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Targeted selection of brownfields from portfolios for sustainable regeneration: User experiences from five cases testing the Timbre Brownfield Prioritization Tool

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Abstract

Prioritizing brownfields for redevelopment in real estate portfolios can contribute to more sustainable regeneration and land management. Owners of large real estate and brownfield portfolios are challenged to allocate their limited resources to the development of the most critical or promising sites, in terms of time and cost efficiency. Authorities worried about the negative impacts of brownfields – in particular in the case of potential contamination – on the environment and society also need to prioritize their resources to those brownfields that most urgently deserve attention and intervention. Yet, numerous factors have to be considered for prioritizing actions, in particular when adhering to sustainability principles. Several multiple-criteria decision analysis (MCDA) approaches and tools have been suggested in order to support these actors in managing their brownfield portfolios. Based on lessons learned from *the literature on success factors, sustainability assessment and MCDA approaches, researchers from a recent EU project have developed the web-based Timbre Brownfield Prioritization Tool (TBPT). It facilitates assessment and prioritization of a portfolio of sites on the basis of the probability of successful and sustainable regeneration or according to individually specified objectives. This paper introduces the challenges of brownfield portfolio management in general and reports about the application of the TBPT in five cases: practical test-uses by two large institutional land owners from Germany, a local and a regional administrative body from the Czech Republic, and an expert from a national environmental authority from Romania. Based on literature requirements for sustainability assessment tools and on the end-users' feedbacks from the practical tests, we discuss the TBPT's strengths and weaknesses in order to inform and give recommendations for future development of prioritization tools.*

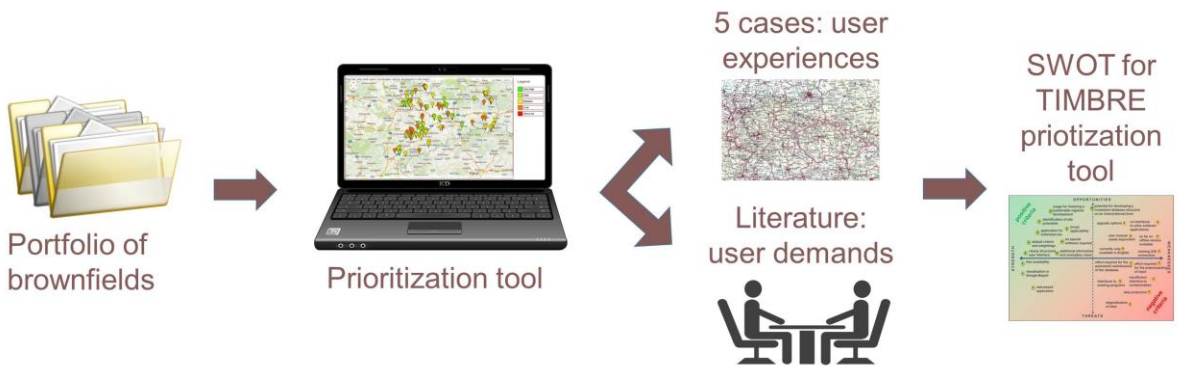
Keywords

brownfield; sustainability; stakeholder; portfolio; prioritization; decision support; case studies

Highlights

- Practical use of ´Timbre Brownfield Prioritization Tool' TBPT is tested in 5 cases.
- TBPT enables classification of sites according to targeted reuse potential.
- TBPT detects hidden reuse potentials and supports brownfield portfolio management.
- Versatility of TBPT is associated with data preparation investment.
- The TBPT can contribute to more sustainable regeneration of brownfields.

Graphical Abstract



Targeted selection of brownfields from portfolios for sustainable regeneration: User experiences from five cases testing the Timbre Brownfield Prioritization Tool

1. Introduction

The efficient use of soils and land has increasingly been understood as a key to sustainable development, stable ecosystem services and food-security globally (Amundson et al., 2015; Bateman et al., 2013; Gardi et al., 2014; Thornton et al., 2007). Land recycling, that is the functional reintegration of brownfields, which have lost their previous function and purpose, is being promoted as an important measure to reduce land-take of fertile soils (EC, 2012) and towards achieving a land-degradation neutral world (UN, 2014).

Indeed, there are many brownfield sites – for example, 120,000 hectares in Germany are brownfield or underutilized spaces between buildings available for reuse (Schiller et al., 2013). Each brownfield represents specific challenges for the environment and adjacent community as it has been affected by former uses; is derelict or underused; requires intervention to bring it back to beneficial use; and may have real or perceived contamination problems (cf. CEN, 2014). Moreover, all brownfield sites vary concerning their unique characteristics, such as location, size, extent of potential contamination resulting from previous use, etc. As a result, diverse stakeholders have heterogeneous concerns regarding successful and sustainable brownfield regeneration (Rizzo et al., 2015).

A concern is often to identify from among a multitude of properties those that present the highest potential for regeneration, or to concentrate limited resources for sites where hazard prevention is of highest priority. In this sense, an effective exploration of regeneration options poses particular challenges in the management of real estate portfolios. It is a complex task for land-owners to prioritize brownfields in a way that provides suitable solutions for both general and specific requirements in an efficient and clearly structured manner.

On the one hand, owners of complex real-estate and brownfield portfolios have to deal with the organization and handling of their portfolio. This becomes increasingly difficult and complex as the number of sites contained in the portfolio increases and the more heterogeneous the (potentially) contaminated sites are regarding previous use or re-use options. On the other hand, it is necessary to give reliable answers with as little effort as possible about the availability of sites according to specific criteria and about the suitability of these sites for certain re-uses. A key issue for portfolio-owners is to match the manifold requirements of a specific development project with a list of brownfield sites with diverse characteristics (Bartke et al., 2014). The same holds for problem-owners or public authorities who deal with brownfields in their (administrative) region and have to decide on the allocation

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of intervention measures. Many institutional property owners or local authorities have developed comprehensive land registers. However, an increasing size and level of detail of these databases goes along with a decrease in clarity and comprehensibility.

Along with the complexity related to the availability of data, a prioritization/optimization process is strictly dependent on the identification of sound goals. As stated by Kiker and colleagues (2005), effective environmental decision making depends on considering (multi)criteria derived from environmental, ecological, technological, economic and socio-political factors, which make the process ‘multi-objective’. By including and accentuating measures of sustainability, more environmentally friendly, economically worth and socially accepted results can be achieved, implementing the three pillars approach of sustainable development (WCED, 1987), which has been implemented in numerous standards and certification systems (Manning et al., 2011; Reinecke et al., 2012).

In order to deal with the complex decision-making processes, several multi-criteria decision analysis (MCDA) approaches and tools have been developed and increasingly applied in different fields, including the land-use context. Prioritization tools based on sustainability frameworks and MCDA allow assessing requalification options from different points of view, respecting the needs of multiple stakeholders (e.g. Chen et al. 2009; Chrysochoou et al, 2012; Nogués and Arroyo, 2016). MCDA tools are used in the presented methodology due to their ability to combine heterogeneous inputs with cost/benefit information and stakeholder views and they are recognized as suitable tools able to support the ranking of regeneration alternatives based on the sustainability framework (Critto et al., 2006; Boggia and Cortina, 2010; Rosén et al., 2015).

However, as Bartke and Schwarze (2015) have emphasized, tools that have the goal to both assess sustainability and give user-support at the same time must fulfill user-group specific requirements in order for the tools to be taken up by them in their practical work. Elsewise, even scientifically perfect sustainability evaluation tools will not be used in practice, for example, if the needed data are not available or their handling is too complex. The authors conclude that the design of sustainability assessment tools must adopt a two-tier approach, integrating top-down a normative perspective, which means a deductive demand for specific tool constituents embodied in and reflecting general sustainability principles, with an bottom-up inductive approach understanding end-users’ needs. Bartke and Schwarze derive at a set of criteria to describe these user requirements, such as objectivity or practicability. Any MCDA tool for prioritizing brownfield selection from portfolios also needs to satisfy user needs and should be tested against ease of use for end-users.

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2. Scope and objective

How can portfolio owners find out which of the brownfields contained in their portfolio present the highest potential for a specific use? Which of the sites should be chosen to make the most effective use of the scarce resources? This article starts from the following real world observation: different stakeholders are faced with a portfolio of brownfields – real estate owners, investors or problem owners – and they are interested in selecting from this portfolio in a targeted way those sites that are most promising to achieve certain aims, such as lucrative or ecologically necessary regeneration. This understanding of portfolio management differs from the financial real estate portfolio management (following e.g. Markowitz, 1952), which focusses on questions of theoretically optimal strategic bundling of real-estate or brownfield portfolios, in which the composition of the property portfolio impacts on the return on investment.

