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The TRANSFORM DSE – an Interactive Decision Support Environment for Serving Smart City Strategy Development and Local Measure Implementation

Wolfgang Loibl, Stefan Vielguth, Jan Peters-Anders, Sebastian Möller, Daiva Jakutyte-Walangitang, Joost Brinkman, Ivo Wenzler, Alex Cramwinckel, Michele Fumarola

(Dr. Wolfgang Loibl, MSc, AIT-Austrian Institute of Technology, Giefinggasse 2, 1210 Vienna, AT, wolfgang.loibl@ait.ac.at)
(DI Stefan Vielguth, AIT-Austrian Institute of Technology, Giefinggasse 2, 1210 Vienna, AT, stefan.vielguth@ait.ac.at)
(Mag. Jan Peters-Anders, AIT-Austrian Institute of Technology, Giefinggasse 2, 1210 Vienna, AT, jan.peters-anders@ait.ac.at)
(Sebastian Möller, MSc, AIT-Austrian Institute of Technology, Giefinggasse 2, 1210 Vienna, AT, sebastian.moeller@ait.ac.at)
(DI Daiva Walangitang, MSc, AIT-Austrian Institute of Technology, Giefinggasse 2, 1210 Vienna, AT, daiva.jakutyte-walangitang@ait.ac.at)
(Dr. Joost Brinkman, Accenture B.V., Gustav Mahlerplein 90, 1082 MA Amsterdam, NL, joost.brinkman@accenture.com)
(Dr.Ivo.Wenzler, Accenture B.V., Gustav Mahlerplein 90, 1082 MA Amsterdam, NL, ivo.wenzler@accenture.com)
(Alex Cramwinckel, MBA, Accenture B.V., Gustav Mahlerplein 90, 1082 MA Amsterdam, NL, a.cramwinckel@accenture.com)
(Dr. Michele Fumarola, Macomi B.V., Juttepeer 56, 2635 MR Den Hoorn, NL, m.fumarola@macomi.nl)

1   ABSTRACT

The contribution deals with the decision support tool developed within the EU FP7 TRANSFORM project, a collaboration of varoiuous partners including 6 cities (Amsterdam, Copenhagen, Genova, Hamburg, Lyon and Vienna) aiming to achieve a significant progress in the transformation towards Smart Cities. The project rests on three main pillars: the development of a Transformation Agenda, designing a Decision Support Environment (DSE) and developing local measure implementation plans. The DSE is carried out by the AIT – Austrian Institute of Technology GmbH and Accenture B.V. supported by Macomi B.V. as sub-contractor of Accenture.

The TRANSFORM DSE tool addresses several features: an "easy to use" interactive scenario development- and result mapping, allowing selection, virtual allocation of measures and finally assessing the local and city-wide effects of the measures regarding impacts on urban environment – due to energy use and greenhouse gas emissions, and on the economy – through implementation costs and effects on the cities' employment and income.

The paper gives an introduction on the topic, describes the process to gather user requirements, decribes the tool design regarding data base, graphical user interface and measure editor and depicts some results through screen shots. Conclusoins will be made rearding the user requirement gathering process, the tool functiality requirments and an outlook discusses steps to improve the toll and extend the functionality.

2   INTRODUCTION – TOWARDS LOW CARBON CITIES

Smart cities are addressed through various characteristics (e.g. Giffinger et al, 2008, Caragliu et al. 2009.Rambol, 2014) which are discussed in several papers presented on this conference. Here we concentrate on the environmental sustainability issues focusing on energy consumption, on transition using renewable energy and on reducing carbon emissions: In the TRANSFORM project the central question is: "How can we make our cities low carbon cities?"

There is a large variety of tools that can be used for decision support in urban energy planning. A more comprehensive list of such tools is described in Connolly et al (2010) or in Stöglehner et al.(2013). Some software tools supporting the energy planning process are CitySim (Robinson, 2009), EnergGIS (Girardin et al, 2010) SynCity (Keirstead, 2009) or ReMAC (Metrex, 2014) However, these tools do not fulfill all following conditions: (i) Support of perspectives of different stakeholders. (ii) Shared understanding of the output among all the stakeholders. (iii) Decisions integration and resources negotiation. (iv) Addressing different exploration and implementation scales, (v) web-based open source application.

Finally it was decided to develop a new tool that meets specific requirements and covers all ranges from local scale to city wide scale. The spatial allocation aspects will be enabled through GIS functionality. Predefined measures related to certain use cases will be integrated in the system to assess possible impacts and interactions on other measures. The project – and the tool –finally helps to prepare, develop and execute the cities' transformation agendas to make the shift towards a low carbon future providing sustainable and attractive environments. Linking strategy with implementation, TRANSFORM shall combine this transformation agenda with single projects to be implemented across neighbourhoods or districts of various cities (Le Fevre, 2013).

