning processes for design new circular economy models.

The concept of circular economy was born in the context of industrial ecology, about the use and manufacture of products, as material resources of urban metabolism.

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The optimisation of the production chains from a linear to a circular model aims to cancel the production of waste, recovering any waste that can take on new value through circular recovery processes [7] and the most of the circularity indicators of a product concern strategies for preserving materials [8].

Moving from the production chains to the built environment that organises these chains, the implications of the circular economy extend, and the city itself, as a human product, can embrace the challenge of circularity. The visions for the future of the circular city are not clearly defined but include looping actions through reuse recycle and recovery [9]. Circularity is multiscalar, multidimensional and place-specific [10] and the management of urban metabolic flows and land use planning affect and produce impacts on each other.

Considering the challenge of managing urban metabolism and land use at the same time, integration of methods and tools for policy and design strategies is required to support decision-makers in such a multi-disciplinar approach. Moreover, circular looping strategies must be regenerative, and a regenerative development considers the interaction among community engagement, resources, and territories.

According to the above purpose, Spatial Decision Support Systems (SDSS) are among the most effective tools of DSS and allow to face complex novel problems as emergency response and public participation [11]. Geodesign process [12–14] can be considered a SDSS. It represents an emerging methodological approach to spatial planning and design, able to address many of the problems encountered in urban and regional planning practices. Step by step, through a series of evaluation and design phases, the Geodesign methodological process allows multidisciplinary groups to interact and collaborate in the creation of alternative scenarios. Cooperation is a fundamental feature for a sustainable and circular economy-oriented transformation, that affect the future of communities and territories [13].

The term *geodesign* was introduced in 2005 by Jack Dangermond [15] who defined it as a multidisciplinary and synergistic approach useful to solve complex problems involving not only territorial and environmental issues but also social and economic concerns [15]. In this sense, the Geodesign methodology represents a useful framework to address the complex spatial issues related to the circular economy challenges and the reuse of cities and territories [16], as it integrates multidisciplinary knowledge with the technologies of Geographic Information Sciences [17].

Urban unsustainable scenarios are spread all over the world, and often they are related to linear economy models. Take-make-dispose model corresponds to extraction-production-consumption actions that have huge impacts on lands. For instance, if material loops are not closed, waste can be disposed of in the landfill, large parts of territories can be consumed, and at the same time, many materials that are obtained from non-renewal resources are extracted. Many materials like sand and gravels can be recycled, avoiding quarries and environmental depletion.

Each human activity is deeply connected to territories. As well as products can become waste, lands or sites turn into unsolved territories in between [18], when abandonment, degradation and pollution become dominant. Wasted lands are a consequence of different drivers. Succeeding the concept of drosscape [19, 20], *wastescapes* are considered those parts of cities as a result not necessarily polluted - but where risk exposure is high - like ghettos, abandoned areas [18, 21], and those places

where social risk caused segregation. The transition of cities toward regenerative circular scenarios needs to bond the resource management, starting from the reduction, reusing and recycling of waste streams and the wastescapes regeneration through land-use planning. In this path, the integration of approaches and tools to support a collaborative decision-making process is proposed following the Geodesign methodology. The paper describes the research purpose and the methodological approach in Sect. 2; the Geodesign Decision Support Environment (GDSE), conceived as a collaborative decision-making process for resource management, is introduced in Sect. 3, and the Geodesign Hub platform is analysed in Sect. 4; the interaction between Geodesign Hub and GDSE by the evaluation maps is presented in Sect. 5; the discussion of results and conclusions are the content of Sect. 6.

2 Research Purpose and Methodological Approach

This paper illustrates the methodological process and the main outcomes of the Geodesign Decision Support Environment (GDSE) [22], to highlight its innovative aspects and critical issues that can be implemented to operationalise resource management and wastescape regeneration. The Geodesign platform has been developed as part of the H2020 REPAiR - Resource Management in Peri-Urban Areas: Going beyond the Urban Metabolism research project, to support collaborative planning processes in the transition to the circular economy. Geodesign process can be considered as a spatial-decision support system (SDSS) to facilitate circular co-design strategies of urban metabolic resources. In an attempt to pursue this goal, the GDSE implemented new types of evaluation maps of waste flows, necessary to support the knowledge of metabolic status quo and to guide the choices for closing the loops.

