Amenity proximity analysis for sustainable brownfield redevelopment planning

Beames, Alistair; Broekx, Steven; Schneidewind, Uwe; Landuyt, Dries; van der Meulen, Maarten; Heijungs, Reinout; Seuntjens, Piet

published in
Landscape and Urban Planning
2018

DOI (link to publisher)
10.1016/j.landurbplan.2017.12.003

document version
Publisher's PDF, also known as Version of record

citation for published version (APA)
Beames, A., Broekx, S., Schneidewind, U., Landuyt, D., van der Meulen, M., Heijungs, R., & Seuntjens, P. (2018). Amenity proximity analysis for sustainable brownfield redevelopment planning. *Landscape and Urban Planning*, *171*, 68-79. https://doi.org/10.1016/j.landurbplan.2017.12.003

Landscape and Urban Planning 171 (2018) 68–79

Contents lists available at ScienceDirect

Landscape and Urban Planning

journal homepage: www.elsevier.com/locate/landurbplan

Research Paper

Amenity proximity analysis for sustainable brownfield redevelopment planning

Alistair Beames[a,b,*], Steven Broekx[a], Uwe Schneidewind[c], Dries Landuyt[d], Maarten van der Meulen[a], Reinout Heijungs[e], Piet Seuntjens[a,b]

[a] Environmental Modeling Unit, VITO, Boeretang 200, 2400 Mol, Belgium
[b] Department of Soil Management, Ghent University, Coupure Links 653, 9000 Ghent, Belgium
[c] Department of Engineering Geology and Hydrogeology, RWTH Aachen University, Lochnerstr. 4-20, 52064 Aachen, Germany
[d] Department of Forest and Water Management, Forest & Nature Lab, Ghent University, Coupure Links 653, 9000 Ghent, Belgium
[e] Department of Econometrics and Operations Research, Faculty of Economics and Business Administration, VU Amsterdam, De Boelelaan 1105, 1081 HV Amsterdam, The Netherlands

ARTICLE INFO

Keywords:
Sustainable urban development
Urban intensification
Location-Allocation
Social cohesion
Human capital
Livability

ABSTRACT

Idle brownfields in urban settings are potential resources that could be put to productive use, meeting the goals of urban intensification, helping to curb urban sprawl on the periphery and benefiting communities living around sites. Various decision support tools exist in order to evaluate redevelopment scenarios. Spatial decision support systems have recently been developed to aid in evaluating the implications of the physical attributes of redevelopment scenarios, with a limited focus on the proximity of essential amenities to the local community. The application of proximity analysis in this context supports stakeholders in determining which social amenities are furthest from the local community and the extent to which including such amenities on-site would benefit the local community. A geographic information system based proximity analysis approach is presented specifically for this purpose. The distribution of walking distances for local households is compared to scenarios in which specific social amenities are included on-site. The approach is demonstrated using an abandoned brownfield case study in the Flemish region of Belgium. The local community would benefit most from having a doctor and pharmacy on-site in terms reduced walking distance. The inclusion of other amenities on-site such as employment, schools, green space, meeting places and shops also shortens walking distances for the local community but to a limited extent in comparison to a doctor and a pharmacy. 'Walking distance' is an indicator that is easily understood by stakeholders and the approach lays the foundation for more detailed analyses that would include frequency of visits.

1. Introduction

The definition of brownfields most commonly used in scientific literature is derived from the United States Environmental Protection Agency's *Brownfields Economic Redevelopment Initiative*. The definition refers to brownfields as "abandoned, idle or underused industrial and commercial facilities where expansion or redevelopment is complicated by real or perceived environmental contamination" (USEPA, 1996; Thornton, Franz, Edwards, Pahlen, & Nathanail, 2007). A commonly accepted definition does not yet exist within the European Union and what constitutes a brownfield varies between Member States. In some states the term is extended to include abandoned sites that are not necessarily contaminated (Hartmann, Török, Börcsök, & Oláhné Groma, 2014; Oliver, Ferber, Grimski, Millar, & Nathanail, 2005; Ramsdem, 2010). Nevertheless, there is a consensus in the European Union that the redevelopment of abandoned urban sites serves the objective of sustainable urban development (European Commission Directorate-General for Regional Policy, 2009). The approach described here is intended to assist stakeholders in deciding upon a use for the site and can be applied to both contaminated and uncontaminated abandoned sites.

In general, brownfield redevelopment depends on (i) the demand for anticipated land-use determining current and future value of land at the site, (ii) the current and future value of land at potential alternative sites, (iii) legal requirements and liability issues, (iv) available remediation and clean-up options defined by the physical and biochemical parameters at the site as well as available technologies and resources, and (v) socio-economic necessities and preferences (Thornton

---

[*] Corresponding author at: Department of Soil Management, Ghent University, Coupure Links 653, 9000 Ghent, Belgium.
E-mail address: alistair.beames@gmail.com (A. Beames).

https://doi.org/10.1016/j.landurbplan.2017.12.003
Received 16 February 2017; Received in revised form 20 November 2017; Accepted 9 December 2017

et al., 2007; Bardos et al., 2016). The scale of abandoned areas in urban centres and the potential benefit of utilising these spaces highlight the need for decision support systems for brownfield redevelopment.

In the Flemish region of Belgium, the number of brownfield sites is estimated to be around 53,000 and is equivalent to a total area of 55 square kilometres (Oliver et al., 2005). Redeveloping such sites is beneficial in terms of the regional context by adding to the supply of available urban land and by allowing for more compact concentric and poly-centric urban zones (Laprise, Lufkin, & Rey, 2015). Brownfield redevelopment may also benefit local communities around such sites in terms of increasing local property values and generally improved liveability, as well as reducing the dependence on transport networks (Talen et al., 2013). The important questions that need to be addressed are (i) the services and amenities to include on-site to best serve the local community, (ii) how the feasible alternatives can best be communicated to local stakeholders and (iii) to what extent the alternatives are sustainable (Norrman et al., 2016).

