REPAiR

REsource Management in Peri-urban AREas: Going Beyond Urban Metabolism

D2.1 Vision of the GDSE Applications

Version 3.1

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Acronyms and Abbreviations

4TU	4TU-cooperation of TU Delft, Eindhoven University of Technology, University of Twente and University of Wageningen
CE	Circular Economy
D	Deliverable
EC	European Commission
EU	European Union
GA	Grant Agreement
GDSE	Geodesign Decision Support Environment
Geo-Col	Geo-Col GIS and Collaborative Planning, Amsterdam
GGR	Gertz Gutsche Rümenapp - Stadtentwicklung und Mobilität, Hamburg
GIS	Geographic Information System
HCU	HafenCity University, Hamburg
LCA	Life Cycle Assessment
IGiPZ	Institute of Geography and Spatial Organisation, Polish Academy of Sciences, Warsaw
INSPIRE	Infrastructure for Spatial Information in Europe
LL	Living Labs
MS	Milestone
OSF	Open Science Foundation
PM	Project Month
PULL	Peri-Urban Living Labs
RKI	Institute for Regional Studies, Centre for Economic and Regional Studies of the Hungarian Academy of Sciences, Pécs
SQL	Structured Query Language
TUD	Technical University of Delft, Delft
UG	University of Ghent, Ghent
UNINA	University of Naples Federico II, Naples
VFG	Vegetable, fruit and garden waste
WebGIS	Web-based Geographic Information System
WMS	Web Map Service
WFS	Web Feature Service
WP	Work Package

Contents

Publishable Summary

REPAiR applies a geodesign approach to the field of waste and resource management. On that account, it aims to reveal both local and space-specific challenges of waste and resource management as well as integrated and place-based eco- innovative solutions for these challenges.

In order to put this into practice, REPAiR combines Steinitz (2012) and Campagna (2014) concept of geodesign with the methodology of Life Cycle Assessments (LCA) and Living Labs (LL) and applies these to six case studies within the EU. As a reference to the peri-urban settlement structures of the six case study regions, the Living Labs, where the combined geodesign/LCA-approach will be used to discuss and co-design solutions and strategies to the specific challenges in waste and resource management, the Living Labs are called PULLs - for *Peri-Urban Living Labs*.

As deliverable D 5.1 explains in more details, PULLs consist of a larger number of meetings, structured differently in terms of type and participants. A major component of each PULL is a series of workshops, in which regional public and private stakeholders from the field of waste and resource management are asked to participate in a co-designing process for solutions and strategies. Providing these stakeholders with a common platform of information and solution design options is the core task for a computerised interactive communication tool called *Geodesign Decision Support Environment* - or GDSE for short. Developing, testing and applying this GDSE is one of the pivotal elements of the REPAiR project. The GDSE will be available as an open source product once the project is finished.

Deliverable 2.1, being the content of this document, develops a detailed vision on how this to-be-developed GDSE should look like and work in order to meet the goals and requirements linked to its foreseen usage. According to this vision:

- The GDSE will consist of two major columns, of which
  - column I corresponds to the above described application as an interactive communication tool enabling a co-designing process for solutions and strategies with stakeholders in the workshop series of the six PULLs, while
  - column II of the GDSE is a common online working space for co-ordinating research work and model development of the big REPAiR team spread out over several institutions and EU-member countries.
- Column I of the GDSE (used for the PULLs) will mainly define the research and model development work of the REPAiR team working on column II.
- Column I will assure an interactiveness of a touch enabled user interface used as a key component in the workshops of the six PULLs.
- Column II will provide the team members with common base data. In order to produce this data, it will also provide tools for harmonising data from differ-

ent sources, integrating submodels of different research partners and coordinating model applications to alternative material and waste management.

- Column I will use a subset of the data from column II for each respective PULL. In order to achieve the above mentioned interactiveness its assessment models are a reduced version of the complete models from column II, using pre-calculated outcome lists as a way to heavily reduce calculation time without compromising accuracy of the results.

Even though already very specific towards certain aspects, the vision for the GDSE presented in this deliverable has to be further defined and concretised in the next steps of the project. These steps have already been defined in the scheme of milestones and deliverables from the project proposal which will be followed as planned.

1 The GDSE in the overall REPAiR project approach

1.1 What is a Geodesign Decision Support Environment (GDSE)?

As already laid out in detail in the REPAiR project proposal[1], REPAiR applies a geodesign approach to the field of waste and resource management. By doing so, it aims to reveal both local and space-specific challenges of waste and resource management as well as integrated and place-based eco-innovative solutions for these challenges.

In the terminology of the REPAiR project a *solution* is technical, organisational or juridical approach to solve one specific material and waste management challenge. Combinations of solutions are called *strategies*. Thus, a Geodesign Decision Support Environment (GDSE) in the context of the REPAiR project is a tool to develop and comparatively assess alternative strategies in the field of material and waste management.

Geodesign is defined by Campagna (2014) as:
"an integrated process informed by environmental sustainability appraisal, which includes project conceptualisation, analysis, projection and forecasting, diagnosis, alternative design, impact simulation and assessment, and which involves a number of technical, political and social actors in collaborative decision-making."

The advances of geodesign compared to older landscape and environmental planning approaches are threefold:

- it allows an extensive use of digital data in design, evaluation and communication;
- it gives a prominent role to design, by developing spatial solutions to specific place-based (genius loci) problems;
- its transdisciplinary nature calls for collaboration.

REPAiR adapts Steinitz (2012) geodesign framework, comprising six questions that are asked at, at least three points in a geodesign project to understand the study area, to specify the methods and to perform the study:

1. How should the study area be described?
2. How does the study area operate?
3. Is the current study area working well?
4. How might the study area be altered?

[1] https://drive.google.com/file/d/0B2CAnntPrD6AYm9rdjVBZmRGcHc/view

5. What differences might the changes cause?
6. How should the study area be changed?

As much as it is helpful to the REPAiR, Steinitz's approach was not yet extensively applied to research questions in the field of waste and recycling. Waste and recycling are closely linked to production chains. *Cradle to grave* is the problem-causing business-as-usual in these chains - and *cradle to cradle* the great vision of a circular economy to be reached step by step. The degree to which production chains are meeting the requirements of the *cradle to cradle* - vision can be measured using life cycle analysis (LCA). In REPAiR, LCA is therefore added as an essential component to Steinitz's approach. LCA analyses the impacts of products along all steps of its production chain and therefore are an important part of the evaluation of (potentially) eco-innovative strategies aiming to use waste as a resource.

Linking LCA to Steinitz approach includes some methodological challenges, as geodesign is - by definition - strongly space-related. Even though all material flows to be looked at in an LCA do have a spatial component, the current state-of-the art LCA methodology does not include fine-scale spatial differentiation. The GSDE - and the REPAiR project as a whole - therefore have to find a way of combining geodesign and LCA by using different levels of spatial differentiation inside and outside to specific, mostly peri-urban, focus areas.

With Steinitz's and Campagna's concept as its methodical starting point and LCA as its major supplement, the REPAiR project creates and uses a Geodesign Decision Support Environment (GDSE) to technically fulfil these approaches and practically apply these underlying methodologies to the six regions, where its Peri-Urban Living Labs (PULLs) are held:

- Ghent (Belgium)
- Amsterdam (Netherlands)
- Naples (Italy)
- Pécs (Hungary)
- Łódź (Poland)
- Hamburg (Germany)

Thus, in sum, REPAiR's Geodesign Decision Support Environment (GDSE) is at the same time:

- a data-based modelling programme for evaluating alternative waste and resource management strategies by modelling social, economic and environmental impacts (e.g. on public health, prosperity, natural resource asset, social well-being);
- a common cloud-based platform for the internal research process of the REPAiR team consisting of 18 research institutes and companies from six different EU-member states;
- the putting-into-practice of the methodological ground concepts (Steinitz, Campagna, LCA) for waste management and recycling;
- the major interface for communicating with the stakeholders brought together in the regional PULLs and including them into a co-design setting;
- an outcome of the REPAiR project by itself, as it will be available as an open source tool to everybody by the end of the project.