Starting from a methodological comparison of the GDSE with the Geodesign Hub (Fig. 1), both open-access web-based collaborative decision support systems, we intend to identify the main common ground in the Geodesign process and the main crucial differences with GDSE, for future integrations.

The highlights of the GDSE process are compared to that of Geodesign Hub to identifies the fundamental steps where landscape and wastescape evaluation maps can be made operative by integrating the eco-innovative solutions and land use policies or projects. In both systems, the Geodesign approach [12] is used, with six questions referred to six models [12] (Fig. 1):

1. How should the study area be described in content, space, and time? To answer this question, reference is made to the data collected for the study and therefore to the representation model.
2. How does the study area operate? What are the functional and structural relationships among its elements? In this case, on the other hand, through process models, knowledge about the territory under examination is outlined.
3. Is the current study area working well? That is where evaluation models come in.
4. How might the study area be altered? By what policies and actions, where and when? Change models try to answer this question. Once developed, they are compared and then used to represent future conditions.

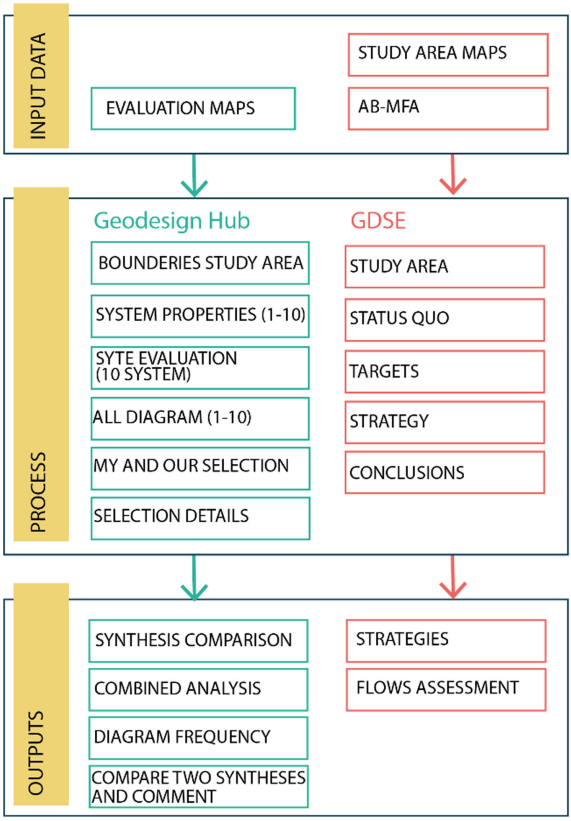


Fig. 1. GDH and GDSE methodological workflow compared (Elaboration of the authors).

5. What difference might the changes cause? It is possible to answer the question through impact models.
6. How should the study area be changed? Through decision models, how the area under consideration can change.

The Geodesign Hub platform allows different stakeholders to be involved and collaborate to reach one or more negotiated design strategy. Conceived at the Centre for Advanced Spatial Analysis at University College London by Hrishikesh Ballal [23], this platform is based on the Geodesign framework designed by Carl Steinitz [24].

This GIS-based tool incorporates planning, landscape architecture, geography, and engineering in a combination of disciplines that constitutes an SDSS, that combine local knowledge and information technologies.

To carry out a process in Geodesign Hub, three main phases are required: 1. pre-workshop; 2. workshop; 3. post-workshop. The first phase refers to the evaluation of the selected area and is based on representation models, process models and evaluation models. The second phase refers to the intervention based on change models, impact models and decision models [12]. This phase is where the Geodesign laboratory takes

place. The third phase refers to the ex-post elaboration of a report. Both the first and the third phase are developed by the researcher who plays the role of facilitator in the second phase. In a similar way, the GDSE process needs a preparation phase before the workshop and a successive phase to analyse the obtained results.

Referring to the Geodesign framework, it is possible to define similarities and differences between the two open platforms, in their basic data and concerning the interactions of input data, process data and output data.

In Geodesign Hub as input data, ten evaluation maps present the status quo of the systems considered. In the software, the maps become interactive and at a later stage, and work together with the different diagrams.