3 DSE – USER REQUIREMENTS ACQUISITION - USE CASES AND DATA

Developing a tool to support decision making requires knowing which decisions shall be made by which users, based on which informations, for what purpose, achieving which targets. This is called user requirements acquisition comprising tool use case identification (related to tool functionality) and data acquisition.

The user requirement acquisition process is rather time consuming: it makes necessary to identify the key stakeholders in the administrative departments of the cities and eventually energy service providers (ESCOs) where the tool shall be applied, to identify the topics turning out as crucial issues for the cities to becoming a smart (energy) city and to identify the relevant data to be able to model measures and to simulate the impacts in an appropriate wayThis involvement of stakeholders is a crucial topic as they know about the use cases for their cities and can provide criteria for the applicability of suggested measures. Thus the use case definition and the exporation of the data availability requires various contacts – per mail, per telephone as well as physical, to be able to receive all information.

As in each city the governance and administrative structures are different, the identifcation of stakeholders, of data owners, of actors responsible for planning and implementation of measures, these requirement investgations take quite some time and have been lasting until now more than a year, where teams of the two tool developing partners AIT and Accenture have visited the six cities several times for project meetings, workshops and bilateral talks. The repetitions of these "stocktaking missions" in the six cities have been necessary, as the stakeholders have changed, the understanding of the topics have been changed, the smart city targets as well as the use cases and related measures to be implemented have been changed and with them to some extent necessary input data.

3.1 Use cases definition

It was decided to establish three initial use cases and the related measures per city. It was important to develop a tool shall satisfy – to some extent - non experts and experts as well, and to consider the different stages of the six cities on theire way to a transfomation agenda and to be able to implement more or less sophisticated measures. So the definition of the use cases as well as the required output had to fulfill a range of requirements to satisfy the various users. At the current stage of the 30 months-project – and we have passed one year now – not all use cases and related measures have been defined.

In general it tuns out that the city representations addresses both the energy demand and the supply side as use cases and select measures: concentrating on (a) construction of smart buildings. (b) building new housing and commercial areas requiring additional energy demand, (c) on retrofitting of buldings reducing the energy demand (insulation, improvement or exchange of heating systems), (d) on establishing distributed energy supply systems (like photovoltaic panels, or groundwater heat pumps) aiming in smart grids, (e) improving and extending district heating and cooling grids (integrating waste heat from industry and services into the systems and connecting new areas to the thermal heat grid). (f) As two cities are harbour cities the large cruise ships with an electicity demand of some thousand guest cabins during their stay in the harbour to be connected to the land grid instead of producing electricity by large diesel generators is a crucial issue. (g) Use cases on mobility are in discussion – here we expect measures like change in the modal split (shift from private to public transport) and reduction of car ownership.

3.2 Data and data gathering:

Data gathering is carried out in collaboration with the cities and their supporting partners following the use case exploration. Data on infrastructure and infrastructure costs to allow further cost estimation of future measures are (or still will be) provided by the infrastructure partners in the TRANSFORM project. Use cases and related measures will be negotiated between the cities' stakeholders and are defined by the cities. Measures will are translated into equations and transferred into code, to be integrated in the DSE.

The data provided by the cities and further stakeholders vary in type and scope – typical data are:

- City layout with focus on buildings and blocks containing specifications to estimate its energy consumption for heating and cooling.

- Population specifications: any details on population, e.g. household size.to estimate electricity consumption.

Wolfgang Loibl, Stefan Vielguth, Jan Peters-Anders, Sebastian Möller, Daiva Jakutyte-Walangitang, Joost Brinkman, Ivo Wenzler, Alex Cramwinckel, Michele Fumarola

- Energy consumption and production: data on (aggregated) consumption and production of various types of energy (e.g. gas and electricity).

In general different data sources are required depending on the measures that are specified into the system. The data sources can be specified on different spatial levels: city, district, or building level. To select the right data, the cities must have defined their use cases to identify and model measures to finally estimate the effects which may be changes in energy demand, in renewable energy generation and in greenhouse gas emissions. The energy service companies (ESCOs) must provide data on network and infrastructure costs as well as on energy generation costs. Providing energy prices for the customers allows estimating savings in energy costs to be related against costs for energy efficiency improvement.