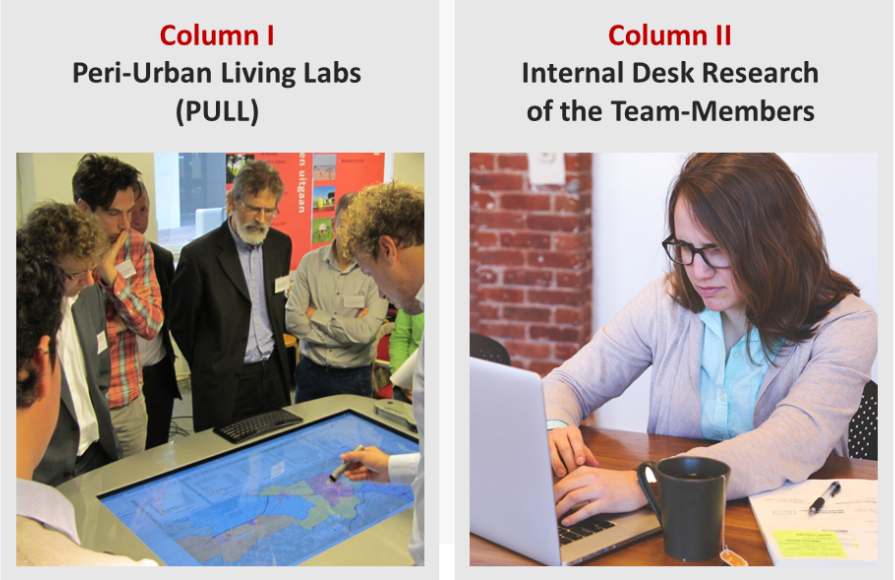

Figure 1.1. *The two columns of the GDSE*

1.2 Two essential roles of the GDSE within the REPAiR project structure

As shown above, the GDSE plays an essential role in the overall REPAiR project structure. Accordingly, the executive summary of the REPAiR project proposal starts with the following sentences:

"The core objective of REPAiR is to provide local and regional authorities with an innovative transdisciplinary open source geodesign decision support environment (GDSE) developed and implemented in living labs in six metropolitan areas. The GDSE allows creating integrated, place-based eco-innovative spatial development strategies aiming at a quantitative reduction of waste flows in the strategic interface of peri-urban areas. These strategies will promote the use of waste as a resource, thus support the on-going initiatives of the European Commission towards establishing a strong circular economy."

Technically and organisationally, there are essentially two roles the to-be-developed GDSE will fullfil:

1. It will be the core element of communication and co-designing with the stakeholders involved in the six PULLs in order to transparently develop, access and discuss requirements and alternative options for solutions towards the specific PULL-topics.
2. It will serve as an important element to co-ordinate the internal research of the REPAiR team.

These two roles define what is referred to as the two columns of the GDSE in Figure 1.1 and the rest of this report. Column I stands for the part of the GDSE especially designed for the Peri-Urban Living Labs (PULLs). Its content, goals and requirements as well as its general GDSE concept are explained in greater detail in Section 2. Column II refers to the part of the GDSE designed to facilitate and coordinate the internal desk research of the team members. It provides them with base layers and datasets. In addition, it sets the ground for a common modelling approach that will later feed into the content of the GDSE's column I. A detailed description of the goals and requirements as well as the general concept of column II can be found in Section 3.

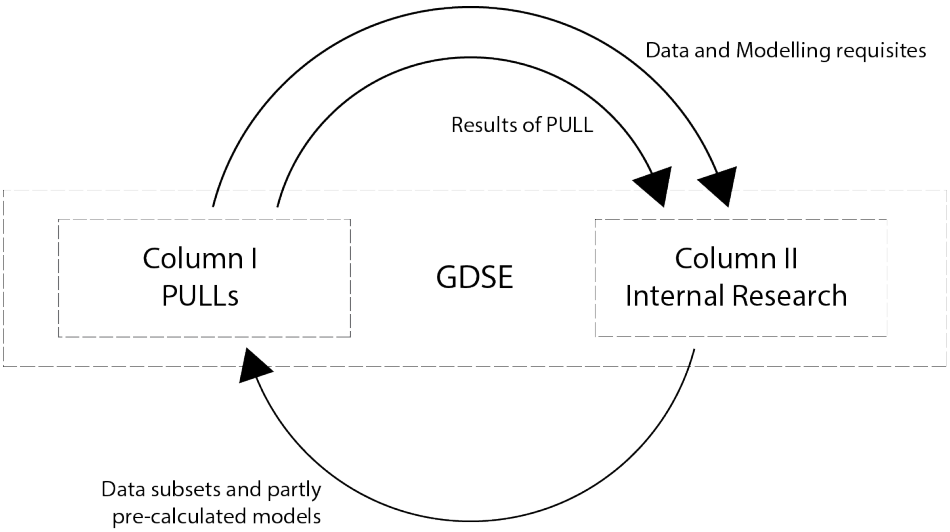

Figure 1.2. *Major interactions between the two columns of the GDSE*

1.3 Interaction of the two columns of the GDSE

The two columns do not coexist without reference to each other. On the contrary, there is a strong interplay between the two (Figure 1.2). Column II, being an integral part of the internal research of the team members, will actually be important in shaping the content of the modelling methodology of column I. Vice versa, the PULL behind column I define most of the research and modelling focus of column II.

Both columns of the GDSE will include databases containing:

- layers of geodata;
- datasets with or without spatial references;
- model components for estimating flows, stocks and impacts;
- management tools for keeping the overview over data, results, versions and strategies.

How these databases will look in detail is partly described in the following sections and will be even more precisely defined in the deliverables to come. Using some of the structures already defined in this deliverable Figure 1.3 links the three relations shown in Figure 1.2 to some of these database components. The three following general aspects are important to highlight at this point:

- The database of the PULL-part of the GDSE (column I) will always be an excerpt of the - bigger - database of the ongoing research process of the REPAiR team (column II).
- The PULL-version of the modelling (column I) will be a “copy” of the research version of the modelling (column II), in which as many sub-models as possible are exchanged for pre-calculated tables and maps containing the effects of (more or less) all relevant and reasonable variations and combinations of solutions (e.g. locations of facilities or options of waste treatment processes) to be discussed or proposed during the PULLs. This high degree of pre- calculation will assure the short calculation times and stability defined as a requirement for column I in Subsection 2.3.

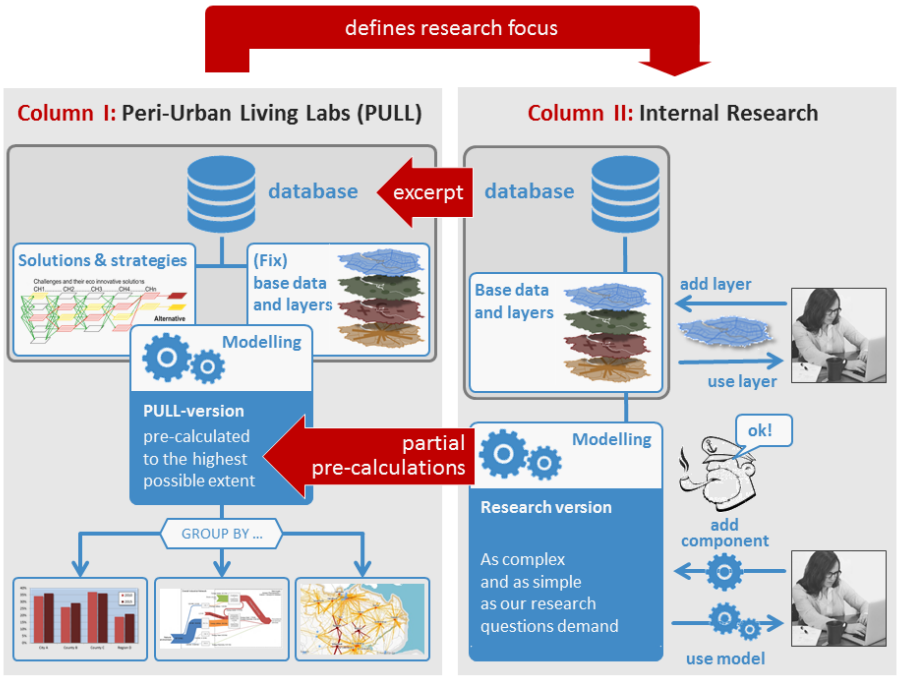

Figure 1.3. *Technical details of the interaction between the two columns of the GDSE*