In the GDSE the interface presents the wastescape maps at the actual state and an Activity-Based Material Flow Analysis (AB-MFA) of material and waste flows. These two maps, however, do not fully interact in the GDSE process.

Besides, the evaluation maps in the Geodesign Hub allow defining those optimal locations where an intervention could be expected. This is especially important in the third phase, where stakeholders, by mutual agreement, choose one preferred scenario among the proposals defined in the second phase of the workshop.

In the GDSE process, there is no real construction of possible proposals, but the qualified researcher proposes upstream, possible places where to implement the eco-innovative solutions already known at an early stage.

Following, the methodological structure and the steps that constitute the GDSE are presented. Subsequently, a comparison with the Geodesign Hub workflow allows presenting the hypotheses for the implementation of wastescape management in the GDSE, having a unique SDSS that connect material flow and land use management in circular strategies.

3 The Geodesign Decision Support Environment: A Collaborative Decision-Making Process for Resource Management

The Geodesing-based GDSE methodology has been developed in the H2020 REPAiR project as an open-source DSS tool to improve resource management in the transition toward a circular economy [18, 25–28]. Mapping material and waste flows the first step to understanding their dynamics and implementing solutions and strategies to improve urban metabolism. The REPAiR project methodology is based on the co-creation framework that is structured in five phases and uses three interactive methodologies: Geodesign Decision Support Environment (GDSE), Peri-Urban Living Lab (PULL), and Life Cycle Assessment (LCA).

The five phases Co-Exploring, Co-Design, Co-Production, Co-Decision, and Co-Governance are performed in PULLs and lead by the Geodesign team. PULLs have been activated by workshops with stakeholders and actors involved in each phase of the project [29]. LCA has been externally developed to assess the sustainability of impacts related to status quo and eco-innovative solutions on each key flow supply chain

selected. In the Naples case study, two LCA have been done for organic waste and construction and demolition waste status quo and for an alternative scenario.

In REPAiR project, the methodology has been developed and tested in two pilot cases, and four follow-up cases. In Naples, the key flows considered are organic waste and constructions and demolition waste, and both relevant wastes flow with different significant impacts in their life cycles and with high impacts on territories and wastescapes. In the methodological framework, PULLs identify the opportunity to let decision-makers know the status-quo, ranking objectives and targets and to enable cooperation for territorial transformations, within a collaborative and adaptive decision-making process.

The GDSE workflow is composed of five sections. It can be managed in setup mode by researchers and in workshop mode for the public sessions. The workflow is here presented as stakeholders can use the tool in a Geodesign session.

The first step presents the study area. It is composed of:

1. the wastescape mapping elaborated in pre-workshop phases; according to the REPAiR framework, implemented by the research group and in PULLs with citizens and local actors (Table 1);

Table 1. Wastescapes layers mapped in Naples study area (REPAiR, D.3.3, 2018)

Wastescapes categories	Layers in legend
Degraded lands	nsw_1_1 Polluted Soils
	nsw_1_2 Artificial Soils
Degraded water	nsw_2_1 Degraded water bodies
	nsw_2_2 Elements linked to degrades waters
	nsw_2_3 Flooding zones
Declining fields	nsw_3_1 Abandoned agricultural fields
Settlements and buildings in crisis	nsw_4_1 Vacant underused buildings and settlements
	nsw_4_2 Urban settlements suffering from fatigue
	nsw_4_3 Poor housing conditions
	nsw_4_4 Informal settlements
	nsw_4_5 Urban lots in trasformation tampered
	nsw_4_6 Unauthorised buildings and settlements
	nsw_4_7 Confiscated assets
Dross of facilities and infrastructures	nsw_5_1 Neglected dismissed underused infrastructures
	nsw_5_2 Dismissed underused public facilities
	nsw_5_3 Interstitial spaces of infrastructures networks
	nsw_6_3 Storage facilities
Operational landscape of waste	nsw_6_4 Waste recovery
	nsw_6_10 Incinerators
	nsw_6_11 Vehicle dismantling

2. some relevant charts elaborated in PULLs;
3. lists of stakeholder groups;
4. descriptions of the waste key flow.