Within the EU Seventh Framework Programme project TIMBRE, researchers pursued this observation and developed a specific tool – the Timbre Brownfield Prioritization Tool (TBPT or TBP-Tool) – drawing on the expertise of scientists, regulatory bodies and business representatives (cf. Pizzol et al., 2016). The aim of the tool is to assist stakeholders in the identification of those brownfield sites that should be preferably considered for regeneration. This is achieved by taking into account a set of success factors, which represent stakeholders' regeneration objectives. The factors are based on the three pillars of sustainability (economic, social and environmental dimensions). It has been designed to be a user-friendly, intuitive, web-based, flexible solution, which supports stakeholders in the allocation of available limited resources to those areas that are assessed to be the most critical, urgent or profitable to be regenerated – tailored to sustainable development or individual needs and preferences of the end-users (Pizzol et al., 2016).

Next to a general discussion of MCDA in brownfield regeneration in a portfolio context, the added value of this contribution is that the TBP-Tool developers actually went about testing the tool's applicability; and this process of asking for and analyzing feedback, to our best knowledge, stands out in terms of a novel contribution to the brownfield regeneration literature.

Institutional, administrative and problem owners of large property portfolios and real estate developers from three countries were asked to apply the TBPT for their portfolios. Their experiences serve to highlight the key characteristics of the tool. A total of five cases are reported here: Practical test uses by two large institutional land owners from Germany, a local and a regional administrative body from the Czech Republic, and by a key expert representing the Romanian National Environmental Protection Agency (NEPA).

Next, this article provides brief background to the state-of-the-art of MCDA application in brownfield management. In section 4, we present the main functionalities of the TBPT. Subsequently, section 5 reports on the experience that the end-users of the TBPT have gained in the Czech Republic, Germany and Romania. In section 6, we discuss the strengths, weaknesses, chances and risks of the tool's application and on how the tool satisfies general, basic end-user requirements. A final section concludes on the potentials of such tools to support sustainable regeneration and gives recommendations for future development of prioritization tools.

3. The potential of MCDA to support sustainable regeneration

Comparative assessments according to different criteria may yield good results when suitable sites for different purposes have to be selected from a large number of brownfields. When pondering the different alternatives, it is essential to base the planning on monetary aspects but also to consider ecological and social criteria. Indeed, a prioritization based on sustainability criteria is a prerequisite to the development of selected brownfields with usually limited resources. For this reason, multi-criteria approaches are suitable to implement sustainability principles, since they allow to take into account information related to all indicators pertaining to the three pillars of sustainability and to integrate them in the light of different stakeholder priorities.

MCDA has been used for sustainability assessment remedial and regeneration strategies by a number of authors at different scales (Agostini et al., 2012; Alvarez-Guerra, 2009; Brinkhoff, 2011; Chen et al., 2009; Cheng et al., 2011; Chrysochoou et al., 2012; Pizzol et al., 2011; Rosén et al., 2015; Schädler et al., 2011, 2012; Smith and Kerrison, 2013; Sparrevik, 2012; Volchko, 2014; Zabeo et al., 2011) which vary in a wide range of aggregation methodologies spanning from outranking methods (based on direct comparisons) to Multi Attribute Value Theory (MAVT) based on hierarchical aggregation.

MCDA approaches allow for the quantification of decision-makers' and stakeholders' concerns, expectations, perspectives related to heterogeneous aspects used to assess alternative courses of action, which can be described by both, qualitative or quantitative indicators. MCDA embeds a considerable amount of different mathematical approaches and methodologies, which differ in the input elicitation phase, in the problem structuration, in the aggregation functions as well as in the presentation and interpretation of results.

Although all the proposed methodologies have been successfully applied and reportedly have been appreciated by involved stakeholders, MAVT methods tend to be preferred due to

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their relative simplicity and linearity which fosters transparency and inclusion of non-expert assessors during the problem definition phase.

Following this reasoning, the TBP-Tool presented in this paper has been based on a MAVT linear aggregation methodology (cf. Pizzol et al., 2016).

4. The Timbre Brownfield Prioritization Tool

The TBP-Tool is mainly based on a survey about success and failure factors in land recycling (Frantál et al., 2012; Osman et al., 2015), which were included in the tool as evaluation criteria. For this purpose, an international database comprising examples of successful regeneration projects was set up. A review of the international literature and a subsequent survey among European experts in land recycling (Rizzo et al., 2015) helped determine the decisive factors to successful economic and ecological brownfield regeneration.

Starting from these findings, the TBP-Tool's MCDA methodology has been structured according to three integration levels (from a wider to a more specific perspective): The first level is represented by 'dimensions', which are specific aspects of the regeneration potential, namely i) local development potential, ii) site attractiveness and marketability, iii) environmental risks, and/or iv) other specific criteria defined by the end-user. The second level is represented by success factors, which are conditions, circumstances, actors that are determinants and contributors to successful brownfield regeneration. The third level are indicators, which are measurable variables used to characterize success factors. By combining the results produced by the different levels, the TBPT provides a comparative assessment, classification and prioritization of a user-defined number of sites contained in a portfolio (for further details cf. Klusáček et al., 2013 and Pizzol et al., 2016).

Moreover, by changing the tool's prioritization settings, sites can be prioritized based on: i) several spatial levels (country, region, district, town, etc.), ii) different factors and relative weightings, and iii) different priority targets, e.g. economic benefit, existing environmental hazards or health risks requiring urgent action, preservation of buildings of historic or architectural value, current political objectives or requirements of the adjacent neighborhood and municipalities.

Fig. 1 summarizes the conceptual approach in a schematic representation of the requirements, input factors and results of the TBP-Tool.

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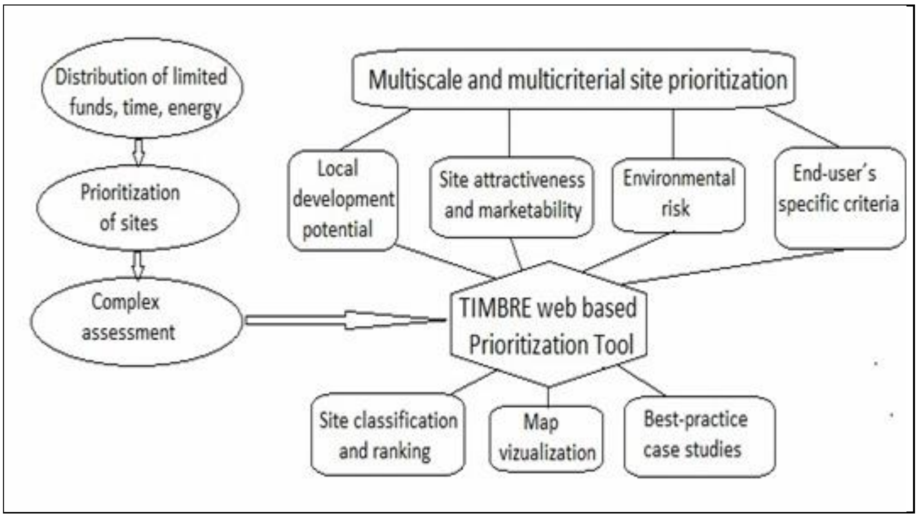

Fig. 1. *Schematic representation of the requirements, input factors and results of the Timbre Brownfield Prioritization Tool (adapted from Klusáček et al., 2014a).*

To enable effective prioritization of a brownfield portfolio, preparation of detailed and reliable data is most important. A precise site survey including mapping, identification, environmental analysis and inventorying of the brownfields is the first step. The amount of data needed can pose a significant challenge. Therefore, the tool was developed in a way that it is not mandatory to enter all details and/or site criteria. To enhance flexibility, the tool can also be used with considerably lower information density. In this case, the comparative assessment is performed with the available criteria and details only – of course, the results will be less precise.

4.1 TBPT system structure

The TBPT is composed of four modules. The 'User management module' assists users during registration, log-in and log-out, password setting and retrieval. Second is the 'Project setting module'. It assists users in the creation, modification and removal of user specific projects. A project is for example a real estate portfolio to be assessed for suitable regeneration investments.

Third is the 'Ranking methodology module'. It implements the MCDA methodology including the identification of factors and indicators suitable for the prioritization objective, the normalization of the identified indicators, their weighting and aggregation into factors, the weighting and aggregation of factors into dimensions and finally the weighting and aggregation of dimensions into the final prioritization score. A detailed description of the MCDA methodology implemented in the TBPT is discussed in Pizzol et al. (2016).

Finally, fourth is the 'Results visualization module', which supports the visualization of calculated rankings and intermediate data, which are provided in form of prioritization ordered tables and geographical maps of sites' locations.

4.2 System requirements

Only a minimum of system requirements has to be met in order to use the TBP-Tool. A common office computer and access to the internet are sufficient. Microsoft Excel® is needed for entering the data and Google Maps® for the graphic representation of the results. Prior online registration is required to access the tool. This ensures that entered data and respective results are password-protected.

The user interface is kept simple and intuitive (see the main navigation bar in the upper part of Fig. 2). End-users' data can be entered into a Microsoft Excel® spreadsheet, for example by uploading data from the user's own portfolio represented in a respective database system.