- The perspective of discussing and co-designing solutions with local stakeholders in the PULLs (column I of the GDSE) is the driving force behind all research and modelling of the REPAiR team members (column II). Thus, even though column I looks like "a poor copy" of column II, it is actually column I's PULLs that define most of the research and modelling focus to be tackled in column II. Otherwise column II (the research version) could not provide the adequate modelling for the PULLs (column I). The definition of the research focus (data and modelling requisites) by column I will be stepwise: First, the PULLs will define the key challenges, the key waste fractions and the territorial scale of the research (Table 2.1). Later the outcomes of the PULL's workshops and meetings (Section 3) will more and more specify the solutions and strategies to be analysed in further detail.

2 Column I: GDSE for the Peri-Urban Living Labs (PULLs)

2.1 The central role of the PULLs in the REPAiR project

One of the major characteristic of the REPAiR-project is its aim to work with real stakeholders in real regions under real conditions. In doing so, REPAiR applies the methodology of the *Living Labs*, bringing together people from the private and the public sector as well as from the research project. As the spatial focus of the REPAiR project is the peri-urban areas, the Living Labs are mostly referred to as *Peri-Urban* Living Labs (PULLs). They will integrate the research and teaching activities related to REPAiR with the activities of local consortium partners, and the collaboration of the userboard and other local stakeholders. A more detailed descriptions of the methodological approach of the Living Labs and its application to the PULLs within the REPAiR project can be found in deliverable D 5.1 (”Methodological guidelines (Handbook) for the PULLs”).

The PULLs are the space and time for the in situ development of strategies for a circular economy (CE) within transdisciplinary teams. Each PULL will include a series of meetings of different kinds. The major events of this series are referred to as workshops. Especially in these workshops the GDSE will play an important role as the medium for exchanging information and co-designing solutions and strategies. The focus of these workshops will change over time.

REPAiR applies a co-creation of knowledge approach, which means that the first workshops will focus on defining the key challenges towards the development of a CE as well as impact categories that are relevant for regional decision makers. Thereafter, the workshops will concentrate on the development testing and evaluation of eco-innovative solutions for the identified challenges and finally on the development of a strategy based on the eco-innovative solutions.

The PULLs in the two pilot case study areas, namely Amsterdam and Naples, have a duration of 18 months each. They run in parallel and will be used to test the different components, specifically of column I, of the GDSE. The four follow-up PULLs have a duration of 3 month each.

The aim and challenge from the point of view of WP 2 is to demonstrate that the GDSE is flexible enough to operate within different cultural and geographical settings. The setup of the PULLs and the methodological approach is being set up and described in D5.1, which is due in project month 6.

2.2 Content of the six Peri-Urban Living Labs (PULLs)

The six PULLs within REPAiR have different challenges concerning the development of a circular economy, which come with different territorial foci in the sense of location and scale, different governance settings, as well as different importance

of the various fractions of waste and resources. Each PULL aims to identify the current environmental, social and economic problems related to the chosen topics and tries to create adequate CE solutions.

Table 2.1 summarises the state of key challenges as formulated by the local stakeholders and partners of the REPAiR consortium until project month 4. A first comprehensive list for the pilot cases will be provided by WP 6 in project month 6.

Case	Key challenges	Key waste fractions	Territorial scale
Naples	Socio-ecological use of wasted landscapes (drosscape and operational landscape of waste)	Wasted landscapes; agricultural waste (bio-waste); building and construction waste	Campania region with focus on the *Land of Fires* (Peri-urban in the Metropolitan Area of Naples)
Amsterdam	Higher level of reuse and recycling of household waste; refurbishment of old and energy inefficient household and office building stock; further development of CE business cases on the regional scale	Building and construction waste; municipal solid waste; biowaste households/agriculture; wasted landscapes	Amsterdam Metropolitan Region - with special focus on the three port areas: in the north and west (harbour), in the south (airport) and in the south east (the green port)
Ghent	Decrease residual waste; shift towards higher VFG fraction; low collection efficiency due to mobility restriction in the historical city centre; increase the attitude of citizens towards separate waste collection; need for *higher value* waste valorisation	Organic flows: green waste, VFG, organic fraction of residual waste; residual waste (inorganic fraction)	Municipalities of Ghent and Destelbergen within the Region of Flanders

Pécs	Improvement of collection and recycling rate of municipal household and municipal institutional waste; reduction of waste deposited in landfills	Paper, plastic, metal glass as well as garden waste	The city of Pécs, it's surrounding villages and residential towns
Hamburg	Improvement of high quality separated collection of recyclables and bio-waste	Household waste	Hamburg Altona and County of Pinneberg
Łódź	Sub-urbanisation pressure and related production of wasted landscapes	Wasted landscapes; packaging materials; industrial waste	Łódź Metropolitan area with a spatial hotspot on logistic and industrial areas along the motorway intersections (Strykow)

Table 2.1. *The six PULL regions of the REPAiR project*

2.3 Goals and requirements for using the GDSE in column I (PULLs)

The GDSE's column I is the core instrument for discussing with the stakeholders during the PULLs and creating a setting for co-designing possible solutions to the specific waste and resource topic of the PULLs (Table 2.1). Therefore, the column I of the GDSE has to be designed for meeting the following objectives:

- Presenting the case studies of the PULLs transparently and time-efficiently; this includes:
  - the status quo,
  - the challenges,
  - the visions as well as
  - a (first) range of possible eco-innovative solutions.
- Empowering the discussion by creating the possibility to:
  - interactively try out proposed solutions and
  - see (at least a pre-chosen sample) of their effects.
- Logging the outcomes of the PULL's:
  - visions,
  - requirement definitions,
  - preferred solutions (combinations)

  - and open questions.

From the above-mentioned goals a number of requirements for the GDSE's column I (PULLs) can be derived. In its core, it has to provide a database for storing all relevant data, describing i.a.:

- the flows, stocks and other characteristics of
  - the business-as-usual state,
  - alternative solutions towards challenges and
  - alternative strategies, meaning: alternative combinations of solutions;
- and the impact evaluation of this business-as-usual state and its alternatives (being the outcome of the impact modelling).

By referring to these data, the GDSE's column I has to provide multiple ways of data visualisation, especially bar charts, flow diagrams and maps. The following Subsection 2.4 will take a closer look at the visualisation aspects of column I.

A real interaction with the stakeholders will only take place, if single solution elements as well as bundles of solution elements can be assessed during the PULL. Therefore, column I of the GDSE has to include a relevant set of (simplified or preselected) models for enabling the interactivity needed for a fruitful and result oriented discussion. These models should be able to show and highlight the differences between the business-as-usual state and the alternative solutions and strategies in terms of flows and stocks as well as impacts on the evaluation indicators to be chosen. During the PULL sessions, model calculations and visualisations, e.g. on the effects of a proposed solution, have to be processable within a matter of 60 seconds or less.

The stakeholder meetings at the PULLs are a one-shot-opportunity for the project. Therefore, column I of the GDSE needs a much higher reliability than column II.