4 THE DECISION SUPPORT ENVIRONMENT (TRANSFORM DSE) –

4.1 TRANSFORM DSE - purpose and approach

The tool serving as an "easy to use" decision support provides actors and stakeholders with a deeper insight regarding the selected city's or district's current performance on energy efficiency, energy consumption, CO_2 emissions and energy supply, as ability to reveal its full energy savings and greenhouse gas reduction potentials.

A planning support process in a city administration is defined through a sequence of steps, and considerations which decision makers pass, in order to achieve certain targets, by establishing measures aiming to change a given set of properties of a given environment. The tool usage flow shall follow those steps, carried out by actors and stakeholders also described in figure 1:
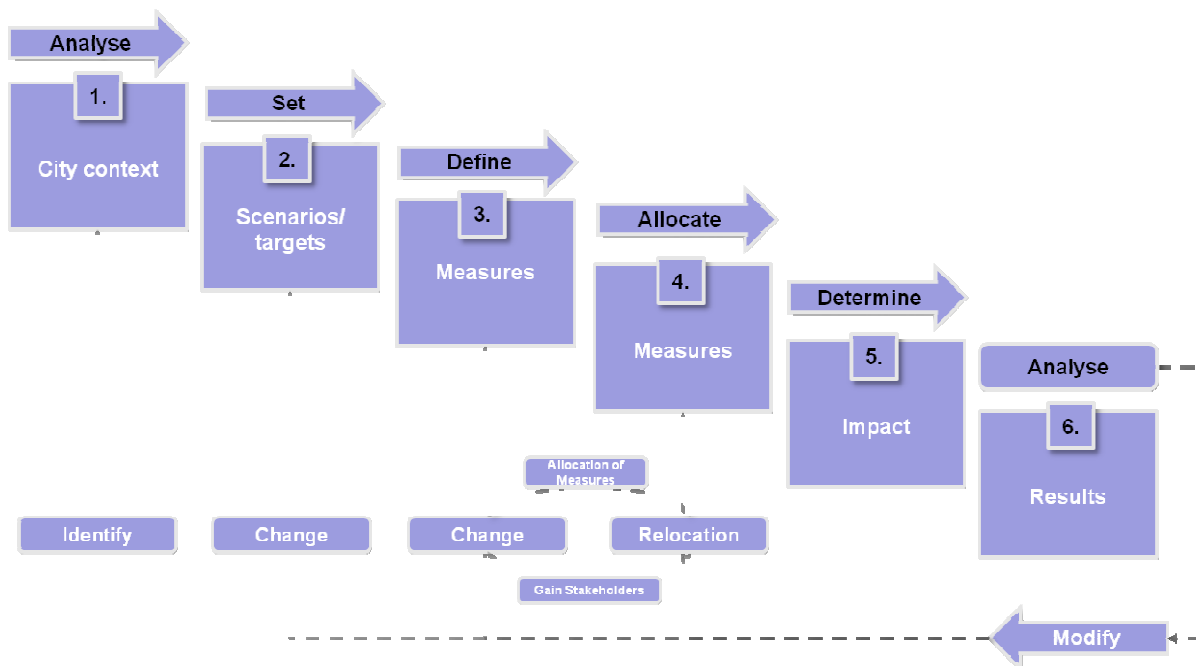

Figure 1: Decision sequence – built as Support Tool - Usage flow

- The starting point of the usage flow is the selection of the spatial context "the city context" (step 1). One city is selected and a spatial scale is addressed: the higher the level of detail of the explored data, the more detailed the analysis can be conducted.

- The selection of a scenario (step 2) provides a set of current and future framework conditions regarding energy demand and energy supply, as well as future changes e.g. of demand (e.g. through urban growth) and of energy prices of the different energy carriers.

- In step 3 measures will be defined – either selected from a set of available nes or edited as a new measure. Such information supports stakeholders in deciding which measures need to be part of the city's transformation agenda and where and when they shall be implemented for improving energy efficiency increase of renewable energy use and mitigation of GHG emissions.

- In step 4 the measures are allocated within the case study area through the interactive map or in the entire city.

- Later on the various impacts is determined – the effects will be simulated over time (step 5).

- Finally the impact shall be explored through maps and diagrams (step 6) and allo steps may be repeated by selecting and or allocated new measures to improve the results.

4.2 The DSE tool concept

To follow the steps depicted in figure 1 the TRANSFORM tool has to cover a range of functionalities: The following figure 2 sketches the concept and marks the usage flow addressed above.