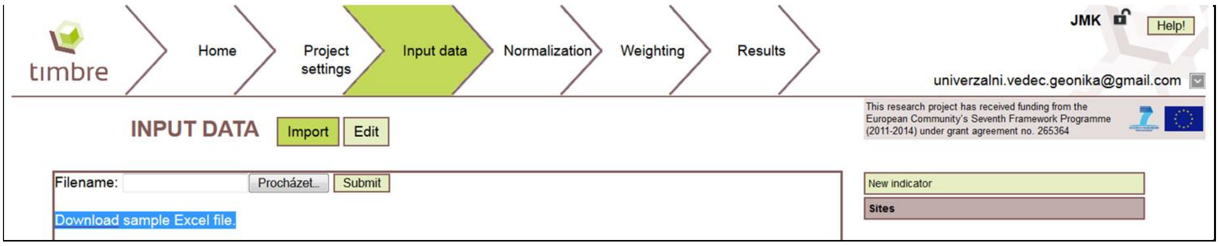

Fig. 2. *Screenshot of the Timbre Brownfield Prioritization Tool showing the data input data screen.*

The software allows for a stepwise evaluation of each site's classifications in the three default dimensions (local development potential, site attractiveness and environmental risks) – representing societal, profit and planetary pillars of sustainable development. These dimensions can be increased in number, enhanced and modified according to the end-user's requirements and aims by manually adjusting the system default factors and indicators and their related weights. This is to ensure adaptability of the tool to local application objectives.

4.3 Data input

Existing databases and registers can be used provided that contents can be converted into a Microsoft Excel® sheet. A template is available on the TBP-Tool's webpage. The geographic coordinates of the sites in question need to be entered to allow for the visualization and cartographic representation. For the prioritization process, central coordinates of a site may be sufficient. To simplify the procedure, coordinates can directly be obtained from an online map service such as Google Maps® or a similar service.

Time and thus costs involved in entering the data considerably depend on the electronic availability of the user's portfolio data. Assuming that a database system exists, which allows data queries to be saved in a table format, the workload will depend in general on the existing data density. Certainly, the acquisition and pre-processing of data for a database requires considerable effort. Moreover, the workload involved in maintaining the databases up-to-date is often underestimated. Therefore, it is the objective of this contribution to give a concurrent evaluation of the costs and workload based on the practical application of the TBPT application in different cases (section 5).

4.4 Presentation of the results

The TBP-Tool offers two options of presenting the results. The tabular view (see Fig. 3), also available as download for Microsoft Excel®, presents the result of the comparative site assessment including the chosen weightings in a clear and comprehensible form. The most suitable sites for specific regeneration scenarios can be directly identified through the calculated components and the ranking of the results. In addition, the results of the default perspectives ('dimensions': local redevelopment potential, site attractiveness and marketability, and environmental risk) are shown. Next to the overall ranking result that guides the efficient allocation of limited resources to targeted regeneration measures, interpretation of the tabular information helps end-users to reveal strengths and weaknesses of individual sites from the portfolio. For example, a low scoring in a particular dimension signposts major drawbacks of a site. At the same time this indicates the critical area of intervention where to consider targeted measures for improvements to minimize or remove these deficiencies.

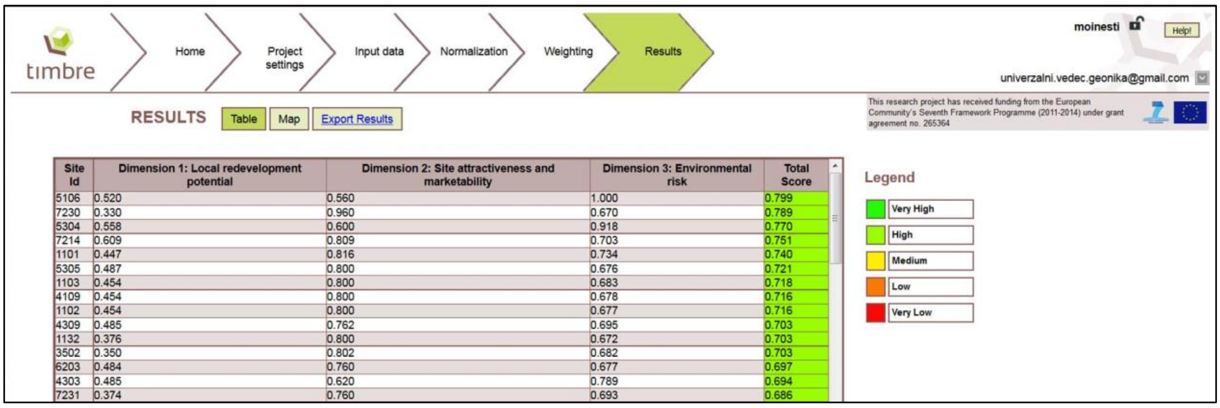

Fig. 3. Screenshot of the Timbre Brownfield Prioritization Tool – Tabular view presenting the prioritization results.

The graphic representation of the results based on Google Maps® (different examples follow in section 5) provides the spatial distribution of the evaluated sites. Again, the results can be presented individually according to the three default dimensions of local redevelopment potential, site attractiveness and marketability, or environmental risk, as well as considering the comprehensive prioritization score, which integrates the three dimensions. The TBPT was designed as a web-based application, accessible from anywhere, via different PCs and tablets, combining the advantages of cloud and stationary solutions. It looks like a desktop application while being in reality an internet website (available through the URL http://www.timbreproject.eu/prioritization-tool.html), which uses GIS web-functionalities only for results visualization (Pizzol et al., 2016). However, some spatial considerations are included in the assessment by filling in the TBPT with data on the distance of each analyzed site from infrastructural connections (railway, freeway, etc.).

5. Practical applications of the TBP-Tool

In order to evaluate the practical usefulness of the TBP-Tool, institutional, administrative and problem owners of large property portfolios and real estate developers were invited to apply the TBPT for their portfolios. Five cases are presented in the following: a local and a regional administrative body from the Czech Republic, two large institutional land owners from Germany, and the Romanian National Environmental Protection Agency (NEPA).

In order to develop products, which are suitable for practical use, TIMBRE researchers collaborated with property and problem owners, in particular with the project partners Society for the Development and Remediation of Brownfields (GESA) and the Romanian NEPA. Next to these, administrations and further potential end-users were contacted in Germany and the Czech Republic. Hence, the cases and analyses presented in the following have emerged from these direct or indirect collaborations with the end-users during the funding of the TIMBRE project. Notably, in each case members of the respective institutions – and not researchers, which were the tool developers – were asked to apply the TBP-Tool and then share with the researchers their experiences and discuss the usefulness of the TBPT. The five application cases and stakeholders are described next, presenting individually their experiences with applying the TBPT with their portfolios.

5.1 GESA portfolio in Saxony, Germany

GESA, based in Berlin, is a company in indirect ownership of the Federal Republic of Germany. GESA is concerned with the regeneration and development of former industrial sites as well as the sale of properties from its portfolio.

Currently, the company's portfolio comprises approximately 1,250 sites, in majority problem-laden brownfields situated in Eastern Germany, which cannot be directly put to new use as a consequence of impairments due to their previous use. Already existing assessments indicate that the majority of these sites can be categorized as category C sites according to the CABERNET classification (cf. Doleželová et al., 2014); this means as brownfields that are not profitable projects for private investors but need public funding or specific legislative instruments to enable any regeneration. In addition to its core business concerned with the remediation, development, administration and commercialization of the company's property portfolio, GESA constantly aims at offering sites of its brownfield portfolio for reuse options. Comparative assessments of its portfolio for the purpose of selecting the most 'suitable' sites constitute therefore an inherent part of the company's development and marketing strategies.

GESA applied the TBP-Tool to assess 100 brownfield sites from its portfolio. These sites are located in the Free State of Saxony in Eastern Germany. For the assessment, GESA created tables (Excel® format) based on its internal database and adapted to the structure of the spreadsheet template provided by the TBP-Tool; missing spatial coordinates were taken from Google Maps® and added to the table.

To gauge the practical usefulness of the TBP-T, next to the quality of the results, the effort needed to run the assessment is of significant practical concern. The time required by GESA for data preparation is estimated to 15 to 45 minutes per brownfield site depending on the type of data available for the respective site. A time-consuming factor was the acquisition of the geographic coordinates and their manual input into the spreadsheet. However, the stated 15 minutes are a realistic time estimate if geographic coordinates are available. GESA's experience with the practical application of the tool suggests that once being fully acquainted with the tool and having built up search routines, a trained assistant may be able to preprocess data for up to 50 sites per day. The subsequent, actual application of the tool for the prioritization of the pool of acquired and preprocessed data was judged by GESA to be a comparatively quick and user-friendly process.