While column II will be largely cloud-based, column I's high need for reliability might lead to the conclusion that its full usability will be needed even in an offline-mode in order to minimise the dependency on the bandwidth and stability of internet connections. The six PULLs will be held in the different regions and will oftentimes include several meetings in more than one meeting place.

2.4 Visualisation types in column I (PULLs)

Data visualisation is the foremost important task for column I of the GDSE. It represents both the core of the information and messages conveyed to the participants of the PULLs, yet at the same time building the ground for stakeholder input through discussion and co-designing. All modelling of the effects of discussed solutions during the PULLs will also go through the channel of data visualisation, as the participants will comment on data assumptions and will clarify their ideas for solutions and strategies by asking for changes within the data set.

By looking at the type of data and analysis relevant in the geodesign approach of Steinitz as well as in the life cycle analysis (LCA), the following three standard types of data visualisation can be identified as the basic requirement for the GDSE's column I user interface:

- bar charts (Figure 2.1, upper row, left and right)

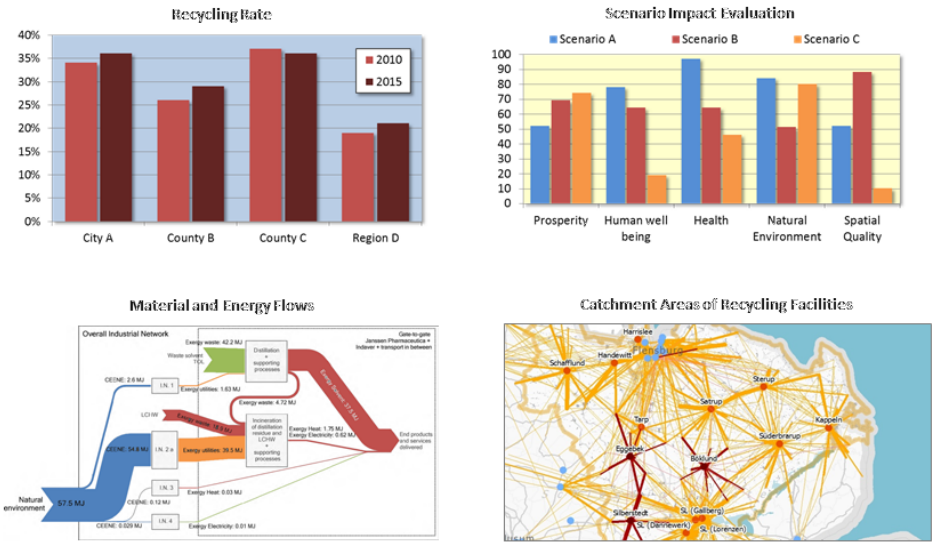

Figure 2.1. *The three standard types of data visualisation within the GDSE*

- flow diagrams (Figure 2.1, lower row, left)
- maps representing locations (dots) as well as flows (lines) (Figure 2.1, lower row, right)

Therefore - as already defined in Subsection 2.3 - the GDSE (column I) must provide interactive data display modules able to display at least the three above mentioned visualisation types. The main contents of the visualisations will be either flows and stocks or impacts.

Within these two main content fields, the data behind the different visualisation types actually are often the same, but - in a SQL-sense of the word - ”grouped” differently. While a bar chart or map might group metabolism or impact data by location, a flow diagram or bar chart might group the same data by process phases. In addition, specific filters can be used, e.g. by waste category or stakeholder.

2.5 General GDSE concept for column I (PULLs)

The PULLs constitute the main mechanism for stakeholder communication as well as for the interaction between the stakeholders and the data and models used for the specific PULL case study. Part of all PULLs will be a series of collaborative workshops, in which *workshop* is defined as a same-place same-time face-to-face meeting in which stakeholders gather on location to discuss issues related to waste and resource management in the peri-urban area of a case study in question. In REPAiR, these workshops consist of interactive structured sessions in which stakeholders are asked to work together on a common interface using computer-based geodesign tools linked to a touch-enabled interface. This interface is the core of the GDSE’s column I.

This approach follows up on the work of Arciniegas & Janssen (2012), who integrated collaborative GIS-based tools and touch-enabled surfaces and implemented this integration in workshop settings. The main rationale within a PULL workshop is that specific tools fulfilling specific roles, can be used jointly by the stakeholders using a common information platform linked to an interactive touch-enabled hardware instrument. Major roles include communication and visualisation of informa-

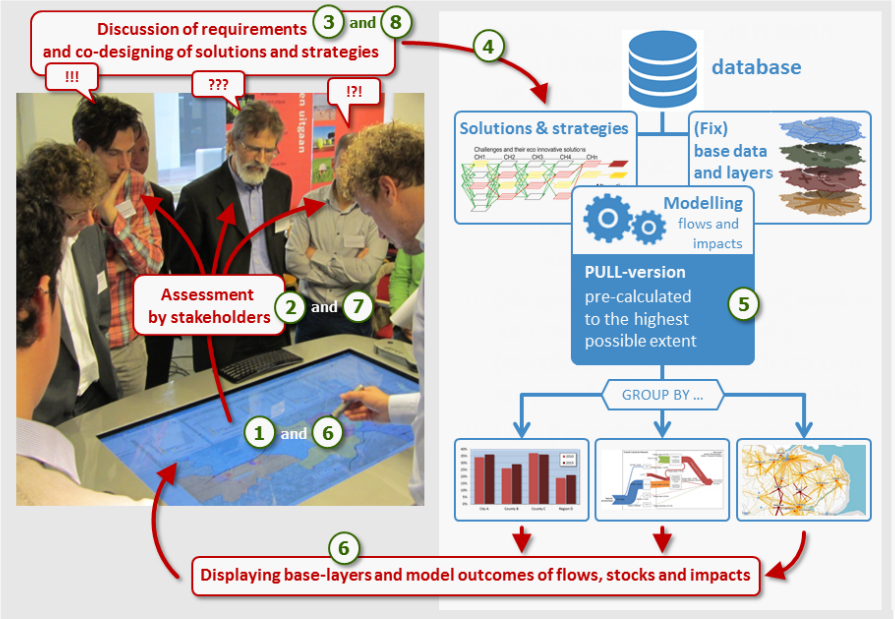

Figure 2.2. *Usage of the GDSE column I in the PULL workshops*

tion, discussion support, and design and assessment of alternative waste management solutions and eco-innovative approaches.

Figure 2.2 illustrates the usage of the GDSE column I in the PULL workshops:

Step 1 A starting set of maps and visualised data is displayed to the stakeholders on the touch enabled interface including at least:

- a brief description of the business-as-usual-state in terms of flows, stacks and impacts;
- a starting set of solutions to specific problems arisen from the analysis of the business-as-usual state.

Step 2 The stakeholders assess the displayed data.

Step 3 The stakeholders discuss the currently displayed setting and

- give further information on the business-as-usual state;
- describe requirements for solutions and strategies;
- discuss and further develop the suggested solutions;
- combine solutions to their preferred strategy.

Step 4 The solutions and strategies modified by the stakeholder's co-designing process are sent to the GDSE column I model version through the touch-enabled interface. Input from stakeholders can be expressed in the form of parameter setting and modification, multiple choice, drawing of simple shapes (i.e. points, lines or polygons). These tools are interactive and intended for workshop settings, which means that tool users are allowed to provide input and generate output in real time through easy to use multiuser interfaces.

Step 5 The GDSE column I model version recalculates flows, stocks and impacts caused by the modified *design* (= eco-innovative solutions and strategies). As explained in Figure 1.3, the GDSE column I model version is a simplified copy

of the more complex models in column II (ongoing research of the REPAiR team members), in which as many intermediate results from column II sub-models are pre-calculated and stored as (long) lists and tables enabling the GDSE (column I) to recombine data much faster. The base layers and data stored in the local database used during the PULL workshop is a subset of the central database of column II covering all six PULL areas and more base layers than needed in the specific workshop.