City data (top left) have to be collected and harmonized to be integrated in a geospatial database which has to cover all different spatial scales (and must be able to aggregate data from the small scale entities (e.g. single houses, blocks) to larger ones (neighbourhoods, districts, entire city).

Then the tool application steps are aligned to the decision steps addressed in figure 1:

Step 1: City Context

The objective of this step is the analysis of the current state identifying possible opportunities e.g. for reducing carbon emissions in their city. After selecting the city the city data will be loaded into the system. Afterwards the analysis of opportunities can be carried out –e.g. by conducting e.g. running variable data queries on several geographic levels and across different assets. This is iterative process where the area, assets or KPIs can be changed after each analysis of opportunities and interdependencies. The GIS-data are visualized in a map.

Step 2: Scenarios/targets

The step is dedicated the definition of scenarios and targets to set the boundaries and scope of the applied model. A first sub-step includes the definition and loading of scenarios like fuel cost trend over the next 20 years. By changing these parameters a sensitivity analysis can be conducted. The second sub-step permits setting of the performance targets for the considered measures. Those include the energy indicators but also costs and non-energy targets. The definition of the different targets should be done by the different responsible and involved stakeholders.

Step 3/4: Measures

In step 3 the objective is the revealing of the interrelations and interdependencies between measures by building a portfolio of measures. Each step is subdivided in three parts. The sub-steps consider creation of measure, enabling measures and preconditions. The execution will be supported by a measure editor. (Details on the measure editor will be shown later).

Step 4 focuses on the allocation of the measures. First the measures are allocated in a selected area and then the time frame will be determined. Both sub-steps have to be discussed with the involved stakeholders to assure the stakeholder commitment.

Step 5: Impact estimation

The impact assessment in step 5 is determined by running the appropriate simulation for the portfolio of measures. Therefore the considered simulation time is defined and the simulation is started.

Step 6: Results

The last step of the decision sequence is the evaluation of the outcome by viewing results and identifying additional actions to close the gap between outcomes and targets. Therefore the results are viewed on chosen tables and graphs. If the outcome does not meet the expectations of the tool user a new simulation can be defined.

Wolfgang Loibl, Stefan Vielguth, Jan Peters-Anders, Sebastian Möller, Daiva Jakutyte-Walangitang, Joost Brinkman, Ivo Wenzler, Alex Cramwinckel, Michele Fumarola
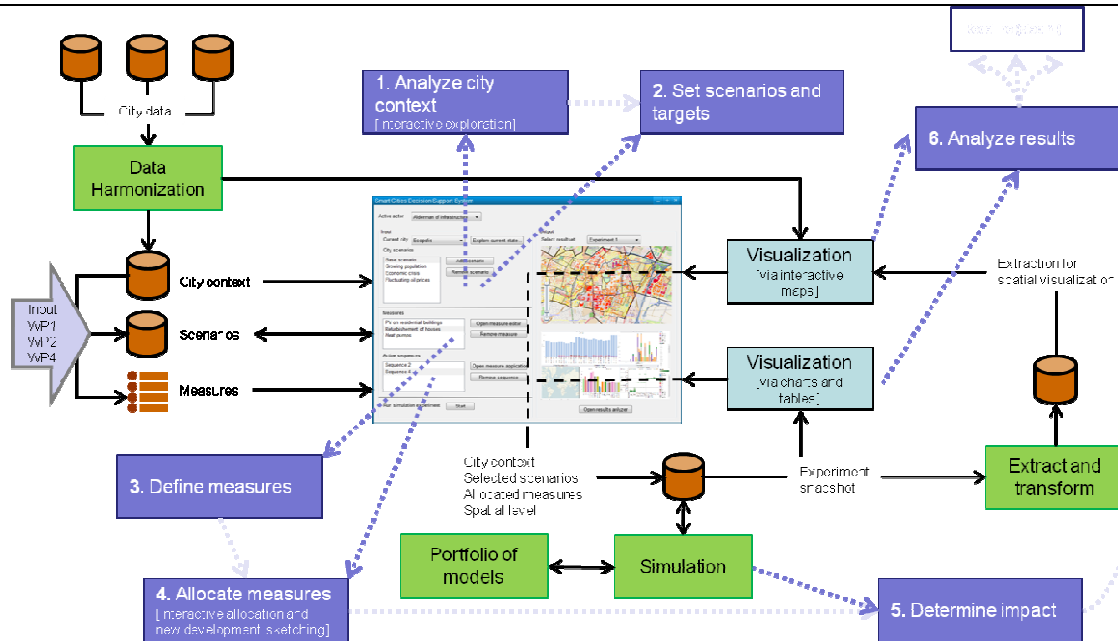
Figure 2: Concept of the Decision Support Tool and the related Usage Flow

Repetition and modification of simulation runs

The DSE will allow modifications at each step of the usage flow: changing the city context, the scenarios, the targets, and the measures or measure combinations. In the final version of the tool the parameters for the simulation runs be stored in log files which allow modifications of single parameters without entering all items again- aiming in a repetition of the simulation through batch model runs.