In the second step, the status quo is described by:

1. flows maps (Fig. 2) and Sankey diagrams of the key flows (Fig. 3);
2. some flow indicators of selected waste key flow on inhabitants or spatial units;
3. map of the study area and wastescape layers;
4. reports of the sustainability assessment on both waste key flows;
5. some lists of general and specific challenges and objectives on local flows.

Status quo of the key flow presents the activity-based material flow analysis, a flow assessment process steps and primary outcomes. In the target section, the objective presented in the status quo can be ranked. Based on some flow indicators defined by the research group, the team of Geodesign can identify the targets for increasing or reducing each significant flow indicator (Fig. 4) per key flow.

The strategy section is the step where stakeholders' groups can build the change model, and it is composed of a set of sub-steps:

1. The eco-innovative solutions (EISs) previously elaborated and implemented in the system are presented. EISs are actions that enable reduction of waste flow.
2. The elaboration of more strategies is activated with the cooperation of stakeholders by selecting the EISs and their implementation area (Fig. 5). These areas will activate a place-based solution, then on specific key flows and actors involved, classified per activity group with the NACE code.



Fig. 2. Activity based-material flow map of mixed construction and demolition waste (EWC 170904) produced in Naples focus area in 2015 (source: Screenshot from GDSE. Elaboration of the authors)

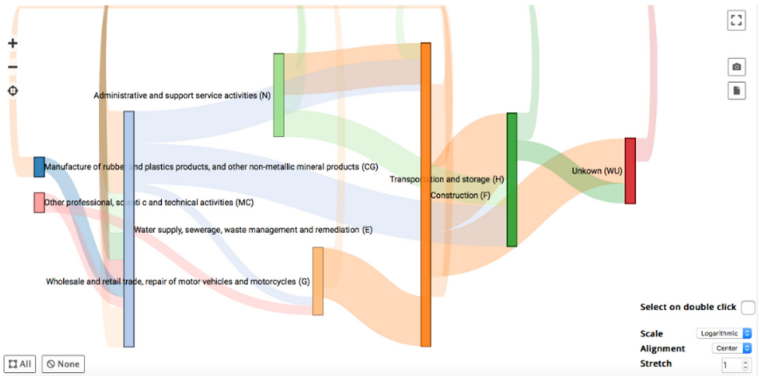


Fig. 3. Sankey diagram at the activity level of AB-MFA mixed construction and demolition waste (EWC 170904) produced from Naples focus area in 2015 (source: Screenshot from GDSE. Elaboration of the authors)

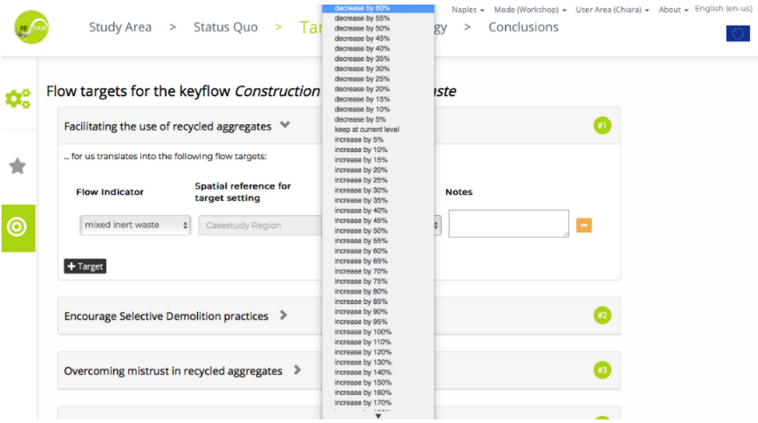


Fig. 4. Flow target selection for key flow (source: Screenshot from GDSE. Elaboration of the authors)