Step 6 The recalculated maps and charts are displayed on the touch enabled interface.

Step 7 The stakeholders reassess the displayed data and flows, stocks and impacts caused by their design using their local expertise.

Step 8 The stakeholders continue their discussion and optimization (thus, loop back to Step 2).

Step X Within the visualisation component, final solutions and strategies (combinations of solutions) and impact assessments are communicated to all stakeholders as maps, flow diagrams and bar charts showing quantitative assessments and rankings.

3 Column II: Internal research of the REPAiR team

3.1 Goals and requirements for using the GDSE in column II (internal research of the REPAiR team)

Although the primary intended use of the GDSE is stakeholder involvement into a discussion supported by a computational system, REPAiR's approach also includes use of GDSE for the ongoing internal research among the team members. The second column of the GDSE is therefore not intended for the use during PULLs but rather for facilitating and coordinating backend processes.

Due to the large project scale involving multiple institutions and experts from various fields, REPAiR needs to feature a single system able to support the ongoing research. The system is meant to enable the consortium members to work efficiently, avoid duplicate work and ascertain transparency of the taken actions. In addition, the system is determined to allow exchange and exploration of the already established data and models between all consortium members.

Column II of the GDSE aims to organise the process of putting together a number of computation and simulation models as well as various spatial and non-spatial data. As a result of the goals described in Subsection 3.1, column II of the GDSE has the following requirements concerning the *spatial information layers*, *data tables and computational models* (henceforth regarded as *GDSE elements*):

Storage and Versioning All the GDSE elements should be stored in a single platform easily accessible to all consortium members. The platform should allow versioning, searching and backtracking of users responsible for GDSE element upload and editing. Although all the elements must be easily accessible by everyone, only a limited number of researchers should be granted rights to add and modify them directly in the platform. The risks of erasing or overwriting crucial data by mistake is to be minimised by automatic system of backup and versioning.

Exchange All the GDSE elements must be shared between all consortium members, therefore intelligent form of documentation and metadata must be established that would allow different members to be sufficiently informed to reuse the GDSE elements. Additionally, different members should be allowed to comment on each other's data, models and results.

Integration The second column of the GDSE is also meant to act as a platform for the integration of models and/or data developed by different researchers in different institutions. Here again an intelligent documentation and metadata is needed to ensure consistency, coherence and correspondence.

Testing The system should also be capable to run tests and save their results. Test computations should be tagged differently than the final accepted elements.

An intelligent system must be set up to secure the transition between test element and to a final one.

Calibration Since a number of models will take not only data layers as input but also various parameters that might not be known from the beginning, the system should allow calibration and logging of these parameters.

Computation The most important function of the GDSE's column II is its capability to run the models based on the provided data. Additional requirements related to this function are clear (however, not necessarily simple) user interface, logging and extensive feedback in case of errors.

Pre-calculation Since the first column of the GDSE requires the pre-computed models for faster real-time model execution, the second column must be able to provide this functionality.

Documentation Intelligent documentation of user responsibilities, actions, versioning and element metadata is a crucial requirement for the model of column II of the GDSE in order to ensure transparency, consistency and integrity of the system. The documentation should be explicit and precise; however, too much bureaucracy should also be avoided in order not to make the procedures of using GDSE too cumbersome.

3.2 General GDSE concept for column II (research of REPAiR team)

The overall GDSE concept has been described in Section 1. Figure 3.1 shows the GDSE workflow for column II in detail. The green line in the image corresponds to the functions of GDSE column II that are associated with the different workflow steps.

First, all data collected and produced in REPAiR are stored, managed and accessed from the second column. The relevant data are used for the models of business-as-usual case as well as for running the models for the alternative eco-innovative solutions. The role of the system in this case is to allow potential changes and actions to work as inputs for the computation. The inputs should be allowed to be adjusted and calibrated in order to fit the models.

Both business-as-usual and alternative eco-innovative solution models are stored, managed and accessed from the second column as well. The models themselves can be tested, calibrated, updated, executed, pre-computed and finally documented.

Model execution results into fixed sets of indicators, that need to be explored by the researchers and documented for the further reuse and comparisons. The exploration tools will be provided by both columns of the GDSE. The indicators will be combined with various other datasets and together will be able to provide information to the user in the form of environmental, social, financial, and other related impacts. While impact analysis and communication play a more important role in the first column of the GDSE, they are also important for the internal research and therefore must be displayed in the second column as well. Finally, the users of the GDSE (mostly researchers, in case of the second column) must be able to provide feedback on every step of the workflow, which would be communicated to those responsible for that data or model.

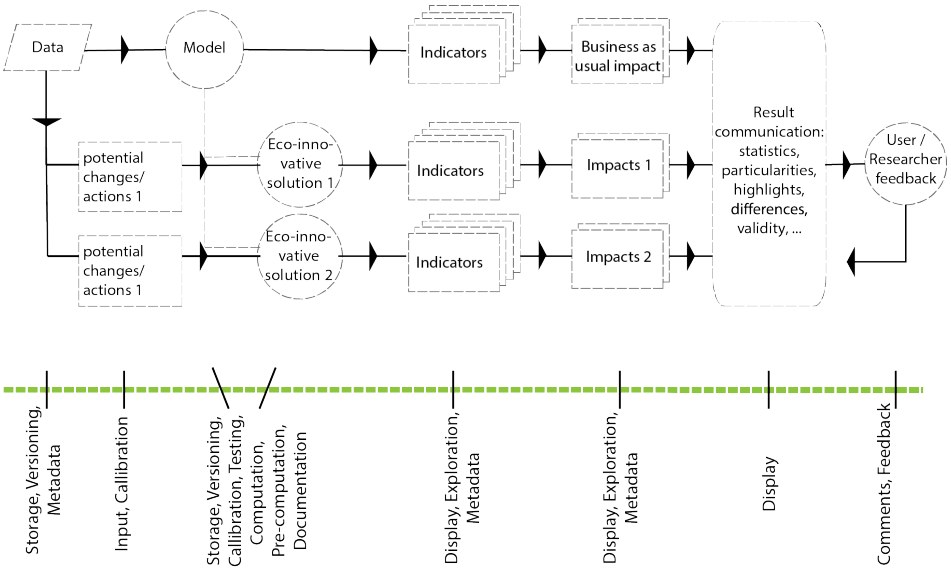

Figure 3.1. *Workflow of GDSE column II and its functions (green line) corresponding to separate workflow steps*

4 Technical and Organisational Concept

4.1 A brief comparison of the two columns

While the above sections described the GDSE rather from a content, user and application perspective, this chapter elaborates the vision for the GDSE a bit more in terms of technology and practical project organisation. As a basis for this, Table 4.1 summarises the different aspects and characteristics of the two columns as defined in the preceding sections. The profile of the two columns set the ground for the technical and organisational choices to be taken in the following subsections.