5 TOOL DESIGN

The DSE tool is developed by AIT and Accenture with strong involvement of the cities during the meetings and the visits, particularly of Amsterdam as project coordinator. The software is finally installed on a Web server at AIT allowing access as mutually committed – either public access or access for selected users from the cities, protected through password entry.

5.1 Software architecture and user interface:

The TRANSFORM DSE simulates the energy consumption and production and the related greenhouse gas emission depending on certain preconditions. The decision support refers to changes in the system with respect to changing energy efficiency in the building stock, changing of energy carriers for heat and cooling as well as for power generation (shift from fossil fuels to renewables) to changing energy supply (shift from central power supply to distributed, individual supply e.g. through PV). The changes are calculated in a spatial explicit way and the impacts regarding energy consumption by carrier and greenhouse gas emission are estimated for spatial entities and for the entire city.

The software is designed through modules working together within the LIFERAY ® portal - an open source user interface appropriate to add, merge and control different functions within one web-site window which allows individual user interface design. An overview of the architecture is shown in Figure 3. A flexible geodata base structure based on PostGreSQL and OpenGIS contains finally the (harmonized) data of all six cities hre the sub set of the selected city is activated.

The graphical user interface (GUI) with control, retrieval and display functionalities has been developed by using standard Web server components such as Apache webserver as HTTP server, the PostgreSQL/PostGIS database and Apache Tomcat as backend for the communication with the database according to the users' queries. Geoserver as map server is used to deliver maps based on the users' requests. In addition, GeoServer provides the ability to integrate data directly into other applications e.g. a desktop-GIS via so-called services (such as Web Feature Service (WFS[1]) and Web Map Service (WMS[2])). The interface is accessible through

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[1] http://en.wikipedia.org/wiki/Web_Feature_Service

every web browser. Using Liferay® , an extensive set of different modules can be flexinle integrated in the interface. A Redmine ® system has been setup to support the software development by monitoring and documenting its progress.

To cover all steps described above the software architecture consists of several modules – a city context explorer, a scenario editor a measure editor and sequence editor for defining the temporal development. Some of these modules are related to the GIS component for spatial retrieval and visualisation. The database layer is the core where the simulation components refer to.
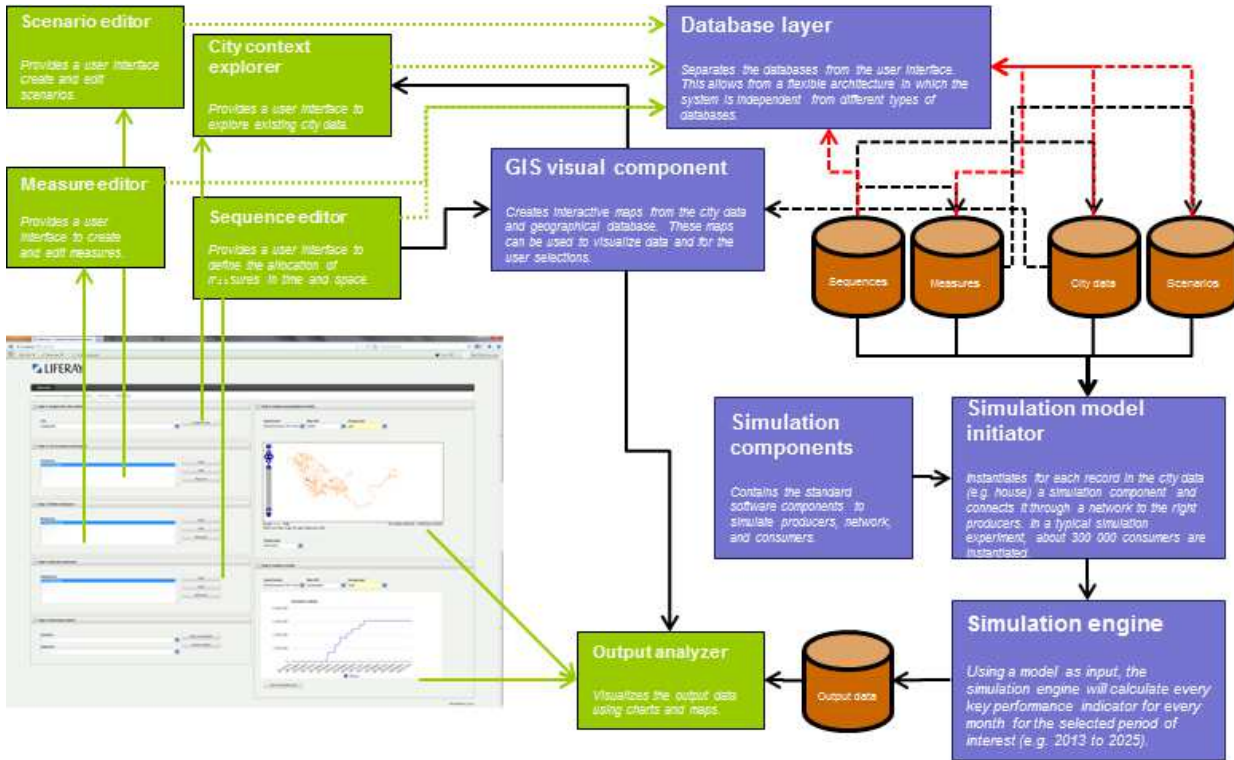