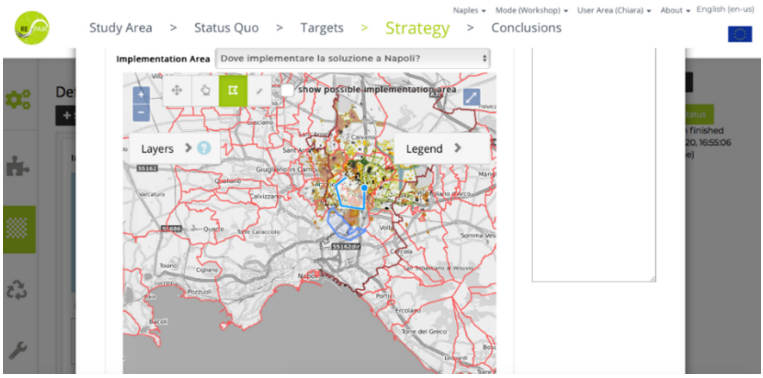


Fig. 5. Strategy elaboration: the selection of an implementation area for an EIS (source: Screenshot from GDSE. Elaboration of the authors)

3. The presentation of modified flows as results of combined EISs in strategies.
4. The control of flow target allows stakeholders to check the effectiveness of their choices.

In the last step of conclusions, results are presented by answering the following questions:

1. How to rank the alternatives per group?
2. Which flow indicators were used for target settings on which objectives?
3. Which target values were set?
4. Which EISs were selected for the strategies? How where the questions answered?
5. Where were the solutions applied?
6. Which actor groups are involved by the selected solutions and which most often?
7. Which stakeholders were chosen for implementing solutions?
8. How much do the strategies modify the flows?
9. Which strategy can meet which own target?

The GDSE workflow activates a decision-making process for the management of metabolic flows only considering the AB-MFA. The wastescape that are presented in the first section remains exclusively in the cognitive context of the co-exploring phase, but do not become operational in the elaboration of the strategies, or models of change. Therefore, the results of the process are based on the knowledge of the wastescape, but they do not give the opportunity to hypothesise policies or projects together with the management of the supply chains. For an integrated circular city strategy, it is necessary to integrate land management. For this purpose, the possibilities offered by the Geodesign Hub platform are analysed below.

4 Geodesign Hub Platform

The Geodesign Hub PSS [23] is an open-source platform mainly used to manage and organise complex problems, mainly related to the territory, promoting a collaborative decision-making process between the different actors involved. Developed to implement the Geodesign framework [12, 22] and to foster participatory and interactive planning [30], it combines the concepts of the planning support system [31, 32] with the principles of web 2.0 [32], which includes and allows different types of activities involving the public to participate in data collection, problem definition and decision-making [33, 34]. The platform is used to support planning processes allowing the different actors involved to interact. Through workshops, the actors engaged are led to define strategies in a collaborative way supported by some tools within the Geodesign Hub [30]. As for the GDSE, there is a configurational management model used by the expert researchers and a laboratory mode implemented in public sessions by the different participants involved. It is also composed of seven sections. The first section is dedicated to the visualisation of evaluation maps related to 10 priority systems (Fig. 6). These represent vulnerabilities and attractiveness for the territory. They are defined in the start-up phase of a project and after consultation with the main contract holders. Usually, 10 are defined, but they can be integrated in relation to the study area

characteristics. Some model systems refer to cultural heritage, ecology, tourism and agri-food sector, green and blue infrastructure, transport, soft mobility, low and high-density housing or trade and industry. Each of these is fundamental to the definition of objectives. They are indicated by acronyms in the platform. Their definition starts with the analysis of the status quo to the elaboration of evaluation maps, which are then provided to the participants during the workshop. The second section (Fig. 6) of the Geodesign Hub interface allows the different actors involved to outline geo-referenced project proposals on an interactive map for each of the different coloured systems. These different project ideas can then be selected and visualised in a third section, where it is possible to view a summary map of the interventions and details about hectares and costs for the whole project. The fourth section is dedicated to the verification of impacts and subsequent comparison (fifth section) (Fig. 7), where workshop participants, divided into teams with the relative objectives to be pursued, select the different diagrams and compare them. In the sixth section, it is possible to compare the teams' proposals by a pairwise comparison and then reach the last section where a joint strategy between the stakeholders is defined through a negotiation phase (Fig. 8). Indeed, the Geodesign Hub platform allows the actors involved in a decision-making process to define a common agreement by reasoning through spatial analysis [30].