	Column I (PULL)	Column II (research of REPAiR team)
Time spent on the analysis, modelling and interpretation	Short, results are analysed on the spot	Long, sufficient time can be dedicated for result analysis and interpretation
Acceptable time for result generation	Short, results must be generated on the fly	Long, result generation can take up to a couple of days
Variety of inputs	Limited to a few types of inputs (e.g. multiple choice, drawing simple shapes, parameter setting)	Flexible enough to accept the needed kind of inputs in various formats
Variety of outputs	Limited to the essential information that can be accessed quickly	Flexible enough to be able to provide the required kind of outputs in various formats
Main users	Participants of PULL (10-15 people)	Consortium members (¿60 people)
Hardware	A single set of hardware consisting of a touch-enabled interface and a standard computer linked to it	Each researcher is using one's own hardware (i.e. his or her own computer)
Software	A single frontend is used, no online communication needed	Each researcher can use the software he or she is most used to (e.g. Excel, ArcGIS, QGIS, SPSS), the online-communication uses standard web browsers
Flexibility	Limited to pre-programmed functions	Very high flexibility

User interface	As user-friendly and interactive as possible	User-friendly, however, flexibility is prioritised to user-friendliness
Access	Local	Cloud-based
Backtracking	Possibility to backtrack to the previous version/solution	
Data types	Both spatial and non-spatial data need to be included	

Table 4.1. *Comparison between the two columns of the GDSE*

4.2 Technical and organisational concept for Column I

This section describes the organisational structure of a PULL, the corresponding workshops, and the support tools used in these workshops. A PULL brings together stakeholders with multiple backgrounds and diverse scopes and interests concerning waste management and eco-innovative strategies for a given peri-urban area. Deliverable D 5.1 'Methodological guidelines (Handbook) for the PULLs' provides a theoretical background and justification for the PULLS.

A PULL includes a series of workshops, all of which follow both a generic format and protocol. A half-day PULL workshop typically follows this format:

1. Introduction and goals;
2. Available data, models and support tools;
3. Tasks and assignment using tools;
4. Presentation of results;
5. Plenary session and discussion.

REPAiR PULL workshops will feature a number of geodesign tools developed to support stakeholders in carrying out one or more specific tasks. The main geodesign support tools are:

- touch-enabled interface;
- drawing and design tools;
- analysis support tools;
- impact assessment tools;
- Life Cycle Assessment (LCA);
- Material Flow Assessment (MFA);
- visualisation tools.

The roles that support tools play in each task of the PULL workshops are defined according to the framework for geodesign of Steinitz (2012), which conceptualises the process of multi-actor geodesign as three-looped processes, each comprising the formulation of six questions (Table 4.2).

Geodesign question	PULL support tool	Roles of the support tool
How should the study area be described?	Touch-enabled interface to display data and map layers	Communication of existing data and models; prompt exchange of local knowledge and stakeholder dialogue; identify stakeholder objectives

How does the study area operate?	Touch-enabled interface to display existing flows, models and maps	To improve stakeholder understanding of the problem
Is the current study area working well?	Impact assessment tools that use pre-calculated inputs coming from Column II	Assessment of current situation and business-as-usual impacts; communicate information about waste and resource management; generate expert feedback about waste and resource management; assess the impact of potential waste and resource management strategies for an area
How might the study area be altered?	Design support tool; analysis support tool; visualisation of impacts; Life Cycle Assessment; Material Flow Assessment	Collect and incorporate stakeholder input
What differences might the changes cause?	Analysis support tool; visualisation of impacts; Life Cycle Assessment; Material Flow Assessment	Assess the impact of potential waste management strategies for an area; assess eco-innovative solutions; compare impacts of alternative solutions and strategies
How should the study area be changed?	Analysis support tool; visualisation of impacts; Material Flow Assessment	Communicate information about the impacts of the alternative solutions and strategies to stakeholders; use this information to improve and optimise the alternative solutions and strategies; finalise strategies and eco-innovative solutions that are perceived as acceptable by all participants

Table 4.2. *Roles of support tools for REPAiR PULLs*

As stated in the REPAiR project proposal, REPAiR intends to implement touch- enabled instruments for all PULLs. Such an instrument (see an example in Figure 1.1, left) can potentially work as a common map and model interface to support discussion between multiple stakeholders and user-map / model interaction. Touch-enabled interfaces are increasingly being utilised as key components of geodesign tools and planning support systems because of their abilities to support communication and learning. In fact, recent studies have reported on both perceived and

measured added values of such instruments, highlighting communication and learning as the main added values (Arciniegas et al. 2013, Pelzer et al. 2013).

The rationale behind the choice of a touch-enabled interface for the REPAiR PULLs is threefold:

1. It constitutes a support tool for face-to-face group collaboration and decision-making.
2. It allows users to work interactively with computer-based tools, without having a computer get in the way.
3. It provides a shared interface that incorporates and links simulation models, GIS tools, and visual analytic tools.

4.3 Technical and organisational concept for Column II

Column II of the GDSE has to fulfill the following tasks :

Storage, exchange and documentation A workflow has to be defined which determines

- who can import data into the GDSE and how,
- who can access which data on which channels and
- how the data is stored, versioned and documented.

Integration and testing The challenge for column II is to

- integrate data from six countries,
- integrate models and tools of different research partners and
- ensure a comprehensive testing environment.

Calibration, computation and pre-calculation Finally, there will be the need to

- calibrate the models,
- run the models to assess different alternative solutions and strategies and
- pre-calculate various datasets to be used in the PULL-version of the GDSE.

On the basis of these requirements, the technical concept deals with the question of which hardware and which software tools should be used for the above listed tasks. The organisational concept looks at how the workflow should be organised within the research team. Figure 4.1 shows the main elements of the organisational and technical concept.

Storage, exchange and documentation

The data used in the column II of the GDSE will be provided by different researchers and practitioners from the PULL regions using all various kind of data formats.

For the GDSE (column II) the OpenScienceFoundation (OSF.io [1]) will be used as a platform for uploading data and tagging the necessary metadata. OSF is an open source tool that provides the features required by the REPAiR project:

- it provides a secure cloud storage;

[1] https://osf.io/

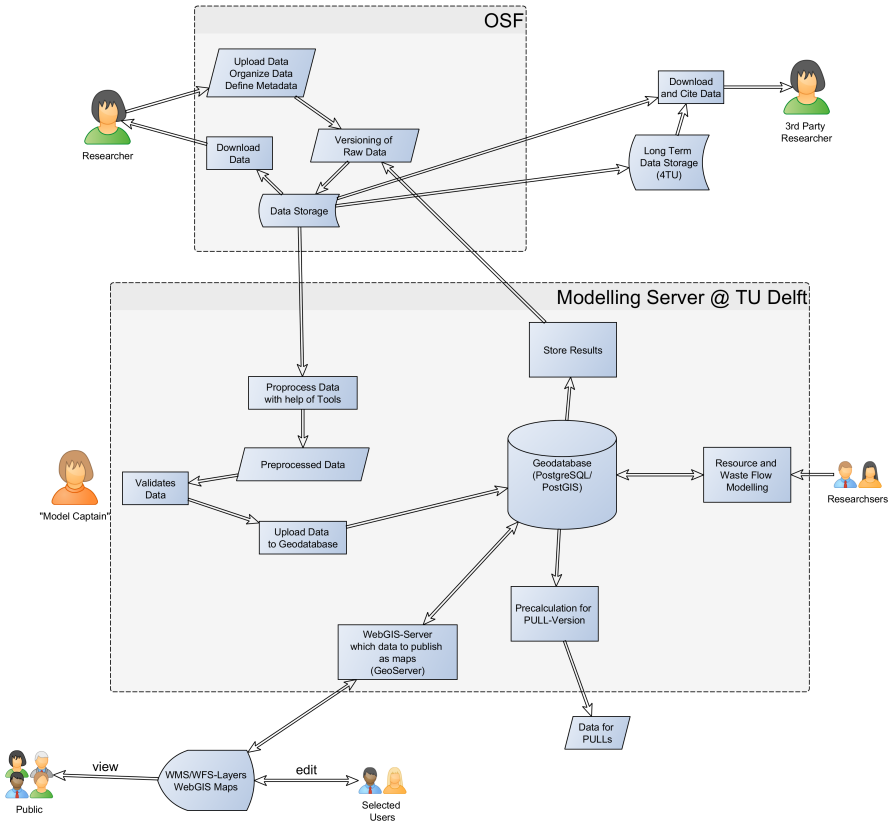

Figure 4.1. *Main elements of the organisational and technical concept for column II*

- it respects differentiated access rights;
- it enables a direct exchange of data to a the modelling server hosted at TU Delft;
- it ensures versioning of the data;
- all data can be cited in scientific publications via permalinks.