The perspective adopted here presumes the location under consideration is “fixed”. Unlike decision support system that compare alternative sites as potential siting locations (Huff, 1963; Thomas, 2002) for a business venture or real estate development project, the appraoch presented here evaluates the potential for different redevelopment alternatives for a specific site. Compact urban development planning is supported by evaluating how walking distances to essential amenities can be shortened for those living around abandoned brownfields. The proximity to essential amenities is determined for the local community living around the site for the current situation, i.e. ‘before redevelopment'. The current situation is compared to scenarios in which additional amenities are provided on-site. The social indicator concept and existing approaches are briefly described in order to show how the approach presented here contributes to the current state-of-the-practice.

1.1. Social indicators

The term “social indicator” was coined by Raymond Bauer in the mid-1960s in work performed for NASA on the anticipated societal impacts in the US Space Program (Bauer, 1967). The concept later evolved through the work of the OECD and Social and Economic Council of the United Nations (Bulmer, 1978), into welfare and well-being based statistics that could be used as alternative measures of progress to that of indicators based on economic growth and material prosperity. This alternative conception of progress reflected the political agenda of the “Social Indicator Movement” (Noll, 2004). Social indicators became the means of determining the “quality of life” of a given society encompassing measures of living conditions and areas of social concern. Social indicators could then be used to monitor change and to assist in policy agenda setting on regional and national scales. The advent of the concept of “sustainable development” during the early 1990′s extended the conception of “quality of life” to include the consideration of future generations (UNWCED, 1987). Social indicators were originally intended to gauge progress on regional and national levels but at present are also applied at city, community and household levels. The European Environment Agency defines social indicators as measures of progress in terms of the following objectives: promoting employment, combating poverty, improving living and working conditions, combating exclusion and developing human resources (EEA, 2015). This scale is commonly used in urban planning research and particularly for urban renewal planning (Colantonio, Dixon, Ganser, Carpenter, & Ngombe, 2009; Hayek et al., 2015; Rall & Haase, 2011).

The decision support systems for brownfield redevelopment discussed here, have applied the concept to the community spatial and functional scale in considering people living on or in the immediate vicinity of a brownfield. The social indicators (also referred to liveability indicators) in these tools value physical facets of the built environment, such as zonation (residential, commercial, industrial), availability of green spaces, accessibility to roads, percentage of sealed soil, historic or landmark buildings or local amenities in walking distance (see e.g. Schädler, Finkel, Bleicher, Morio, & Gross, 2013; Wedding & Crawford-Brown, 2007). The unit of analysis is the landscape itself and this is aside from perceptual analysis included in other approaches (Pediaditi, Doick, & Moffatt, 2010; Ryan, 2011). Pediaditi et al. (2010), focused on how stakeholders perceive the effectiveness of certain sustainability assessment tools and based their conclusions on meta-data from applying different tools. Ryan (2011), proposes a combination of landscape assessment and how the landscape is perceived by stakeholder (Ryan, 2011). The approach presented here attempts to measure the extent to which including different amenities on-site reduces the walking distance of residents to such amenities.

1.2. Existing decision support systems specifically for brownfield redevelopment

Two broad categories of *decision support systems for brownfield redevelopment* exist; indicator based multi-criteria analysis (MCA) tools and stakeholder participation frameworks. The indicator based MCA tools can be further categorized into tools that include spatially explicit indicators and those that do not. The tools that include spatially explicit indicators differ slightly by relying on automated computational processes in translating spatial data into indicator values. None of the tools to date are exclusively focused on determining the proximity of amenities to the local community, and instead, each of the tools includes at least a few proximity based indicators. Table 1 shows the indicators included in the existing tools. The selection reflects tools described in scientific literature, which focus on brownfields and include spatial based social indicators.

The Sustainable Brownfields Redevelopment (SBR) Tool and *SIPRIUS*, were designed to compare alternative redevelopment scenarios *ex post*, although it would be possible to apply them as *ex ante*. SBR is a retrospective tool for evaluating the success of completed brownfield redevelopments (Wedding & Crawford-Brown, 2007). All 40 indicators in the tool, including the proximity indicators, are normalized to a percentage by dividing the indicator values for the redeveloped site by the values of the site prior to redevelopment. The results are then weighted using an analytical hierarchy process (AHP). The internal normalization

Table 1
Proximity based indicators included in decision support systems for brownfield redevelopment.

Tool	Authors	Indicators
Smart Places	Thomas (2002)	Percentage of work force within 30 min of site
SBR	Wedding and Crawford-Brown (2007)	Percentage of new employees who live in the local region Net jobs created per acre Walking distance to green space in minutes Walking distance to cultural amenity in minutes Walking distance to restaurant/grocery store in minutes
MMT	Schädler et al. (2011, 2012,2013	Primary school in walking distance Local amenities in walking distance
LEED-ND	Talen et al. (2013)	Housing and jobs proximity Neighbourhood schools Access to civic public spaces Access to recreation facilities
SIPRIUS	Laprise et al. (2015)	Net employment density Proximity of school facilities Proximity of commercial facilities Proximity of recreational facilities

allows for a range of different indicators to be compared along with the proximity indicators, which include factors such as *property value increases*, *tax revenues from the site*, *energy saving* and *environmental health risks*.

SIPRIUS is a digital monitoring tool that also combines a range of indicators together with the proximity indicators (Laprise et al., 2015). As opposed to normalizing impacts according to the change brought about on-site, each of the 41 indicators are compared to a scale of reference that represent *a minimum threshold*, *a national average value*, *a desired target value* and *a best practices value*. The indicator results are evaluated individually. Reflecting the implications of each indicator individually, as opposed to normalizing and aggregating the results, avoids losing the sense of absolute scale.

The approach developed by Thomas (2002) addresses the question of optimizing brownfield redevelopments in terms of land-use siting decisions. The approach is coupled to a geographical information system (GIS) tool called *Smart Places* and determines the optimal land-use for a selection of unused brownfield sites within a region. The potential land-use allocations include industrial, commercial, residential or agricultural land-use. Each site is evaluated according to 30 indicators, 12 of which are proximity based calculations. The *Smart Places* component is used to map the brownfields considered.