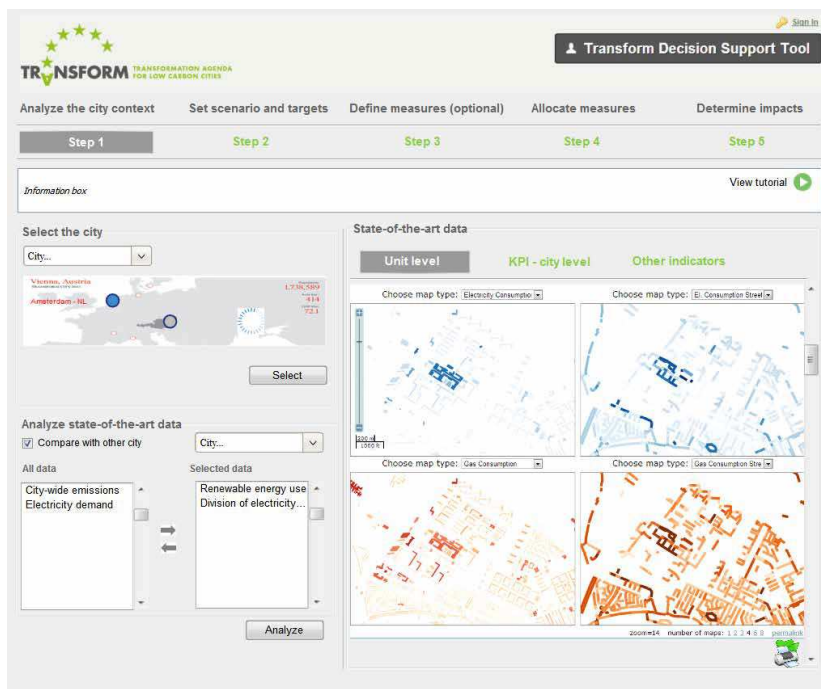Figure 3: Architecture of the decision support tool

Figure 4: Graphical user interface – initial page

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[2] http://en.wikipedia.org/wiki/Web_Map_Service

5.2 Application interface

The application accompanies the six steps (described in 4.2) to make decisions regarding measures to be implemented for improving smart city properties of the respective city. The initial screen is shown in figure 4. Clicking on each of the step-buttons leads to the next step on the way to achieve a decision.

The initial step 1 screen allows the selection of the city, a comparison with the partner cities in the project and the exploration of the characteristics of the selected city or a particular district or neighbourhood, as seen in figure 4. The mapping control and spatial retrieval functionalities which play a particular role are addressed in a section 5.4.

The step 2 screen allows selecting and adapting future scenarios by changing the framework conditions through entry fields, sliders, etc. and shows the development over time of the different framework-describing indicators through diagrams. Screen 3 is dedicated to the definition of measures (see section 5.4)

5.3 Database design and processes

Due to fact of highly dispersed data sets across the cities taken into account with respect to structure, content and availability, the topic of data integration, management and storage is a big challenge. As the data gathering is still ongoing it has been learned that the best approach for minimizing the time to make the data available to the application and to cope with less resources, a more flexible approach has to be chosen. So in contrast to traditional software development processes especially in the field of data warehouse projects where all the available data sources have to be screened and analysed in advance and the strategy and methods for cleaning up, harmonizing and integrating the data is created afterwards, the given data sets are loaded as they are to the city related stage areas within the database at first.