User roles will be defined with the corresponding rights to read and write data. For sensitive data, private repositories will be set up, where only specific users will have access rights. For all uploaded data a data plan will define, which metadata have to be provided. As mentioned, the store data can be cited in scientific publications using a permanent link to the OSF web page.

The usage of the OSF web page and tools as part of the GDSE (column II) will be organised as follows:

- For all researchers and students within the REPAiR project the OSF web page will be the first and central online user interface to be used to contact column II of the GDSE.
- Each of the six PULL-regions will have an own folder to organise region-specific data.
- Intermediate and final results of the modellings (being processed on the modelling server at TU Delft) will also be provided on the OSF-Platform to all researchers in dedicated folders.

- All programme code will be hosted on GitHub[2], which allows versioning of all code. For the GDSE the GitHub-page will be integrated into the OSF page. For the long term Storage, the REPAiR GDSE uses the 4TU-Datacenter, which guarantees a long term availability of the project results.

Data storage in a geodatabase

The GDSE's core element is a central database server which stores all needed data. On that server the open source database PostgreSQL will be used with PostGIS as its spatial extension. The server will be hosted by TU Delft.

One single database will store all data with the same content and structure in all six PULL regions, e.g. land use data, data on population densities and infrastructure locations. In addition, a separate database for each PULL region will store the specific data available only for the respective region as well as data related to its specific waste and resource management questions. All data on resource and waste producers and treatment facilities will have a spatial attribute (ranging from exact coordinates to a very generalised *inside the rest of the world*-tag indicating that a feature is located somewhere outside the PULL region). Spatial attributes are needed to calculate location related indicators or group data by spatial entities in order to display them in form of tables, maps and flow-diagrams (Subsection 2.4).

In addition, data on organisational and governance structures, such as the service areas of different waste companies can be stored in the geodatabase. Also specific data on behavioural patterns such as per-capita waste generation and recycling rates in different areas will be stored in the geodatabase. Among others, geospatial information like these will support the more qualitatively oriented analyses of governance issues carried out in WP 6 in the different PULL regions.

Data visualisation

The GDSE's column II will make the above described data for the six PULL regions easily available to the REPAiR team members via a WebGIS server. A GeoServer (an open source WebGIS tool) will be set up as part of the GDSE in order to provide dynamic maps for all six PULL regions.

Team members can also use these data as Web Map Service (WMS) and Web Feature Service (WFS) layers in order to integrate them into their own GIS system runned locally on their desktop computer using either ArcGIS or QGIS. The latter GIS system is open source.

There will be a common set of layers that can be displayed in all six PULL regions. In addition, there will be layers on specific topics relevant for the corresponding PULL. It is technically possible to allow direct editing of data to (selected) users via a WebGIS-Page. This could be a useful tool for stakeholders in the PULL-Regions without Desktop GIS-Capabilities. However, the question of documentation and versioning have to be assured in this case.

Integration and testing

The data available on the different topics in the PULLs will be very heterogeneous in terms of spatial scale, time, and other attributes. This data has to be integrated. The aim is to generate consistent data sets for each PULL region, but also to generate comparable core data sets for cross-regional analyses. Therefore, special effort has to be made in order to generate comparable data sets allowing compar-

[2] https://github.com/

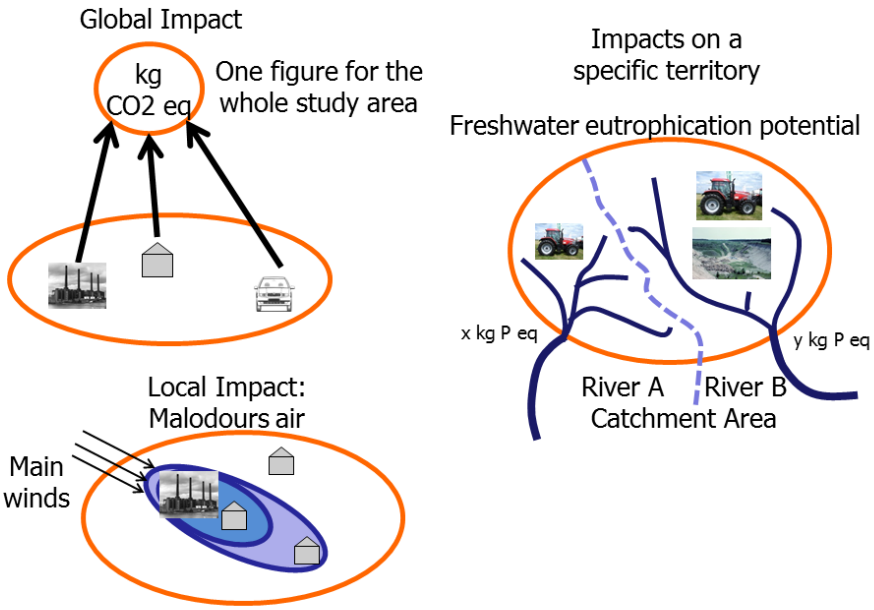

Figure 4.2. *Exemplary indicators evaluated on different spatial scales as outcome of the GDSE modelling*

ative material flow and life cycle analyses across different PULL regions treating likewise waste and resource management challenges.

For the just described integration of the data (as well as the model integration, see below) a so called *model captain* will be defined (see respective icon in Figure 1.3). The model captain will most probably be a small team consisting of the WP leaders of WP 2, 3 and 4. In addition, each PULL region will be asked to designate a data-coordinator, who will be responsible for acquiring all local data needed for the specific PULL.

During the data integration raw data of very different formats and scales will have to be harmonised. For this, different steps of preprocessing will be required. In order to harmonise the spatial levels, data with an address-information will be georeferenced. Data only available on a larger spatial scale can be disaggregated into smaller scales (e.g. the INSPIRE raster grid). From smaller scales, data can be aggregated to all kinds of larger spatial levels in order to calculate the relevant indicators. To support this work, the GDSE will provide tools for:

- defining database schemas;
- georeferencing address data;
- disaggregating data to small areas;
- aggregating data to different spatial levels and
- exporting data into different spatial and non-spatial data formats.