The *Mega-site Management Tool* (MMT) determines optimal brownfield redevelopment scenario designs for the specific site in question (Schädler, Morio, Bartke, Rohr-Zanker, & Finkel, 2011; Schädler, Morio, Bartke, & Finkel, 2012; Schädler et al., 2013). The site is divided into land-use parcels or ‘planning units’. Each planning unit can potentially be allocated one of three land-use types: residential, recreational or industrial. An algorithm generates all the possible combinations of mixed land-uses that can be included on-site and then evaluates each according to a set of 23 Boolean indicators. The spatial indicator results are evaluated according to threshold values. The proximity indicator threshold is 500 m, which is considered to be ‘within walking distance’.

LEED-ND is a certification system to determine the extent to which an area is suitable for urban redevelopment (Talen et al., 2013). The method is based on a checklist of 56 indicators that can be used to compare the suitability of different sites within a city or urban centre. The proximity based indicators listed in Table 1, are evaluated in terms of whether a land parcel is within reach of an amenity by foot, along the street network. The walkable threshold is 0.25 miles (402 m). The work of Talen et al. (2013) is about the expansion of the green building principles toward urban design considerations.

Out of the tools that include spatially explicit indicators, only the MMT tool uses an automated computation process to derive a result. *Smart Places* and LEED-ND only use GIS to graphically illustrate results. The existing approaches generally evaluate on-site scenarios in terms of what they provide for on-site inhabitants. Proximity to amenities has only been measured in terms of distance from the site and not households around the site and only in terms of meeting a threshold value (Laprise et al., 2015; Schädler et al., 2011, 2012, 2013; Talen et al., 2013). The approach presented here allows the user to understand the nominal scale results of the proximity indicators for the entire community around the site. Therefore the implications for the neighbouring community of different site redevelopment scenarios are made explicit.

1.3. Spatial proximity analysis

Spatial proximity analysis is applied to relate a selected element to neighbouring elements and uncover proximity relationships. It can be performed with standard GIS platforms on feature or raster data. The mathematical relationships behind these tools can also be applied without a GIS platform. A variety of proximity tools exists, e.g. to allow for the creation of buffer zones, the determination of point or raster cell distances, the allocation of an area to a specific point or the analysis of travel paths along networks.

Spatial proximity analysis has been used for a multitude of operations e.g. in environmental risk and exposure assessment (Maantay & McLafferty, 2011), to determine the influence of neighbouring catchments in regional flood frequency analysis (Ahn & Palmer, 2016), to find optimal parameter combinations in a Pareto space according to a certain criterion when modelling laboratory batch tests (Schneidewind et al., 2014), to assess the spatial patterns in fossil records (Leighton & Schneider, 2004), to study the level of innovation with regard to certain geographical aspects (Shearmur, 2011) or for urban planning purposes by e.g. studying the impact of lake proximity to residential real estate prices in the Wuhan, China (Zhang, Tan & Tang, 2015). Spatial proximity analysis can be performed with standard GIS platforms using a combination of tools that locate the nearest feature and determine the transport infrastructure distance between features. Both of these operations are performed in the Huff model and in ArcGIS Location-allocation analysis, in order to pinpoint the most suitable location for siting a business (Huff, 1963; Huff & McCallum, 2008). The Huff model determines the probability of patronage from the adjacent areas. Such approaches are also denoted as gravity-based modelling. The potential spatial extent of the customer base is determined for comparable and competing features. So for example the catchment area for competing shops can be identified.

Unlike choosing the best location for siting a business venture, the focus of the approach presented here is to determine a use for the idle site that best serves the community, addressing social amenities in particular. The approach presented here focuses exclusively on the walking distance to amenities for residents living around the site, without considering the competing ‘gravitational forces’ between the same types of amenities. Each household is allocated the nearest amenity along the road network. Understanding how the same amenities, such as shops, compete would be relevant from a shop owner’s perspective. A school might also be interested in how many residents they would have to cater for, given the proximity of other schools. The approach presented here is instead focused on the convenience for the residents, assuming residents would want to travel to the nearest amenity. The approach can evaluate future redevelopment alternatives for idle brownfields.

The evolution of GIS based tools for brownfield redevelopment can be traced back to spatial planning indicator based methods that compered the number of residents to available amenities, without considering proximity (Smith, Nelischer, & Perkins, 1997). Schädler et al. (2011, 2012,2013 built on the proximity considerations included in the approach developed by Wedding and Crawford-Brown (2007), by mapping the location of the site and available amenities. The approach presented here builds on the existing approaches by: i) including a broader range of amenities supporting the functioning and liveability of a community; ii) considering the local community around the site and not just the future site inhabitants and the immediate neighbours of the site; iii) explicitly considering the range of distances of local inhabitants to amenities, and not only whether the amenities are within a defined threshold distance.

2. Methods

Indicators are used to evaluate the impact of including certain amenities on-site in terms of a reduction in walking distance for local residents. Available road network data is used to determine walking distances. The indicator results are analysed in two steps. Firstly, the relative importance of the amenities is compared by aggregating the amenity-specific distributions into a mean and comparing it with the national average. Secondly, the extent to which the distribution of walking distances for local residents are decreased by including amenities on-site, is evaluated. The results reflect which amenities are further away from the average resident than the national average. The results also reflect which amenities included on the site would reduce the average resident’s travel distance. The results show the extent to

Table 2
Impact categories, category goal definitions, related existing indicator sets and related spatial indicators considered in the approach presented here.