After cleaning and norming the city stage data the queries are developed and provided as views to generate the information needed to realize the as it is situation for the particular city, this is related to decision step 1 of the application (city context).

The information which has to be processed within the database encompasses the following categories:

(a) Geospatial datasets as polygons, lines or points

(b) Statistical datasets describing energy related properties of the physical entities in terms of

- Characteristics influencing energy consumption (e. g. for heating and cooling [building quality influencing energy efficiency])
- Activities demanding energy (e. g. power demand of households, services, production), time series data

(c) Parameters which provide the scenario background

- Population growth factors, energy prices
- Public transportation costs and modal split fractions

(d) Parameters which provide factors to estimate local energy production, energy consumption, energy savings potential, supply costs, environmental impact etc.

- Electricity generation factors (e. g. for PV panels/m²)
- Energy demand factors, (e. g. heating demand for houses by age class, electricity demand for households or flats by size class)
- PV installation costs per kWh, energy consumption in kWh per flat in density classes Greenhouse gas factors (e. g. for different energy carrier and heating or production systems)

(e) Specification of scenarios based on a), b) and c)

(f) Specification of measures (i.e. formulas to be calculated) based on a), b) and d) and auxiliary information required to carry out a simulation experiment.

The basic data structure as it will be used during the project is summarized in the following figure 3. As it is shown and described above each city dataset is transferred to the city related database scheme. This is done by usage of DB maintenance tools and especially for GIS based datasets the data can be loaded by open source software tools e. g. QGIS to the database. After cleaning the data and applying a common naming

definition the data is available for further usage. Regarding to the measures definitions which are worked out together with the cities as much as possible data which is needed as basis for the realization of the measures is generated based on the given data and provided to the application layer. It has been shown that this is still high effort task due to very different data sets and measures to be implemented.

The implementation of a centralized data store according to data warehouse standards is currently not possible due to lack of resources and missing accurate specifications regarding measure definition and available data. So the strategy is to create this step by step or at least describe the situation based on the given and still evolving status to have a guideline by the end of the project in place which can be handed over to the cities as basis for further development of data process and governance standards within the cities organization. The data structure and retrieval process is summarized in the following figure 5:
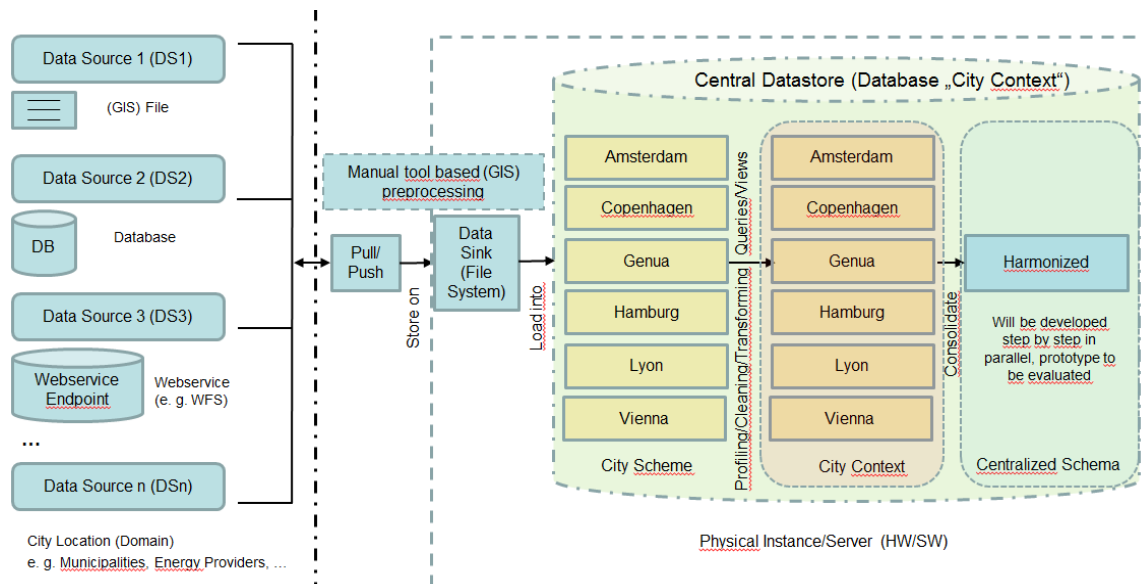