As regards the contents, the prioritization of the brownfields – so far mainly classified as C sites – showed i) that there are large differences in terms of the marketability of the sites contained in the portfolio, and ii) that particular sites have a substantial development potential depending on the targeted reuse option. Fig. 4 provides a cartographic representation of the prioritization of GESA data.

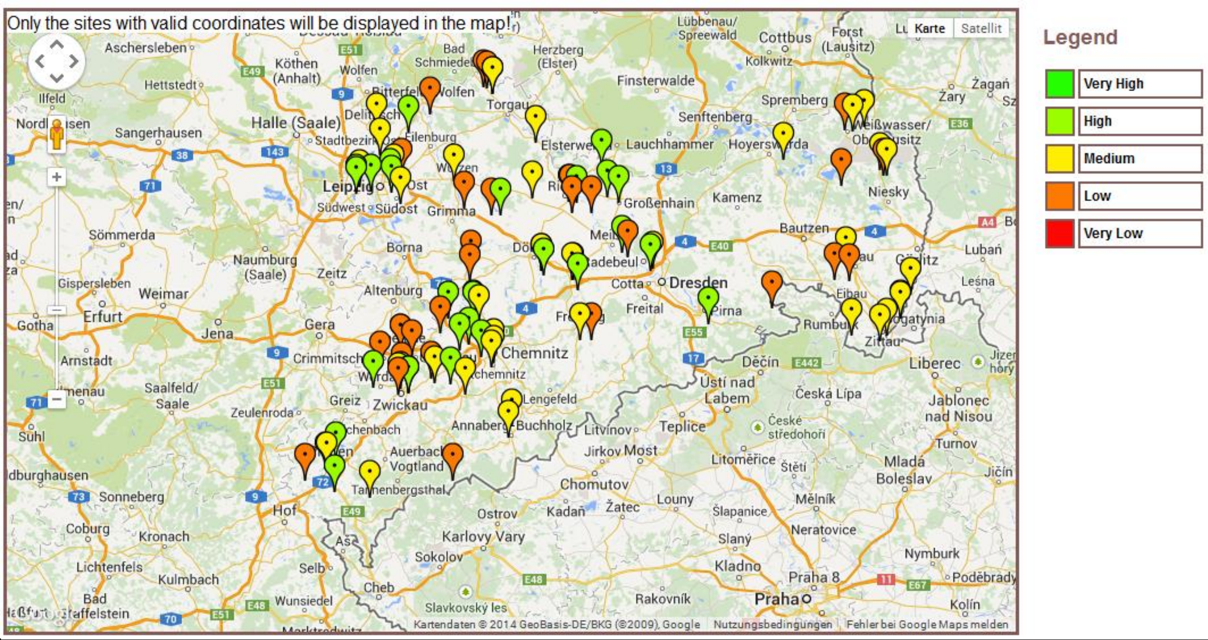

Fig. 4. *Screenshot of the Timbre Brownfield Prioritization Tool – Cartographic representation of the prioritization result after processing exemplary sites of the GESA portfolio in Saxony.*

As stated by GESA, the outcome suggests that applying the TBP-Tool offers the chance to obtain wider-ranging information on the marketability potential of particular sites and to effectively aim at identifying prerequisites for the development of sites.

5.2 LEG portfolio in Thuringia, Germany

Acting on behalf of the Free State of Thuringia, the State Development Corporation of Thuringia (LEG) is a well-established (re)development agency responsible for particular sites, quarters and neighborhoods, as well as for entire regions in the Free State of Thuringia in central Germany since 1992. In its role as a property manager and promoter of economic development, LEG focusses on the regeneration of brownfield sites in its region. As GESA, LEG Thuringia faces the challenge of identifying the most suitable sites from its portfolios for projects to be realized for environmental protection, economic or political reasons. Both companies have their portfolio data stored in varying formats and aimed at finding a quick, cost-efficient as well as informative approach to analyze their extensive portfolios in accordance with their specific requirements.

In 2005/06, LEG in cooperation with Thuringia's urban and rural district administrations prepared a regional register of brownfield land. This register lists 7,200 sites comprising an area of some 6,800 hectares. 200 of the sites included in the 2005/06-register that were classified as C sites were chosen as illustrative and typical by LEG and assessed with the TBPT.

The spatial coordinates needed to be identified for all sites and were together with the further required information added to the template spreadsheet of the TBPT. This required about 30 minutes per site. Fig. 5 provides a cartographic representation of the prioritization result.

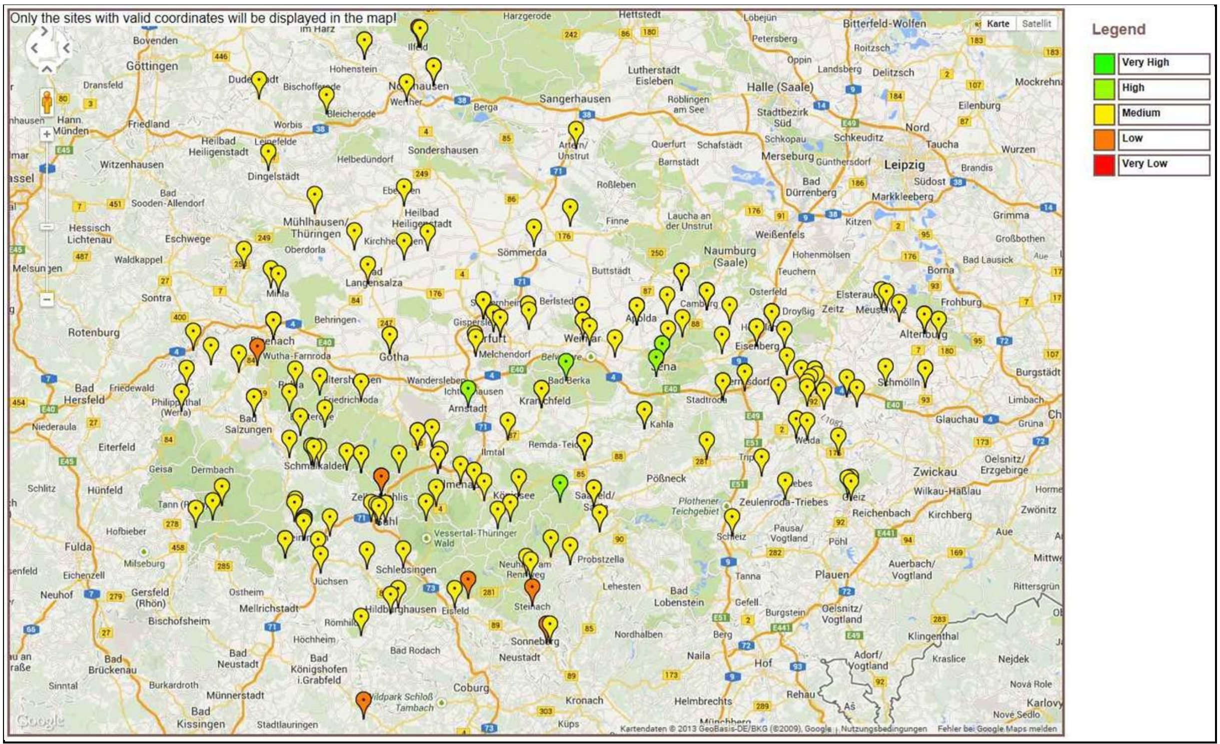

Fig. 5. *Screenshot of the Timbre Brownfield Prioritization Tool – Cartographic representation of the prioritization result after processing exemplary sites of the LEG portfolio in Thuringia.*

The outcome was in general in line with the expectations the expert of LEG, who tested different weights' settings in order to obtain a manageable low number of sites with high regeneration potential in order to suggest these sites to possible investors. The results confirm, for example, that the marketability of some of the sites increases with the vicinity to urban agglomerations (prioritization factor: *peripherality*). However – and although quite uniform at the first glance in Fig. 5, the prioritization results as detailed in the tabular output also held surprises. For specific reuse options of certain sites, the TBPT indicated higher marketability values than anticipated by LEG. Some sites received higher scores than expected and were therefore given increased attention. It can be presumed that a higher visibility of site potentials resulting from the application of the TBP-Tool will increase the demand for these sites in the future.

5.3 Brno urban brownfield database, Czech Republic

Next to the brownfield owner and developer perspective, the problem owner perspective was to be included. In particular in Eastern Europe, administrative bodies, such as municipalities, face the challenge to direct limited resources to the regeneration of brownfields from a portfolio of derelict and potentially contaminated sites (e.g. Tintera et al., 2014).

With 380,000 inhabitants and an area of 230 km², Brno is the second largest city in the Czech Republic. Brno has a strong industrial tradition. After the return of the market economy in 1989 and as a consequence of the shift in Brno's economy in the 1990s, an increasing number of urban brownfields emerged in a deindustrialization process seen with comparable consequences in most post-socialist states (Kunc et al., 2014). In the same period, also Brno's development was influenced by intensive residential and commercial sub-urbanization trends or close behind the administrative borders (Domalewski and Baxa, 2015) and intensive new urban developments on greenfields created pressure to regenerate existing brownfields.