Impact Category	Indicator Goal Definition	Considered in Indicator Sets Proposed by	Related Spatial Indicators
Access and Mobility	Ease with which community members are able to reach different locations on the redeveloped area via various transport possibilities (Morris, Dumble, & Wigan, 1979)	Newman, (1999); Repetti and Desthieux (2006); Romano and Ercolano (2013)	Implicit in proximity analysis
Community Health and Safety	Preserve the physical well-being of community members by protecting them from unacceptable risks related to the state of the local environment and by ensuring adequate access to medical assistance when necessary (Marans, 2015)	; Newman (1999); Romano and Ercolano (2013)	Travel Distance to Doctors Travel Distance to Pharmacies
Human Capital	Provide the opportunity for community members to acquire the necessary marketable skills, employment experience and education that would allow them to participate in the labour market and add economic value to an activity (Ostrom, 2000; Roseland, 2000).	; Newman (1999)	Travel Distance to Employment Travel Distance to Schools
Social Cohesion	Support the healthy and functioning civil life of a community that is brought about by positive social interactions, strong interpersonal bonds, communal solidarity and a sense of belonging to the community amongst its members (CCSD, 2000; Chan, To, & Chan, 2006).	; Phillips and Stein (2013); Repetti and Desthieux (2006)	Travel Distance to Green Spaces Travel Distance to Meeting Places
Convenience	Ensure community can acquire essential daily consumables (Newman, 1999; Van Kamp, Leidelmeijer, Marsman, & De Hollander, 2003).	; Newman (1999); Repetti and Desthieux (2006)	Travel Distance to Shops
Urban Aesthetics	Spatial configuration of the physical landscape that limits negative sensory experiences and ads to the sensory appeal of a built environment (Berleant & Carlson, 2007).	Repetti and Desthieux (2006); Romano and Ercolano (2013)	Not included here

which travel distance is decreased in meters.

The calculations were performed using a combination of GIS software platforms including the VITO *GeoDynamiX* Toolbox (https://vito.be/en/land-use/land-use/geodynamix-towards-better-land-use) and ArcMap. A full description of the calculation procedure can be found in the supporting information which includes a table listing all the software required.

2.1. Amenities

A survey of scientific literature on urban renewal and sustainable urban development identified six key social impact considerations. The impact categories include 1) Accessibility and Mobility, 2) Community Health and Safety, 3) Human Capital, 4) Convenience, 5) Social Cohesion and 6) Urban Aesthetics. The indicators in each category are listed in Table 2.

Seven amenities were identified that support the social functioning of a community in line with the indicator goals listed in Table 2. *Accessibility and Mobility* is considered implicitly by measuring the distance to amenities. Improvements in the transport infrastructure would allow greater access to local amenities in terms of reducing walking distance however changes in transport infrastructure are beyond the scope of the approach presented here. *Community Health and Safety* in the existing frameworks focus on exposure to traffic emissions, which is also a function of proximity to highways and high traffic zones (Newman, 1999; Romano & Ercolano, 2013). Emissions are also a factor of the road network design and cannot be entirely reduced by the on-site spatial design. *Accessibility and Mobility* and *Community Health and Safety* also overlap in terms of the potential for road accidents. High traffic volumes and speeds result in greater pedestrian accidents (Loukaitou-Sideris, 2006; Southworth, 2005). Reducing dependence on automobiles and allowing for walkable urban areas would also reduce the associated risk of pedestrian accidents; however this is beyond the scope of this study. Medical assistance is another factor considered in the *Community Health and Safety* category and two indicators are 'distance to doctors' and 'distance to pharmacies'. The existing *decision support systems for brownfield redevelopment* (Table 1) do not consider doctors in the vicinity of the site in question although it is an important indicator in urban renewal literature (Colantonio et al., 2009). The existing tools consider distance to employment and education which support the development of *Human Capital* (Ryan, 2011). Areas for commercial activity and shops are also included in both urban renewal and existing tools and fit into the category of *Convenience*. *Social Cohesion* is the last impact category considered and includes indicators of the accessibility to areas that support social interaction and provide for a sense of place amongst community members (Ryan, 2011; Stedman, 1999). Urban aesthetics are not specifically considered. Green space is included under *Social Cohesion* and provides recreational opportunities and potential social interaction, although green space also supports urban aesthetics (Freeman, 1999; Herbst & Herbst, 2006; Nohl, 2001; Philipp, 2001; Phillips & Stein, 2013; Smardon, 1988). The proximity of important amenities that support the liveability and social functioning of a community can be considered together with existing approaches for supporting brownfield redevelopment and spatial planning more generally.

2.2. Radius of influence

The impacts to the local community living around a potential brownfield redevelopment are considered within a defined spatial area. A buffer around the brownfield in question is the spatial extent considered (Malczewski, 1999). The buffer is referred to here as the 'radius of influence' (ROI) because the local residents within the buffer are influenced by the redevelopment scenario on the brownfield in the centre of the buffer. The approach considers the extent to which having a particular social amenity on-site will bring the local community residents, within the ROI, closer to such amenities. The same ROI extent of 1 km is used for each amenity. Amenities within and outside the buffer are considered. The buffer simply defines the extent to which residents located around the site are considered.

The choice of 1 km as the radius extent is based on social amenities generally being within a kilometre of the average Flemish household