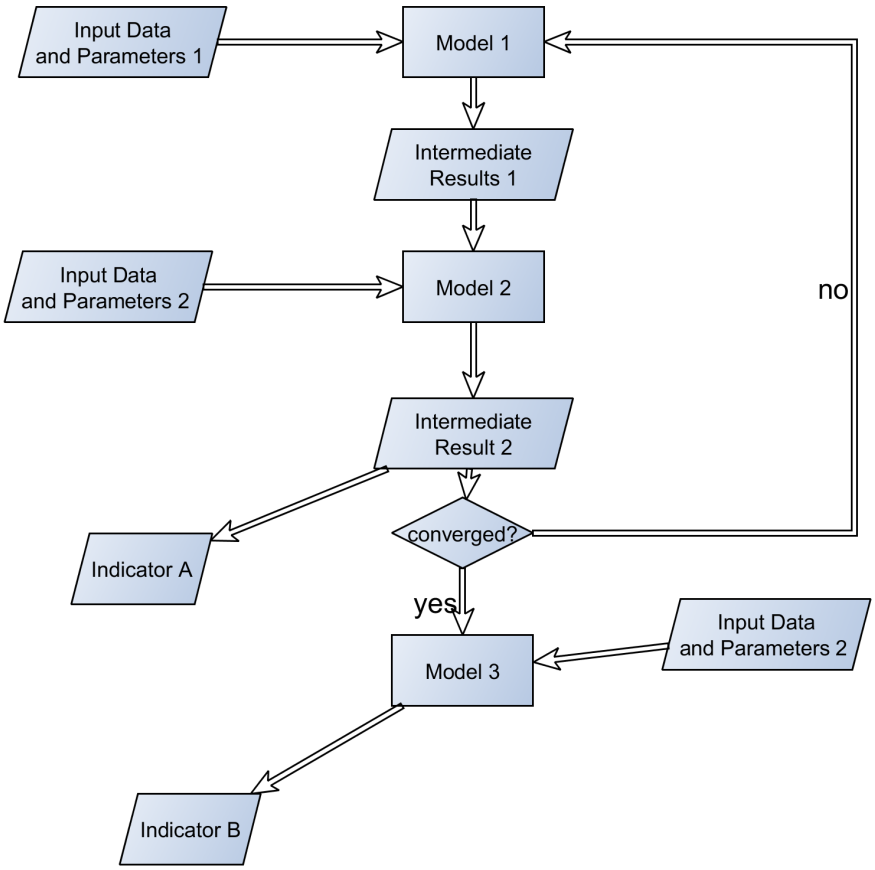

Figure 4.3. *Aspects of the model management*

Model management and strategy management

The comparative assessment of alternative solutions and strategies[3] through spatial, material flow and life cycle analyses is at the core of the REPAiR project's research focus and therefore also of the GDSE's functionality. Thus, modelling plays an important role within the GDSE (and the research work in general). The modelling will provide a predefined set of indicators for each strategy to be assessed during the research process or the PULLs. As shown in Figure 4.2 the calculated indicators from the spatial, material flow and life cycle analyses can be evaluated on different spatial scales.

The GDSE will not consist of one big super-model, but will combine a number of different submodels already existing or to be developed by the REPAiR project partners, especially in WP 3 und 4. The researchers working on these submodels use very different software for their building. Therefore, the models have to be integrated into the GDSE's modelling environment and clear interfaces between the submodels have to be defined. In addition, a clear order of execution have to be defined. Figure 4.3 visualises the different aspects of the model management.

While the model management defines the interplay between the submodels (in-

[3] In the terminology of the GDSE a "strategy" is a combination of solutions. A "solution" is a technical, organisational or juridical approach for approaching one specific material and waste management challenge (Subsection 1.1)

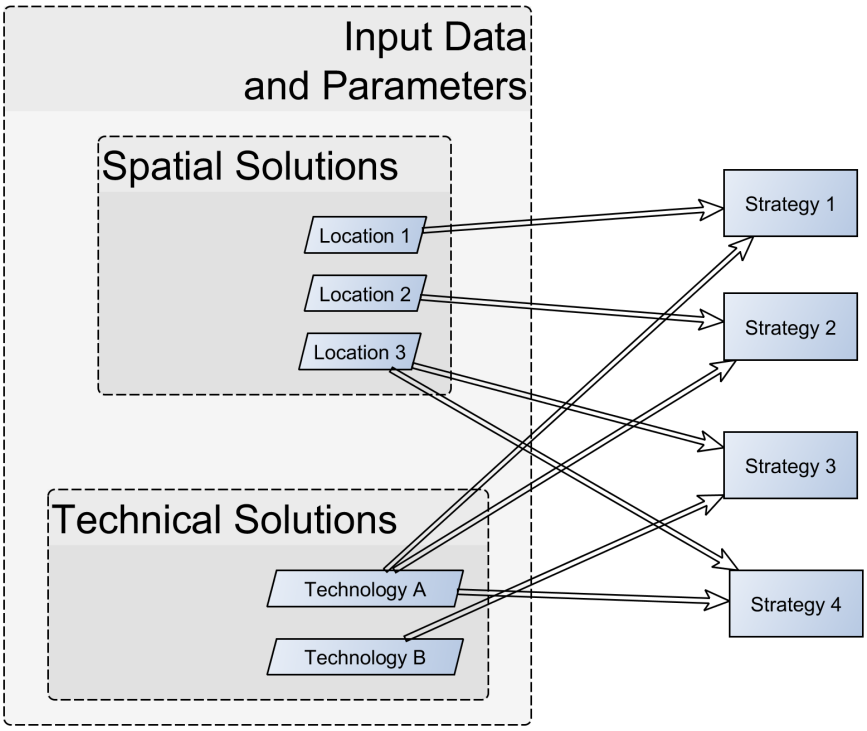

Figure 4.4. *Aspects of the model management*

terfaces, input/output data, order of execution, etc.) an additional *strategy management* will organise how the data for alternative strategies (being discussed in a PULL or a research setting) are processed comparatively through the same sequence of (sub-)models using the appropriate input parameters for each strategy. While doing this, the *strategy management* has to ensure that no incompatible solutions are combined into the same strategy.

The strategy management will also give the GDSE users a chance to compare the outcomes of the models for the alternative strategies. The differences between the alternative strategies and the business-as-usual reference case (Figure 3.1) can also be visualised and displayed via the WebGIS. Figure 4.4 visualises these different aspects of the strategy management to be integrated into the GDSE's column II.

For the practical use column II will also provide a testing framework that gives feedback, if submodels fail. A continuous integration framework ensures that errors occurring by changes in one submodel can be detected in an early stage. Small scale unit tests of individual functions and methods have to be tested within the submodels.

Precalculation of data

In the PULLs, a lot of data is required to be used in the workshops. While the time needed for the above described modelling is - within certain boundaries - not too critical during the research phase, during the PULLs it should not exceed 60 seconds. Therefore, as already explained in Subsection 1.3, the outcomes of as many submodels in column II should be precalculated and transformed into (long) lists of results rapidly accessible for the modelling during the PULLs.

Thus, another important goal of column II is to provide this preprocessed data for the workshops and the column I version of the GDSE model. Therefore, an interface between the research of the REPAiR team and the PULLs as to be defined including the required content as well as the data format.

5 Next steps for the GDSE: from a vision to its implementation

The present deliverable 2.1 is the first of WP 2, which develops the GDSE, and sketches out a vision of its basic capabilities. The next steps on its way to implementation within the project have - just like the vision presented in this document - to be coordinated not only within WP 2 but also with the other WP teams.

With respect to this context, Table 5.1 lists the key actions during the next six months of the project that will define and concretise the GDSE in more details.

	Deliverable /Milestone	Key Tasks in relation to WP 2	Key Responsible Partners	Time
MS 2	Detailed technical concept for each GIS-based component	Develop technical concepts for both columns of the GDSE	GGR, TUD, Geo-Col	PM 10
D 2.2	Data Delivery Plan	Description of requirement of data as well as data delivery plan;	GGR, TUD, UNINA	PM 10
		Agreement on Data Captains per case;	TUD, UNINA, IGiPZ, RKI, HCU, UG	PM 5
		Setup of column II	GGR, TUD	PM 6
MS 10	Definition of system boundaries and goals and data assessment	Setup of spatial scales for data acquisition;	TUD	PM 10
		Develop methods of data aggregation and disaggregation	GGR, GEO-Col, TUD	PM 10
MS 11	Questionnaire for household and companies	Determine how to integrate qualitative data as well as behavioural data into the GDSE	GEO-Col, TUD, RKI	PM 8
D 4.1	Data Availability Report - pilot cases	Check fit of GDSE data management structure and available data on impact assessment and proposed indicators	UG, GEO-Col, TUD, GGR	PM 8[1]

D 5.1, MS 18	Pull Handbook and Preparation of PULLS	Integrating GDSE Testing into PULL setup (Section 4.2)	GEo-Col, UNINA, TUD, GGR	PM 5
		Setup Column I: Defining a way of testing different touch-enabled interfaces and	GEO-Col, TUD	PM 6
		Selection of system of choice	GEO-Col, GGR, TUD	PM 12
MS 24	Draft decision models	Developing a concept on how to integrate decision models and priorities of decision makers in column I	GEO-Col, TUD, GGR	PM 8
D 8.4	Data Management Plan	Define methods of data storage and versioning	TUD, GGR, RKI	PM 6

Table 5.1. *Next milestones and deliverables which further define and concretise the GDSE*

[1] postponed from PM 6

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