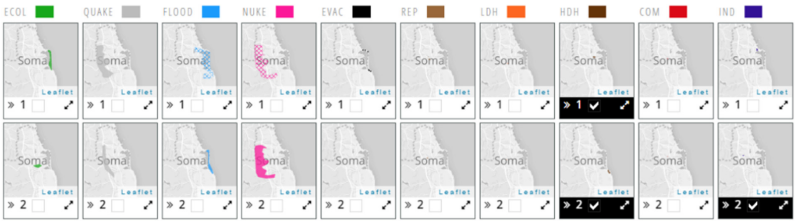


Fig. 6. Designing with diagrams: simple diagrams across systems synthesised into designs (source: Screenshot from Geodesign Hub platform https://www.geodesignhub.com/. Courtesy of Hrishikesh Ballah)

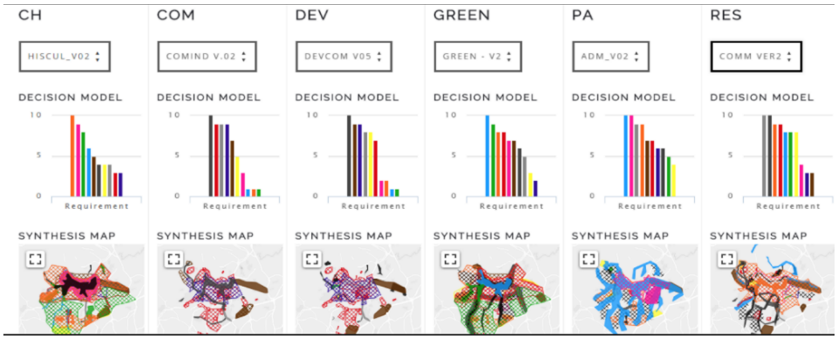


Fig. 7. Synthesis comparisons design: compare decision model and negotiations table (source: Screenshot from Geodesign Hub platform https://www.geodesignhub.com/. Courtesy of Hrishikesh Ballah)

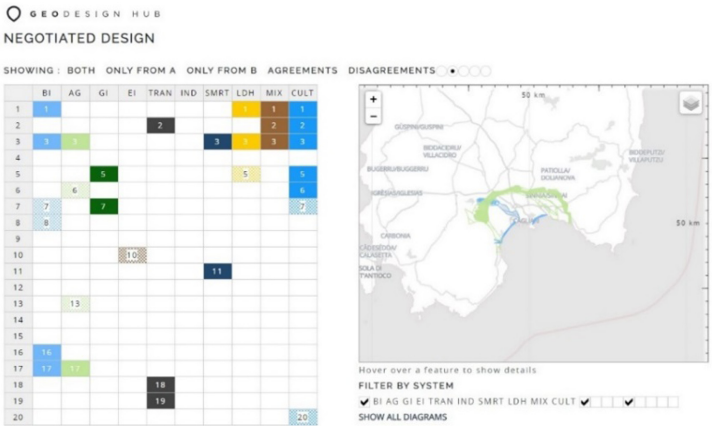


Fig. 8. Negotiation design (source: Screenshot from Geodesign Hub platform: DLA Geodesign workshop 2020 https://www.geodesignhub.com/. Courtesy of Hrishikesh Ballah)

5 Geodesign Hub and GDSE Interplay: Evaluation Maps

Each territory inherently has its vocation [14], and consequently, to define the evaluation maps, it is necessary to consider every aspect of the territory in question. The evaluation maps within the Geodesign Hub platform are built at an early stage by expert researchers who spatially analyse each phenomenon starting from the description of its conditions in the status quo. Evaluation maps can be constructed in three main ways:

1. Sketching by hand using printed maps and red, yellow, green markers and digitising the sketched maps directly on Geodesign Hub.
2. Using the GIS software where to insert the various existing data to analyse it then spatially.
3. Using automatic sprits, but, in this case, it is necessary to have previous knowledge in programming languages.

In the Geodesign Hub software are loaded in the pre-workshop phase the evaluation maps that are represented with a standard colour gradation (from red to green) defining the parts of the territory more attractive or vulnerable for given land use. The maps are elaborated for all the systems taken as reference for the study of the selected area. The researchers of the Geodesign Hub articulate the process of creating such maps in 10 systems that describe the main characteristics of the territory [14]. Each system corresponds to an evaluation map. The colours to be used can be either three (red, yellow, and green) or five (red, yellow, light green, green, dark green) and is specifically related to technical knowledge of the study area.