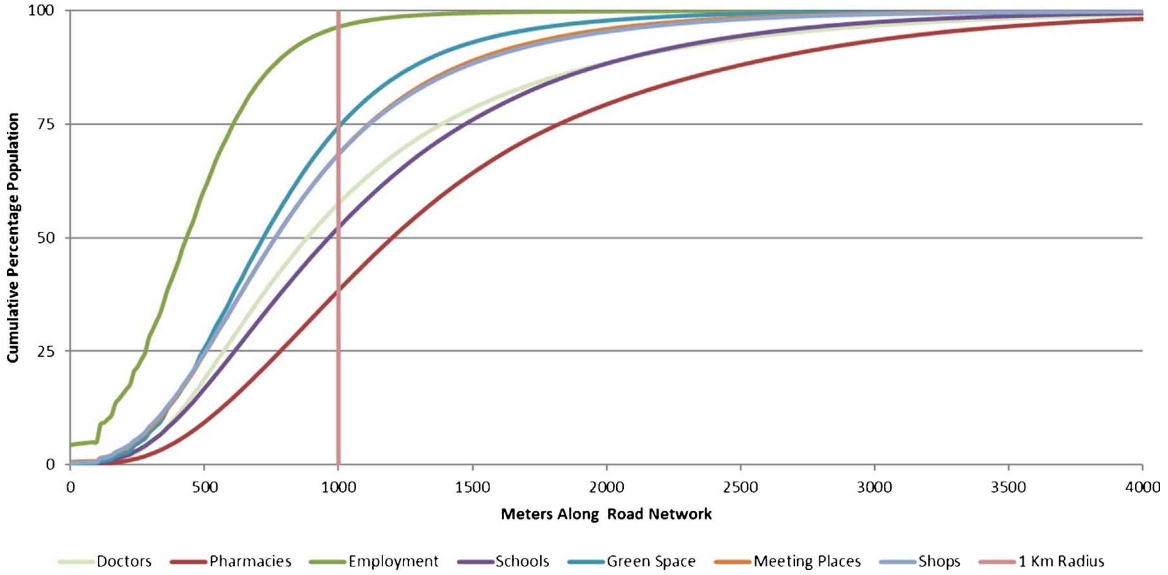
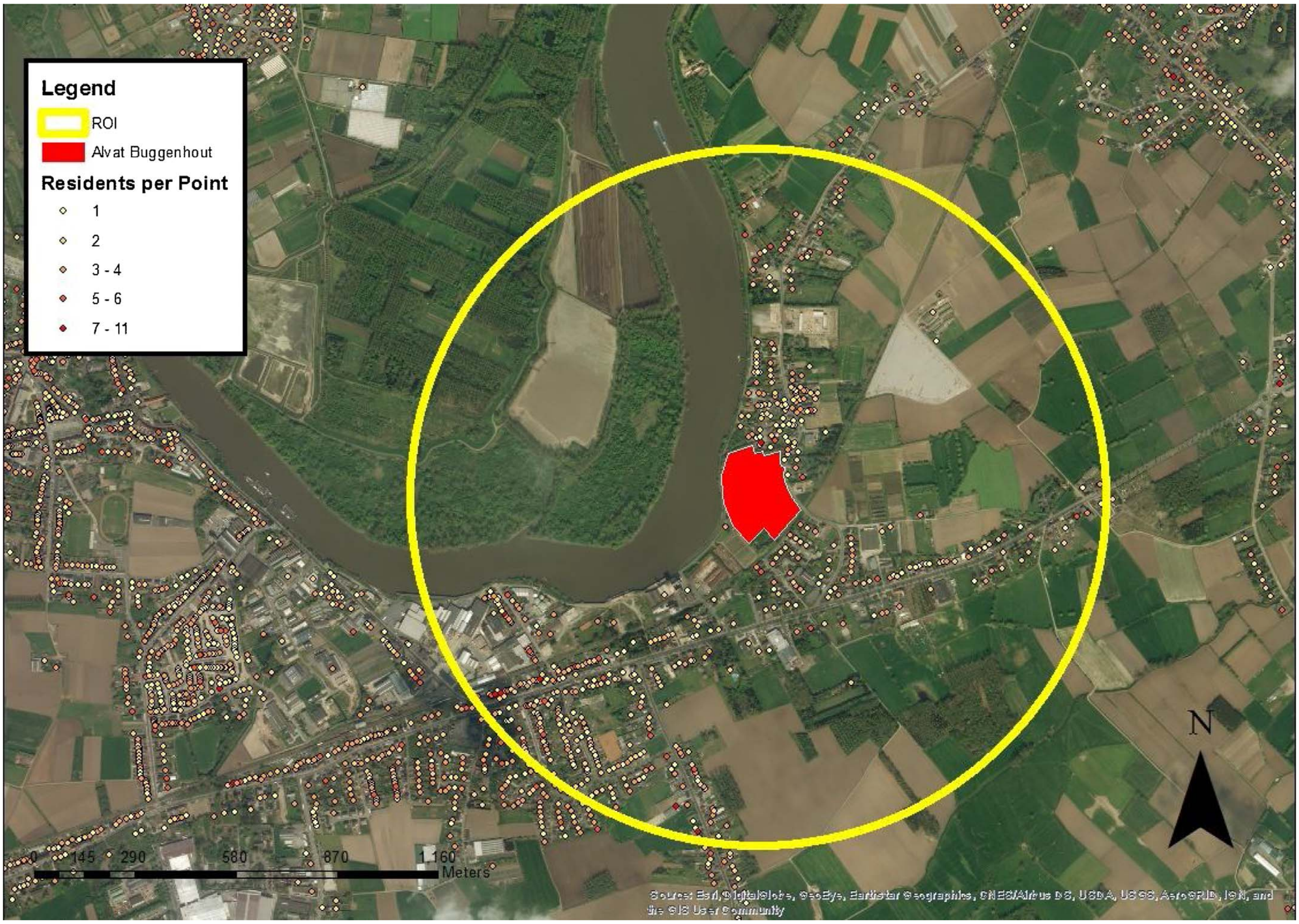


Fig. 1. Cumulative distribution of walking distances of households in Flanders to social amenities. Data from VITO's GeoDynamiX Toolbox was used for the calculations (Van Esch, Poelmans, Engelen, & Uljee, 2011). More than 50% of all households are within a kilometre, along a road network for each of the amenities considered apart from pharmacies. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Fig. 2. Alvat Buggenhout brownfield within 1 km radius and resident locations. The Alvat Buggenhout case study site (red fill) is at the centre of the ROI (outlined in yellow). The locations of households within and outside the radius of influence are represented by points. The points reflect the number of residents per household in a graduated colour ramp from light yellow (representing one resident per location) to dark red (representing 11 residents per location). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

(see Fig. 1). A detailed step by step explanation of the calculation procedure is included in the supporting information. The cumulative distribution of the distance of Flemish households to the different amenities was calculated for Fig. 1. The distribution serves as a threshold according to which the site in question could be compared. In other words, the average travel distance of a Flemish household to amenities was used to define the ROI. On average Flemish households are within 1 km travel distance of all of the amenities. A further step not performed here would be to develop amenity specific distance thresholds, since each amenity differs in terms of density and spatial distribution.

The primary question addressed by the approach presented here is whether the brownfield is located in a community within the average national distance to social amenities and the extent to which including such amenities on-site shortens their walking distance.