Figure 5 - Data retrieval and storage

5.4 Mapping and spatial retrieval functionality

The mapping module of the DSE tool consists of a server backend and a client front end. The backend is based on PostGIS spatial datasets translated from datasets delivered by the participating cities. The client is based on Open Layers and features a so called free hand selection feature which has been developed for the TRANSFORM DSE. Selected functionalities of a standard desktop GIS are provide in order to give also non-GIS experts the possibility to make use of these functions. The interface design is simple and gives the users a similar experience known from e.g. Google maps. The mapping functionality allows interactive exploration of physical and socio-economic framework conditions of the particular district and also all energy related data for single elements (e.g. buildings, blocks) or aggregates (e.g. blocks, wards, districts) or for the entire city. The spatial retrieval functionality allows the selection of geometric entities through mouse cursor or on a touchscreen. Thus interactive placement of possible measures at block-scale or district-scale is possible, allowing for an ex-ante assessment of effects of those measures (e.g. energy-efficiency improvement or technology & control improvement of blocks, fuel mix optimized towards GHG reduction, household and business electricity consumption reduction etc.).

The following figure 6 shows the free hand selection application in Amsterdam which allows allocating measures to certain areas or blocks and leave out the rest.

5.5 Measure editor

Measures are defined in equations that model the infidel change on production, consumption, costs and emissions of an entity. Each equation is individually calculated during simulation experiments and fed back to the system (being the entire system) through energy networks. Using this method, users have to follow a bottom-up approach where they need to define the changes on an individual level to be able to calculate the aggregated impact over time on a city level.

Wolfgang Loibl, Stefan Vielguth, Jan Peters-Anders, Sebastian Möller, Daiva Jakutyte-Walangitang, Joost Brinkman, Ivo Wenzler, Alex Cramwinckel, Michele Fumarola

Currently only a limited set of measures are established and a limited set of inpout data. If additional data are provided and futher measures are suggested by the citiies' stakeholders and coded to allow an impact assessment further measures can be integrated.

Figure 6: Spatial retrieval – free hand selection of areas of interest.

5.6 Results and presentation

The results are presented using geographical visualizations as shown above and using SpagoBI, business intelligence software. The latter allows for a thorough exploration of the output data by allowing the user to define charts other than the predefined ones. The latter is important as the detailed KPIs change depending on the stakeholders that are using the tool. Figure 7 shows an example of the usage of SpagoBI integrated in the decision support tool. Besides SpagoBI also other charting tools are in discussion which can be easily exchanged within the Liferay® environment.
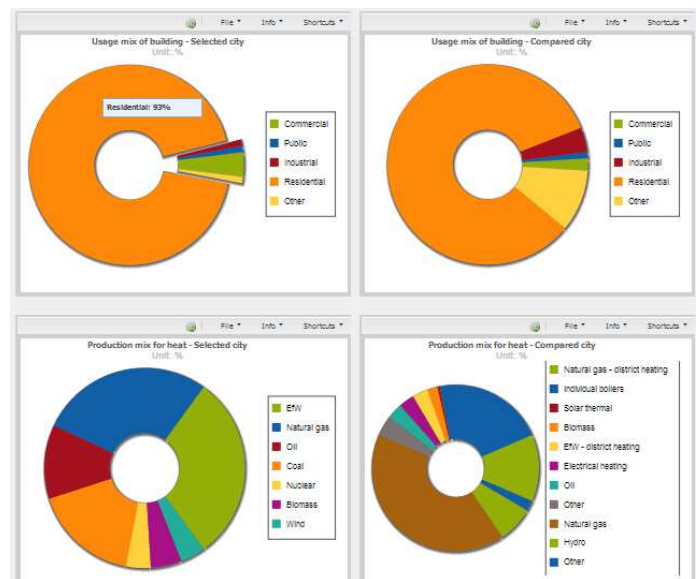

Figure 7: An example of output using SpagoBI

6   CONCLUSIONS AND OUTLOOK

The tool development was a challenge as the different stakeholder groups in the partner cities have been quite demanding regarding usability, functionality and flexibility.

The integration of a measure editor and the interactive spatial retrieval features makes the DSE tool attractive and provides flexibility unknown until now. Although we as developers have been working hard to establish high usability the application requires still some training due to the complexity of defining scenarios and measures and to understand the principles of the simulations in terms of spatial relation, temporal sequence and interdependencies within the urban system.

For the future it is planned to extend the usage of the DSE to be applied in a serious simulation game. One distinct property of a simulation game is to create shared intelligence by helping us enable social

construction of meaning, propagate ideas and skills, and enhance and facilitate communication (Gillert, 2008). This advantage shall be finally achieved to enhance the decision support of the DSE towards smart cities.

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