Brno city administration began to address brownfield regeneration at the turn of millennium, when the results of de-industrialization process of the city started to be visible and became an issue for both the citizens and for the elected local government. To support communication and to attract potential investors, a database of brownfields was gradually generated resulting in a comprehensive database of Brno's brownfields in 2010. In 2012, a web-based map application, which makes the entire portfolio of collected brownfields publicly accessible, was developed by city officials (SM Brno, 2015). At the end of 2014, the periodically updated Brno database of non-regenerated brownfields contained 124 sites of various original uses with an area larger than 0.5 hectares that are owned by public but also private bodies with a total area of approximately 420 hectares. More information on the sites can be found in Frantál et al. (2015).

The preparation of data for the TBP-Tool processing was experienced to be complicated in the case of brownfields in the urban district, since other than usually used indicators had to be utilized (e.g. functional zones of the city, retail saturation, property value of flats, distance to central district of the city). It was necessary to aggregate some data with respect to the specifics of Brno's urban structures and due to data inconsistencies on the local level. This took around 50 minutes per site. Fig. 6 provides a cartographic representation of the prioritization result obtained for the Brno portfolio.

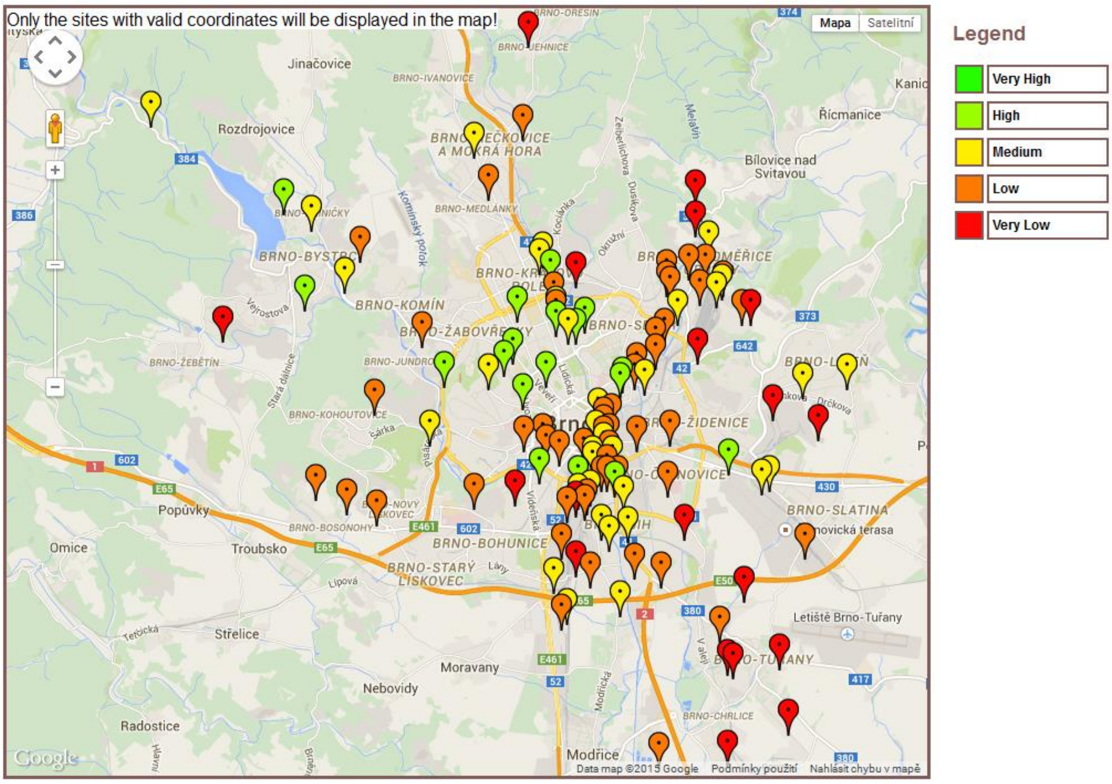

Fig. 6. *Screenshot of the Timbre Brownfield Prioritization Tool – Cartographic representation of the prioritization result after processing sites of the City of Brno brownfield database*

Interpreting the results of the prioritization, a crucial component for the growing development potential of the sites seems to be related to the distance/proximity from/to the city center and distance from main traffic thoroughfares. Thus, brownfields originally used for agriculture on the city outskirts show the lowest potential. From that perspective, the results are not regarded as surprising. However, the prioritization results were more challenging and inspiring in the inner city areas, where urban brownfields are spatially concentrated (especially in proximity to railway infrastructures). As reported in Frantál et al. (2015), three clusters could be delimited – Brno's urban zones with the most frequent occurrence of brownfields, where these sites represent the most urgent challenge for local urban planning. As shown in their analyses, brownfields of larger extent and those with less or no contamination have the highest redevelopment potential – no matter of the specific location.

5.4 RDA database of South Moravia, Czech Republic

The database of brownfields created by the Regional Development Agency (RDA) contains brownfields of six predominantly rural districts of the Eastern Czech South-Moravian region with relatively low population density next to the city of Brno: Blansko, Brno-Countryside, Břeclav, Hodonín, Znojmo and Vyškov. Therefore, it has to be presupposed that brownfields in the RDA's portfolio have to compete with many new development zones on greenfields and new industrial and commercial zones. The enormous problem of brownfield regeneration in this region is related to sites of agricultural origins, because they are often located in small rural municipalities with reduced attractiveness for potential investors. Generally, in smaller municipalities, even temporary energetic use is regarded as a successful redevelopment (Klusáček et al., 2014b).

A main goal of the RDA is to contribute with its database to regional development through consultancy and assistance to both public and private bodies for planning regeneration projects. The first version of a database had been based on a register of brownfields that was built by CzechInvest Agency in 2005-07 and a database of the Regional Information Service of the Regional Development Center. Based on these materials, RDA officials carried out field research in 672 municipalities in 2010 in order to learn more about the recent developments of brownfields and to collect updated data. Information gathered from the individual municipalities were unified and integrated into a web-based tool in 2011, which is available at http://www.brownfieldy-jmk.cz/. The RDA database is periodically updated and serves both as source of information for municipalities while planning their development and to attract potential investors.

At the end of 2014, the RDA database consisted of 235 brownfield sites that cover almost 890 hectares. The sites represent brownfields of various original uses (industrial, military, agricultural, etc.) and various ownerships (public, private, mixed) (cf. also Pizzol et al., 2016).

It took around 25 minutes to prepare the data for an individual site for assessment in the TBP-Tool. Fig. 7 provides a cartographic representation of the prioritization result.

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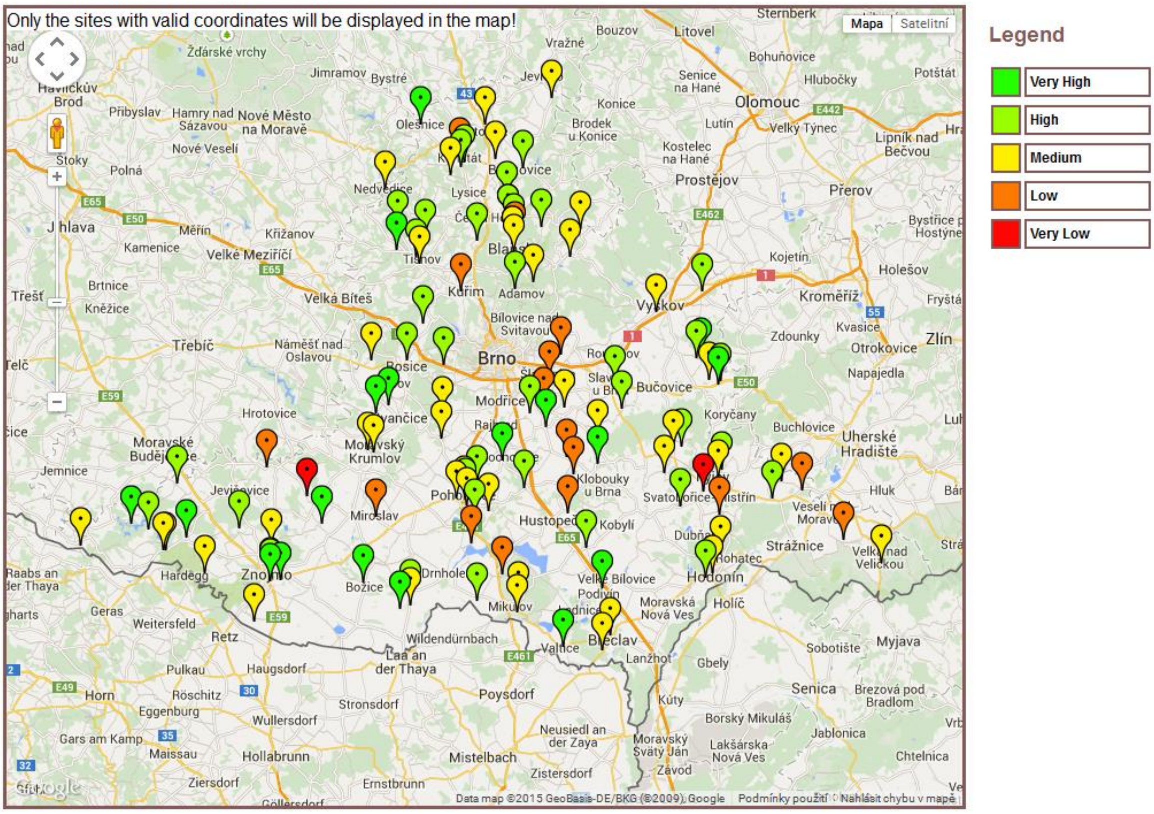