The distance to the nearest amenity along the transport network is calculated for each resident within the ROI. The calculation is performed separately for each of the seven indicators. Two raster layers are combined in this operation. The first raster layer represents the distance to the nearest amenity for each grid cell within the ROI. The nearest amenity may lie within the 1 km boundary or beyond it. The raster layer represents distance values for the grid cells that lie within the ROI and may refer to amenities at different locations, depending on which is closest to each individual grid cell. The cells beyond the ROI represent 'no data'. The second raster layer represents the number of residents for each grid cell within the ROI. The two layers are multiplied using Hadamard multiplication. The result is a spatial layer representing distance to the nearest amenity per resident per grid cell. The calculation is performed a second time with the site included as the amenity in question. The distance to the closest amenity when included on-site is compared to the present idle site scenario for each resident. Distribution curves for both amenities on-site and the idle site can then be compared for each type of amenity. The distance value for all residents is summed and divided by the total population within the ROI to determine a mean distance for the ROI.

The distribution curves in Fig. 1 were calculated in a similar manner by simply extending the distance per resident raster layer to include the entire region.

The approach is applied to a case study in Flanders, Belgium in order to illustrate how the results are interpreted, the extent to which such an approach is useful and its potential weaknesses.

3. Case study

Alvat Buggenhout is a 4.6 ha abandoned brownfield, 24 km northwest of Brussels city centre, adjacent to the Scheldt River (Fig. 2). The site is surrounded by residential housing and agricultural crop land. To the south of the site are several active industrial sites. The Scheldt River separates a large area within the radius of influence from the site. The area on the opposite side of the river from the site is an uninhabited green area and not considered in the assessment. If there were residents on the other side of the river, then their travel route would include crossing the nearest bridge. Data on the location of pedestrian footpaths that are not adjacent to the existing roads, was unavailable. Footpaths exclusively for pedestrians could easily be accounted for if data becomes available.

The site was a former chemical container restoration facility. On-site operations resulted in the subsurface being heavily contaminated with a range of different solvents and heavy metals. People living around the site would benefit from having the site remediated, the dilapidated buildings removed and the site put back to use. In its present state, the site is of no benefit to those living around it and revitalizing it would generate value for the local community in terms of both providing services and increasing the local real estate market values. The site would need to be remediated prior to redevelopment. Fig. 2 shows where the local residents are located within the ROI. Fig. 3 shows all the existing amenities within and outside the ROI.

4. Results

Including the different amenities on-site brings the average local resident closer to each of the different amenities. The indicator metric is of the nearest amenity to each cell in the ROI; therefore it is possible that people living on the periphery of the ROI may be nearer to amenities outside the ROI than to the brownfield site. This can best be explained by looking at the heat map in Fig. 3. Fig. 3 shows that a doctor already exists within the ROI to the south west of the site. Figs. 4 and 5 show how residents in the immediate vicinity of the site have their walking distance to a doctor reduced when one is included on-site. The raster cells, representing proximity, immediately around the existing doctor are already illuminated. Including a doctor on-site does not influence the households in the immediate vicinity of the existing doctor. In other words, they are not brought nearer to a doctor. The households to the east of the site are however brought closer to a doctor by having a doctor included on-site and the raster cells are therefore illuminated. The extent to which the average household is brought closer to the amenities is dependent on the spatial distribution of existing amenities and this varies between the different amenities.

Fig. 6 is an overview of the walking distance calculation results represented in a radar diagram. Fig. 6 provides more detail in terms of how the distribution of distances across the ROI is affected by including the different amenities on-site.

The radar diagram (Fig. 6) allows the results of the different indicators to be represented in one graph. The relative changes brought about by including the different amenities on-site are reflected in terms of distance. The axes therefore reflect distance. The changes in walking distance to amenities for the average resident within the ROI are represented for the present idle site scenario (yellow wedges) and when amenities are included on-site (orange wedges). The mean for the entire Flemish region is represented with the broken green line.

The greatest changes in the radar graph in Fig. 6 are due to the inclusion of a doctor and a pharmacy on-site, followed by a school and then shops. A slight change is brought about by including a meeting place on-site and very little to no change occurs as a result of including green space and employment on-site. In terms of the Flemish mean (green broken line), the site is well located with the average resident being below the Flemish average for all of the amenities except schools. The Flemish average is less insightful than considering the entire distribution, which also reflects outliers in isolated rural areas. Fig. 7 provides a closer look at the distributions of walking distances for Flanders and the distribution of distances amongst residents in the ROI.

The dark blue distribution curve in each graph in Fig. 7 shows the cumulative percentage of the population within the different distances for Flanders. The change in distance for the average local resident is reflected by the shift in the weighted arithmetic mean from the present state of the site (vertical red line) to a scenario where the amenity in question is included on-site (vertical green line). The ROI changes when the amenity in question is included on-site with a shift from the present distribution (purple curve) to the future distribution (light blue curve). All of the graphs include the cumulative percentage of the population on the y-axes and the range of travel distances on the x-axes, beginning from 0 through to 4 km.

The largest changes amongst all the graphs are brought about by including a doctor and/or pharmacy on-site. A pharmacy on-site will bring at least 75% of the population approximately 500 m closer to the nearest pharmacy. It is clear from the radar diagram (Fig. 6), that the average resident in the ROI is already closer to a pharmacy than the average Flemish resident. The entire cumulative distribution curve for Flanders is also below ROI distribution curve. Including a pharmacy on-site will bring the whole population closer to a pharmacy however, the whole population is already within the average Flemish proximity to a pharmacy. Including a doctor on-site however, will bring at least 75%