Each of these five colours represents a fundamental characteristic:

1. Red (Existing): Better not compromise the system.
2. Yellow (Not Appropriate): it is not a good idea to act in that place.

3. Light green (Capable): interventions can only be identified if the right tools are available to support them.
4. Green (Suitable): it is possible to define the project in this area because the territory is already provided with appropriate technologies to support the project.
5. Dark Green (Feasible): the area is feasible to define a project.

In the REPAiR project, a mapping of the wastescapes has been made, in order to identify them as places to be redeveloped and put into a system with waste conceived as a resource on the territory in the perspective of the circular economy. In the process, they were mapped through hard data elaborated by the research group and soft data derived from a collaborative mapping activated in PULLs [35]. Regarding the relevance of including evaluation maps in the GDSE, the Geodesign Hub platform helps to reflect and reason on some issues not to be underestimated. In itself, wastescapes represent critical areas or critical elements of the territory. These can be identified such as: disused buildings, places to be reclaimed, interstitial areas of infrastructure, buildings to be demolished that produce waste (Table 1), and their regeneration represents one of the objectives to be pursued on which it is necessary to develop eco-innovative considerations and solutions. By reasoning with respect to the Geodesign Hub, wastescapes become subsystems of the ten main systems. For example, since they represent highly critical areas in the status quo, they should be assessed individually according to the criteria that make them suitable or not suitable for transformative planning actions. The ten reference systems suitable to pursue the regeneration objective, also defining in the function of eco-innovative solutions, could be:

1. Environmental system;
2. Green infrastructure system;
3. Blue infrastructure system;
4. Transport system;
5. Soft mobility system;
6. Cultural system;
7. Functional mixing system;
8. Agricultural system;
9. Industrial system;
10. Energy system;

For each of these systems, as described in detail above, it is necessary to create evaluation maps on which to reason in order to identify and define both governance and planning strategies. All this can simplify the participatory process and the active involvement of the different actors not only in the analysis phase, developed during the PULLs, but also in a preparatory phase of solutions and decision-making.

A further challenge is to identify which criteria and indicators need to be considered in order to converge the evaluation of the interactive waste stream with the evaluation maps for each of the systems. The idea could be to display in single screen waste streams and evaluation maps both in the first phase of the analysis and in the impact and final transformation phases. In this way, the regeneration of territories through

planning tools in a virtual environment acquires greater importance because it also evaluates waste management and considers every aspect of it, thus determining cyclical and sustainable processes for territories.

6 Discussion and Conclusions

In recent years, the research towards a successful model design of circular economy implementation included different studies and scientific publications, concentrating on business model, product design and process individually [36]. At the same time, the circular economy is seen as an opportunity to conciliate the competing objectives of economic, environmental and social benefits [37].

According to Velte et al. [36] circular economy can be described with a hierarchy of objectives, based on the value-focused thinking approach for widening the decision context and exploring the consistency of the decision-maker purposes and the strategic decision context. This means that, for a decision-maker, the context-specific alternatives need to be elaborated and evaluated considering an integrated, dynamic and open decision-making process. Indeed, a decision-making process can be defined as a procedure of learning and negotiation between a multiplicity of actors and the decision-maker, where mutual interaction allows to improve the decision.

Implementing the Geodesign process as a dynamic methodology means encouraging interaction and collaboration between all actors who are involved in a decision-making process. At the same time, GDSE starts considering wastescapes and waste flows as a whole system, but in eco-innovative strategies design, wastescape is just a layer to select the implementation area of the solutions. Territorial and spatial planning is not part of the capability of the platform. It allows us to have a dynamic view of the status quo of waste and material flows and to have an interactive material mass balance according to the selected solutions.

The Geodesign process enables a collective DSS, that involves and activate a public, private, people partnership making operative the decision-making process. It can support planning oriented to circular economy process, by considering waste flows as resources for eco-innovative strategies in the landscape regeneration. The integration between the Geodesign Hub maps management and the GDSE process allows to combine the opportunities of each of the two approaches and to structure a Decision Support System suitable for making the circular economy model operational, applying the value-focused thinking approach. This paper presents the first step of a methodological process and some considerations for integrating active management of territorial, metabolic and social resources through planning and evaluation tools.

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