Fig. 7. Screenshot of the Timbre Brownfield Prioritization Tool – Visualization of the prioritization result after processing sites of the Regional Development Agency of South Moravia brownfield database

As regards the results of the prioritization exercise, an obviously higher potential for redevelopment is identified in sites located near transport nodes and transport axes (especially highways) and those in proximity of relatively larger (district level) cities. On the other hand, the lowest potential is linked to the sites in peripheral municipalities, where the population is decreasing due to negative net migration rates in the last decade.

Prioritization on the regional level showed interesting spatially differentiated results, reflecting that the development potential of various types of municipalities strongly differs in South Moravia. The surprising fact about these results is that even brownfields in peripheral positions can have quite good development potential if they are not polluted and if they are located in good positions in the settlements system.

Comparing these results with the Brno urban brownfield assessment presented in the previous section, one needs to keep in mind that 1) the assessment has been done by different stakeholders with different regeneration objectives and 2) that the TBPT prioritizes the sites within one portfolio. This means, what might be an undesirable site in one portfolio (e.g. city) might not be preferable in a neighboring one (e.g. the regional perspective).

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5.5 National database, Romania

The context in which the TBP-Tool has been applied in Romania is somewhat different from the previous case studies and warrants two brief explanations. The first concerns the definition of terms and the availability of data and the second the institutional context of applying the TBPT in Romania. Brownfield sites in Romania are most frequently associated with the contamination of soil (Cobarzan, 2007). In contrast to their German and Czech counterparts, Romanian decision-makers do not pay explicit attention to the regeneration potential of more or less contaminated sites, and also for public sector actors, this is still an emerging field of attention (Alexandrescu et al., 2014).

The TBP-Tool has been applied to a selection of 132 sites from a portfolio of brownfields in Romania. All sites were not in use when they were inventoried in 2007-08. They belonged to a larger set of 1,851 potentially contaminated sites, of which the reminder were landfills or contaminated but still in use. The database reflects the best available dataset of the brownfield situation in Romania.

The time needed to prepare the data has been estimated at 350 hours for the 132 sites, that is about 2:40 hours for each site. This extended time was necessary because the original database lacked a significant part of the information needed for prioritization, for example the geographic coordinates of a site, the area of the site, its previous uses, its proximity to infrastructure etc. In some cases, it was necessary for the NEPA expert to call the local environmental agencies or town halls to gather the missing information. In conclusion, the Romanian case was the most demanding in terms of meeting the data requirements of the TBP-Tool.

The representation of results in Fig. 8 shows that only a minority of sites (6 %) have high redevelopment potential, 44% medium potential and half of all sites have low potential. Not surprisingly, most of these sites are located outside the major urban centers of Romania, such as Bucharest, Cluj Napoca, Constanta or Iasi. Moreover, all of them have either confirmed or expected contamination. This finding is consistent with the previous observation that information on these sites was collected due to contamination concerns rather than due to their redevelopment potential. Moreover, the context in which the TBPT was applied in Romania lends further credence to this interpretation.

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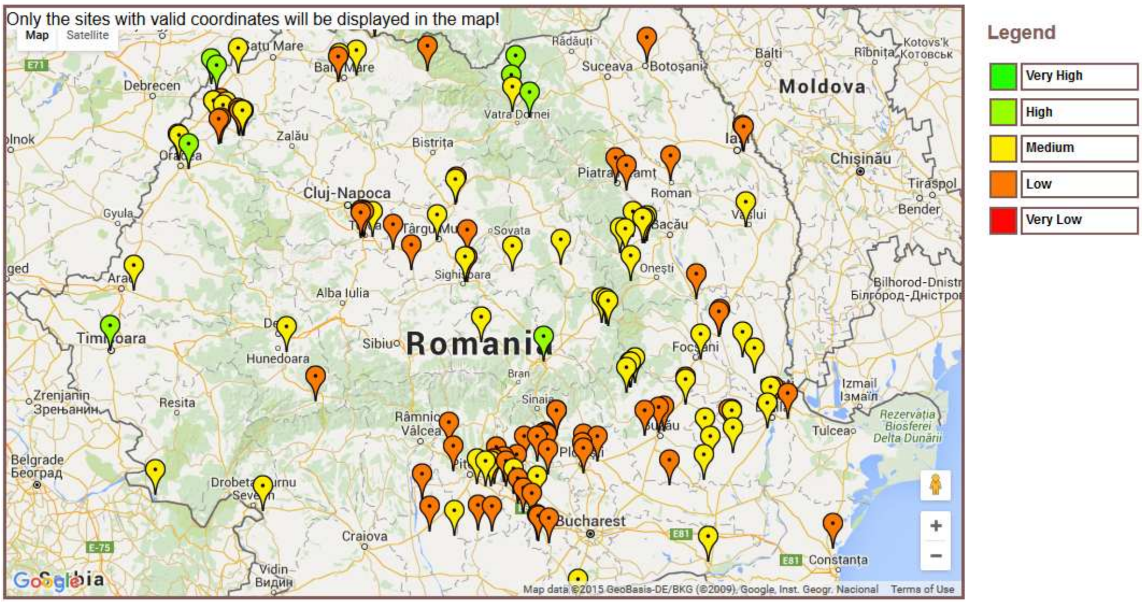

Fig. 8. Screenshot of the Timbre Brownfield Prioritization Tool – Map of redevelopment potential of selected contaminated sites in Romania.

The representative of the NEPA who was interested in applying the tool did so out of professional motivation but, he explained, no one else from the national environmental authorities was interested in applying a prioritization tool. This expert was part of the TIMBRE consortium and therefore applied the tool outside of his routine professional activities. He nevertheless appeared convinced of the usefulness of the tool and would have advocated its widespread adoption as an official assessment and prioritization tool. However, his intentions remained unfulfilled when he was required to retire from NEPA. Despite this expert's interest in applying the tool, it appears that the prospects of using the TBPT by national-level actors in Romania are limited. The major hindrance seems to be the narrow and often misguided equation of brownfields with the problem of contamination and the consequent lack of attention to the redevelopment potential of brownfields.

6. Discussion: Strengths and weaknesses, sustainability and user requirements

To further identify and summarize the potentials and limitations of applying the Timbre Brownfield Prioritization Tool, the authors structure their discussion twofold: First, criteria established from the end-users' feedbacks on using the TBPT are presented in a SWOT – strengths, weaknesses, opportunities and threats – framework (cf. Krogerus and Tschäppler, 2008). Second, the more general ability of the TBPT to trade off user requirements and sustainability requirements are discussed along a set of criteria suggested by Bartke and Schwarze (2015). Each of the assessments is based on expert judgment by the authors and invites for further discussion, i.e. it does claim a careful but not a conclusive evaluation.

6.1 SWOT analysis

Fig. 9 illustrates the identified criteria to assess the applicability of the TBPT. The criteria were identified by the authors in a process of interviewing the TBP-Tool users from each of the cases introduced in the previous section. Their opinions, suggestions and remarks were obtained in personal communication after the tool applications had been conducted. The criteria were individually gauged regarding their respective quality of being a strength or a weakness and of representing an opportunity or a handicap (or even a potential threat) for the applicability of the TBPT. For example, the free availability of the tool was regarded unanimously by the users as strength, but neither related to a considerable opportunity nor risk for the applicability. The fact that the tool is currently available only in English has been mentioned by some users as a drawback, which is a weakness as it discourages users from non-English-speaking regions – at the same time few experts argued, that the tool has still potential of improved applicability by translation to other languages. The criteria will be presented in further detail below.