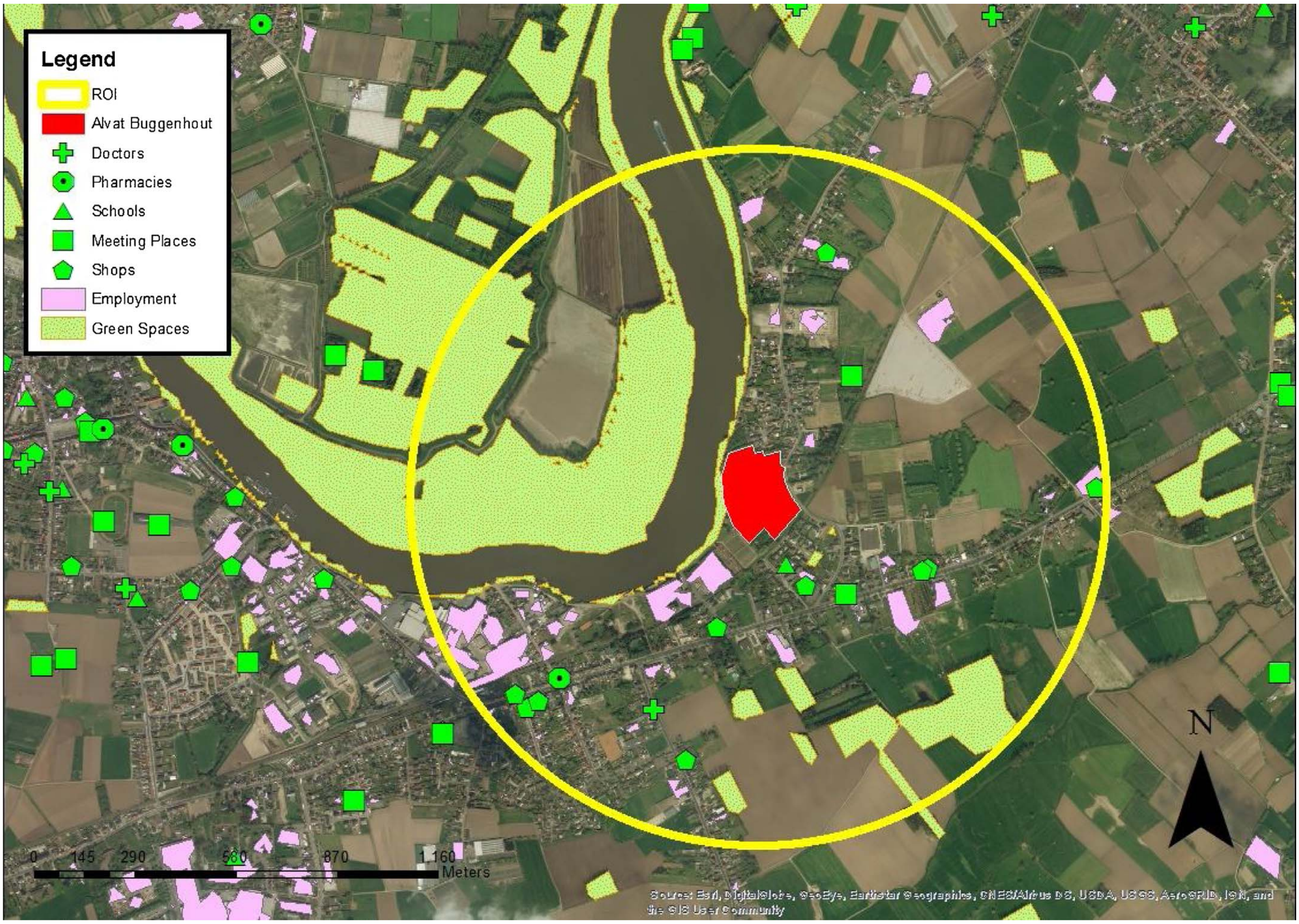


Fig. 3. Alvat Buggenhout brownfield within 1 km radius and locations of existing amenities. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

of the population above the cumulative distribution of the Flanders, which is not evident when only considering the Flemish average in the radar diagram (Fig. 6). 75% of the population will also be brought at least 500 m closer to a doctor. The map of exiting amenities in Fig. 3 also show one doctor and one pharmacy within the ROI. The other nearest doctors and pharmacies are not in the vicinity of the ROI.

Including a school, meeting place and/or shop on-site reflect a more moderate change. The cumulative distribution of the ROI for schools and meeting places show a shift, with 25% of the population having the most benefit in terms of reduced walking distance. The shift in the distance of 25% of the population is greater for schools than meeting places. Having a shop on-site, on the other hand, brings at least 75% of the ROI population closer to a shops. If a choice were to be made between a shop or a school there would be trade-off in a relatively small reduction in walking distance to schools for most of the population, on the one hand, and a larger reduction in walking distance for to a shop for the 25% of the population, on the other hand. The map of existing amenities in Fig. 3, shows that a school already exists right next to the brownfield site. This is the only school in the ROI and in its immediate vicinity. The map also shows that there are at least 8 shops in the ROI and its immediate vicinity but they are not well distributed across the ROI. Instead the shops are concentrated along the road running across the south of the ROI.

Providing employment and green space on-site has relatively little influence on the network travel distance for the local community. There is almost no shift in the ROI cumulative distribution curves in Fig. 7. The map of amenities in Fig. 3 show that green space and areas of employment are well distributed across the ROI and in its immediate vicinity.

5. Discussion

The discussion section addresses the potential shortcomings of the spatial proximity analysis approach adopted here, where it can be further developed and its relevance to other contexts beyond brownfield redevelopment.

5.1. Extent of ROI

Two conditions need to be considered when centring and defining the spatial extent of the ROI, namely 1) the size of the brownfield site and 2) the spatial distribution of amenities in the surrounding area. Some brownfields are far larger than the Alvat Buggenhout example used here. Petroleum Zuid in Antwerp, for example, is 103 ha. In the Petroleum Zuid case, a third of the ROI (drawn from the centre of the site) would be occupied by the site itself. The exact location of amenities on large brownfield redevelopment scenarios could vary greatly. In this case, it would be necessary to specify exactly where the different amenities will be located on-site in the redevelopment scenario, the on-site transport network and site access points. The 1 km ROI could then be centred on the future location for each amenity separately.