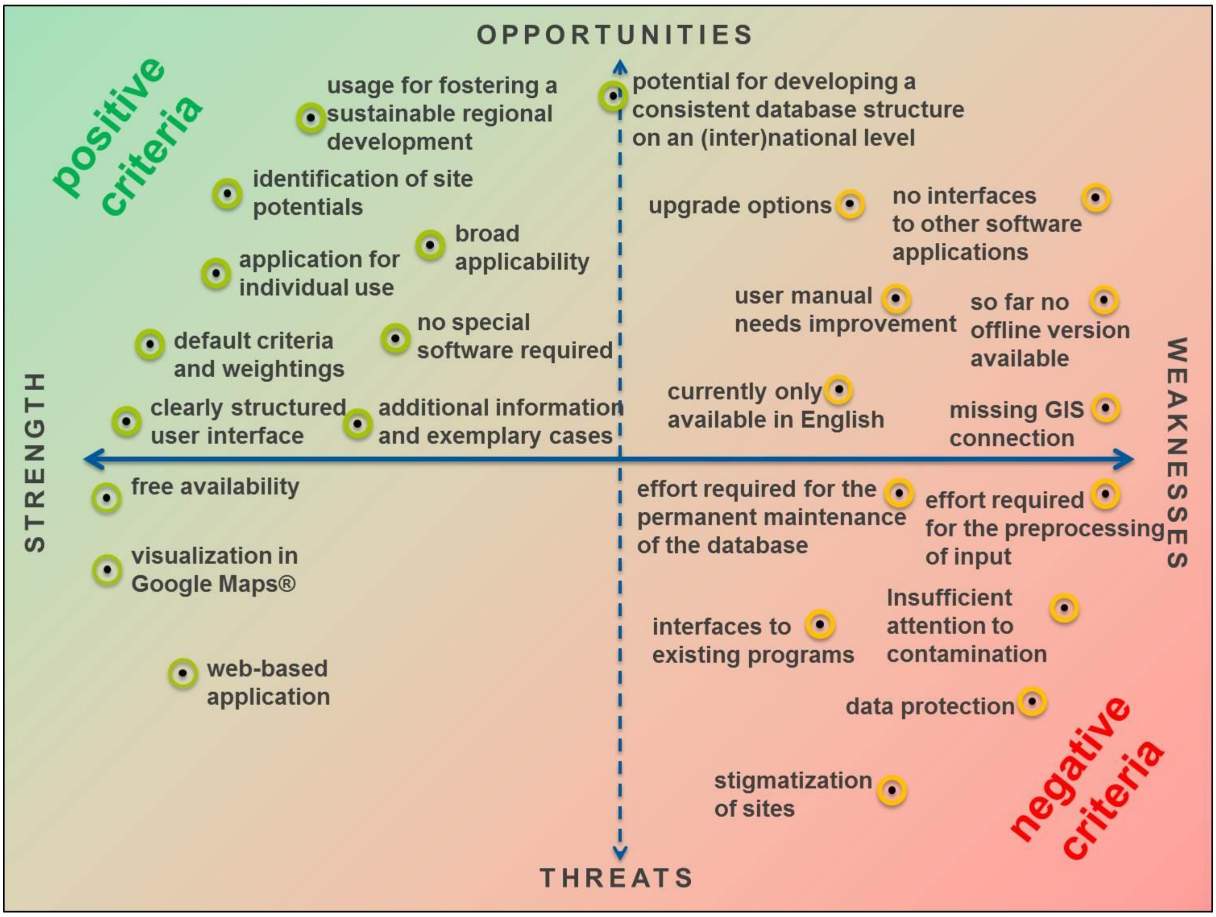

Fig. 9. SWOT analysis grid of the Timbre Brownfield Prioritization Tool (adapted from Bartke et al., 2014).

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Without weighting specific criteria higher than others, the SWOT grid indicates an even occurrence of positive and negative criteria. Besides the strengths purposefully built into the TBPT, such as its free availability, clearly structured user-interfaces and user-friendliness, the opportunities provided by the further usage, distribution and extension deserve special mentioning. This refers mainly to the option of applying the TBP-Tool for fostering a sustainable regional development. Local communities, planners and/or planning agencies can use the TBPT to get an overview of their brownfield sites and their characteristics in light of the sustainable development of a specific region (demography, energy, industries, development potentials of regions, etc.). This opportunity, in addition to the TBPT's consistent database structure, indicates the potential for obtaining wider distribution, paving the way for the synchronization, exchange or pooling of databases from various users.

Notably, a positive user response referred to the individual configuration option of the TBPT with regard to the research-based default criteria and weightings for the assessment of dimensions, factors and indicators. Intended to deliver a ranking of the sites according to their most effective regeneration potentials, the flexibility in weighting the assessment parameter reflects the users' expectation that sustainable regeneration should be defined in terms of the portfolio-specific context, for example regional or sectorial. Normatively, this finding needs to be discussed (as indicated below), but regarding user acceptance, it appears as a key strength.

A substantial barrier to a widespread application is seen in the effort required for the pre-processing the data before the actual prioritization process can be started. The evaluation process itself was quick and easy, but getting there was perceived as a labor-intensive procedure. This may diminish the generally user-friendly operation of the TBPT. It is unclear to which degree potential users are willing and able to invest time and human resources to pre-process data to such an extent. Facilitating the standardization and unification of input data from different sources by applying certain pre-steps before the prioritization procedure itself starts, seems to be crucial to enable wider usage of the TBPT. In the cases studied, the needed set-up time was on average between 15 and 50 minutes per site. A noteworthy exception was the Romanian case with more than two and a half hours of preparation work per site. While the German end-users indicated that the effort of about 15 minutes per site is acceptable and competitive, the Romanian experience is undoubtedly not. Interestingly, the preparation of data for (small) municipalities was in all cases a much easier task in comparison to preparation of data at the sub-municipal level of larger cities.

The use of databases of suspected contaminated sites often led to stigmatization and decreased property values in the past even though the status of a site as 'contaminated' had not been confirmed beforehand (cf. Bartke, 2011 for the impact on diminution in property

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value). This should be kept in mind when using the TBPT and communicating the results for low-contamination sites to avoid similar situations for those brownfields, which are often indeed ecologically affected. In some cases, such as Romania, it is the latter sites that are of most interest in terms of prioritizing interventions. For this reason, the user from this country pointed out the lack of detailed attention to contamination in the environmental risk dimension of the standard version of the TBPT as a weakness.

Threats of using the TBPT were seen in its character as a web-based application. Hopes of the tool developers regarding wide availability and ease of user met clear concerns regarding data protection and technical vulnerability. This means that the available online version of the TBPT also has drawbacks. Its use is probably not appropriate when handling sensitive or confidential information. This makes a decentralized version a desirable solution for a frequent application of the tool. According to the authors, this aspect should be given priority when developing the TBPT further. Usage of an off-line version of the TBPT might overcome existing skepticism and fears related to the protection of data and their potential misuse.

Concerns were also linked to the objectivity of results of the TBPT. The tool is primarily targeted to support tailored solutions as perceived by individual end-users. The results generated by the tool thus reflect the priorities of any given user and cannot be assumed to be universally acceptable. Clear communication is therefore needed with regard to the underlying weightings and evaluation dimensions, factors and indicators. This means that the TBPT seems to be more useful for in-house use by experts than for wider external communication, which would demand either trust in the expert end-user or the clarification and communications of the prioritization factors. Indeed, this point was stated now and then in the cases. The German GESA and LEG portfolios are strictly protected. Therefore, LEG and GESA experts pointed out the data protection and stigmatization concerns and they favored an offline version of the TBPT for their in-house use. In contrast, the Brno brownfield database and the portfolio of the South Moravia RDA are publicly available on the internet and therefore the data protection was only a marginal issue for these tool end-users.

Experts related to the Brno case emphasized the missing connection to GIS as a considerable weakness. A link to GIS is regarded as important for urban planning purposes in order to enable end-users to simply select the different layers that would bring important information about ownership structure, master plan, addresses and administrative division. This seems one of the possibilities to further develop the TBPT. On the other hand, the web-based database of the South Moravia RDA is using Google Maps® and therefore their experts appreciated the fact that the TBP-Tool is also using this (very simple) system. Simplicity of the TBPT system was usually among the most frequently invoked strengths and recommendations for further use by testers.

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6.2 Basic user requirements

Bartke and Schwarze (2015) identified different criteria to characterize sustainability assessment tools for brownfield regeneration decisions. They show that different end-user groups hold different preferences regarding tool properties. For example, representatives of the general public stress the importance of participation and decision-makers need practicable and flexible tools, while scientific experts consider objectivity to be the most crucial asset of a high-quality tool. Their findings emphasize that academics and experts tend to attach less importance to the flexibility and practicability of decision support tools than do decision-makers. Instead, they set great store on impartiality, objectivity and the close link between the method and the normative demands of sustainability. Decision-makers, by contrast, rank practicability as the most important. For the purpose of our analysis, the decision-maker group's preferences are the most interesting, as they are the most likely to hold portfolios of brownfield sites on which they want to effect a prioritized selection. Therefore, their hierarchy of preferences regarding the criteria of desired tool characteristics is indicated in Table 1 in order to discuss the actual performance of the TBPT in relation to these requirements. Bartke and Schwarze (2015) list illustrative questions to support an assessment of the respective criteria, which are represented, too. The second column introduces our evaluation of the TBP-Tool against these questions. This assessment has been done in our best intent of fair and impartial appraisal.

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Table 1: Ranking of sustainability assessment tool requirements by decision-makers based on Bartke and Schwarze (2015) and evaluation of the Timbre Brownfield Prioritization Tool against these criteria

Criteria – ordered from the first (most) to the least important from the perspective of decision-makers – and illustrative questions to assess tool quality	Evaluation of the Timbre Brownfield Prioritization Tool against the illustrative questions used to assess the quality of sustainability assessment tools
1. Practicability: How quickly and straightforwardly can the method be applied? Does understanding the method involve training or reading lengthy manuals? What costs are entailed by conducting the method – and how much time is required? How much data is needed? Are the results easy to assess and are they comprehensible?	The TBPT is quick to use, if data are prepared. Understanding the prioritization MCDA method demands some knowledge and familiarization with background of default factors, which can be time intensive. Conducting the prioritization itself is very simple and quick, and – given that weightings and selection of factors are clear – results are easy to assess. Notwithstanding, a drawback is the effort needed to prepare the data. Input of data by using widespread Excel® software reduces the burden.
2. Flexibility: Is the method tied to local circumstances or does it work only for certain categories of land or use? To what extent can the methods' modalities (such as criteria) be adapted to local conditions?	The TBPT is highly flexible. Weightings of factors are adjustable and even dimensions can be added. Prioritization modalities can be fully adapted to local conditions or sectoral contexts and end-user requirements. This adaptation requires input of weights and factors to the tool; the tool does not advise how to obtain these.
3. Institutional embedding: Can assessment methods be embedded in formal procedures such as regional planning and municipal zoning? Can they be subject to legal or jurisdictional review for binding decisions?	Given the flexibility, a clear documentation of chosen assessment weights and criteria is necessary to include the method in formal procedures, which demand transparency of assessments and results.
4. Participation: To what extent can interest groups have their concerns included? Are conflicts made transparent and subject to debate among stakeholders?	The TBPT does not guide a facilitation of broad stakeholder participation. Notwithstanding, in order to reach an agreement of weights and criteria used in the tool, a participative procedure integrating stakeholders could be applied by the end-user.
5. Transparency: How transparent are the assessment methods and the calculation algorithms? Are the evaluation methods comprehensible and traceable? Do they indicate risks and uncertainty?	The method and algorithm have been documented by the tool developers. For interested persons, the methods are traceable – for lay end-users, the prioritization calculation might seem to be a 'black box'. The TBPT indicates neither risks nor uncertainties regarding the ranking results or quality of data.
6. Objectivity: Is it possible for the methods to be manipulated by users or others involved in the assessment? Are the findings free of external influences? Are they science-based? Are the evaluation aspects sustainability-orientated?	The default setting of weights and factors is science-based regarding successful, sustainable brownfield regeneration. If end-users adjusted the setting to the specific context, this objective fundament is left. However, flexibility allows adjustment to local sustainable development contexts. Only if settings are transparent, results support objective decisions. Only password-protection limits the risk of external influences on the results.

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Comparing the criteria and the properties of the TBPT as presented in Table 1, we find that the TBPT does fairly well on the criteria being most important for decision-makers. In particular, the practicability and flexibility indicate a high usability of the TBPT. On the other hand, the tool performs less strong with regard to the criteria participation, transparency and objectivity as can be exemplified in the fact that the TBPT does not actively ask for a broad participation to determine the prioritization settings. In this regard, the tool might be judged as pure quality or having only illustrative value from the scientists' perspectives, who according to Bartke and Schwarze (2015) would value such tool properties high. However, as these characteristics are less important for decision-making end-users and could be only achieved in a trade-off with more highly demanded properties, the TBP-Tool seems well designed to suit such end-user requirements from the decision making field.

Considering the contribution of the TBPT to support more sustainable regeneration of brownfields in real estate portfolios, the picture is more blurred. The question of reliability of tool results regarding normative sustainable development adherence cannot be clearly answered. On the one hand, the TBP-Tool is based on scientific and in a stakeholder process generated success criteria for effective brownfield regeneration. On the other hand, these settings included in the tool as default values can be altered by the end-users. Then again, this enables a scaling of the general sustainable development paradigm to the local context, which has been requested in several corners of the sustainability literature (e.g. Bleicher and Groß, 2010; Hartmut et al., 2008). A precondition to ensure such contextualized adjustments as sustainable development is the broad participation of stakeholders. Although the TBPT does not foresee a facilitation of such broad stakeholder participation, the tool nevertheless does allow the end-user to go through such a procedure in order to reach an agreement on weights and criteria to be used in the tool. In this way, the Timbre Brownfield Prioritization Tool can indeed support more sustainable brownfield remediation.

7. Conclusion and outlook

The web-based TBPT enables interested end-users to assess their brownfield portfolios and to prioritize them according to different regeneration objectives. The presented approach includes key criteria in sustainable prioritization of regeneration sites and is based on an aggregation framework designed to be flexible and transparent, allowing for the assessment of different and upcoming perspectives of stakeholders and in this regard arguably in general on sustainable development. Indeed, one of the main strengths of the presented tool is its ability to be flexible and easily applicable to different contexts and requalification objectives, as the proposed methodology allows the end-user to adjust weights, normalization functions, indicators, factors and even dimensions. However, the TBPT could be improved in the future to better handle a lack of available information and to implement alternative algorithms, which deal with specific decision-making aspects.

The TBP-Tool was developed during an international research project and, accordingly, it is not only tailored to the needs of a specific individual user, but rather provides a comparative site assessment according to reasonable criteria and indices which have been identified through a stakeholder's participation process. In this way, the TBP-Tool allows for a reliable prioritization process taking into account suggestions, needs and perspectives of a wide range of involved stakeholders.

The TBP-Tool presents an opportunity for portfolio owners and/or managers to carry out comparative site assessments, and its application seems especially effective for rather heterogeneous and complex portfolios. The time effort of 15 to 50 minutes per site required for the data pre-processing appears acceptable in view of the significance and broad applicability of the results. This effort can be reduced considerably when data is imported systematically using own databases and data retrieval routines as well as by implementing workflows. One of the main uses of the TBPT is to serve also small portfolio owners as a basis for creating own real-estate databases. This, as in the case of the Romanian end-user presented here, will however be related to a higher investment of resources.

The use of MCDA in brownfield portfolio selection is perfectly suited as the problem to be faced is inherently based on multiple heterogeneous criteria, which are not directly comparable. Moreover, the inclusion of user specific weights allows for different stakeholders to tailor the final ranking according to their preferences. The proposed MCDA methodology is based on Multi Attribute Value Theory with clear and transparent aggregation steps, which, if compared to other possible MCDA methods (e.g. Promethee, Electre, AHP, etc.), has the advantage of requiring less user inputs and not being seen by the user as a complex black box. The methodology can, nevertheless, be improved by including uncertainty both in the inputs classification and user weights. This way the obtained result would be generated by a probabilistic assessment and the end-user would be presented with a more realistic likelihood of possible outcomes rather than a deterministic ranking. Moreover, a sensitivity analysis could also be performed in order to provide a better understanding of the relationships between input and output variables and their related weights. This will support decision-makers in the discussion and use of the provided results.

Owners and administrators of complex property portfolios who aim to base their land development decisions on site characteristics will benefit from the application of the TBP-Tool as the available configuration and weighting options allow to directly target desired characteristics and to identify the most suitable sites contained in the portfolio. Some may

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argue that the TBPT will be of limited use for politically motivated site decisions as in such cases ‘objective’ site characteristics tend to play a minor role. It is nevertheless possible for users to factor in political networking as part of the user-defined criteria. For example, it is possible to construct an indicator to capture which configurations of political actors at the national, regional or local level are more or less conducive to the redevelopment of brownfield sites. The TBPT assessment that includes only objective factors could then be compared to the assessments that include the political factor to see what range of variation is introduced by the latter. This opens up some interesting opportunities to enhance the customizability of the prioritization tool still further, but this is a broad enough topic to require exploration in future work.

An important remark is that, more than the large amount of results obtained through the application of the presented methodology, the tool has been useful in order to foster discussion and evaluation of criteria and aspects which would probably not be otherwise addressed and openly discussed among stakeholders.

Bartke and Schwarze (2015) concluded that no sustainability assessment tool can accomplish a satisfaction of all user groups’ requirements and sustainability principles at the same time. They stressed, however, that eventually the application of tools by decision-makers is needed in order to contribute to sustainable development at least to some degree. Therefore, tools have to be designed to meet these end-users’ requests. “Sustainability principles cannot be reflected equally to their full extent going through the process of end-user specific design” (ibid, p. 22). The TBPT seems to be a prime example for such a tool being tailored to decision-makers needs with an attempt to integrate sustainability as far as possible.

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