With regard to the densely populated urban areas where many amenities already exist within a 1 km radius of a site, the approach presented here would only generate noticeable changes in proximity for

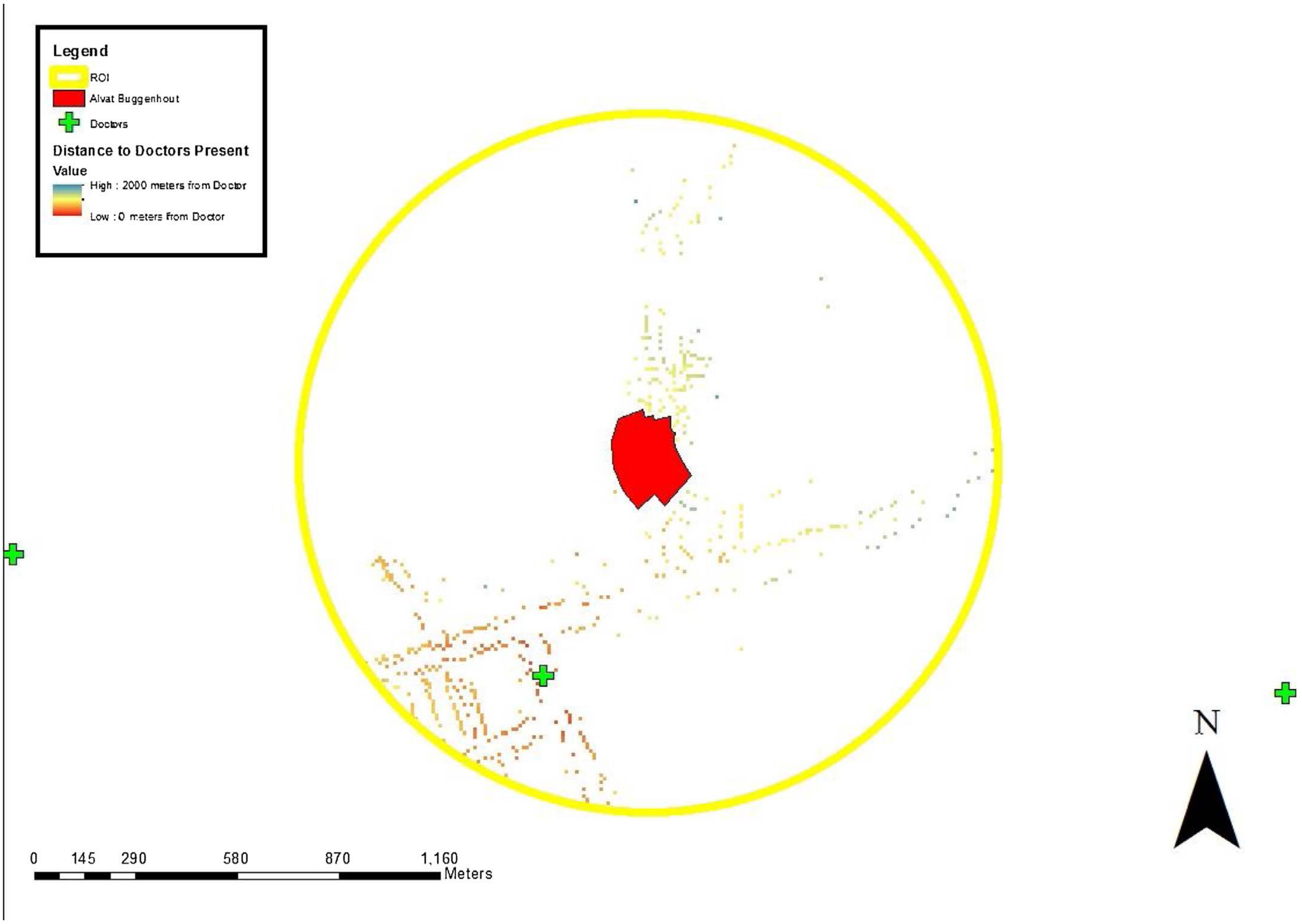


Fig. 4. Heat map representing the proximity of residents within ROI to doctors at present. The existing doctor is represented by a green cross. Only raster cells where residents live are included. The colour of the raster cells represent distance to doctors along a scale from blue (which is 2000 m) through yellow to red (at zero meters). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

those residents immediately around the site. In such cases it may be useful to generate results based on a smaller ROI. Another approach would be to determine the extent of the ROI based on the average capacity of local amenities. Therefore the ROI is extended from the site up until a boundary that includes a population size that can be accommodated by the specific amenity. This approach would require the additional step of collecting capacity data. It is also possible that in rural areas with small populations, the ROI would have to be very large. Beyond a certain extent a large ROI is not informative and shows only incremental changes per percentage of the population.

It is important to consider the physical geography of the location under consideration. In the case study discussed here, the ROI is separated by a river. The area within the ROI on the opposite side of the river is uninhabited. If that area was inhabited, then it would not be useful to consider those residents since any amenity on-site would not reduce their travel distance to those amenities. Considering residents on the other side of the physical barrier (in this case the river) would simply dilute the results unless there was a bridge or tunnel connecting the two sides of the river. The same would apply to other physical barriers such as hills or lakes.

The approach presented here also requires that the necessary high resolution spatial information is available. The spatial information must include the location of residents as well as all existing amenities and the road network. In this case, only walking distances were considered in terms of the routes residents could travel along the road network. A more accurate evaluation would include other footpaths beyond those adjacent to roads.

5.2. Indicator sub-categories

Including both a doctor or a pharmacy on the Alvat Buggenhout brownfield site would bring about the greatest reduction in walking distances out of the amenities considered. Therefore *Community Health and Safety* is the impact category where the most improvement can be made in terms of proximity. The case study site is well positioned in terms of the other impact categories *Human Capital*, Social *Cohesion* and *Convenience.* Existing indexes and social indicator sets consider the number of residents with access to amenities without considering their spatial distribution (Newman, 1999; Repetti & Desthieux, 2006; Romano & Ercolano, 2013). The same applies to the decision support systems for brownfield redevelopment discussed here, namely *The Sustainable Brownfields Redevelopment (SBR) Tool*, *LEED-ND* and *SIPRIUS* (Laprise et al., 2015; Talen et al., 2013; Wedding & Crawford-Brown, 2007). These approaches can be integrated with a spatial proximity evaluation by considering the capacity of local amenities. The capacity of services like doctors' posts and schools is a dimension in addition to proximity. The capacity dimension for some services includes additional levels of detail that make it relevant to whether it serves the local community. For example, the number of students within the ROI and the average age of the students should be considered when determining which stage of education a school included on-site should cater for. The proximity to schools indicator can therefore be sub-divided into the

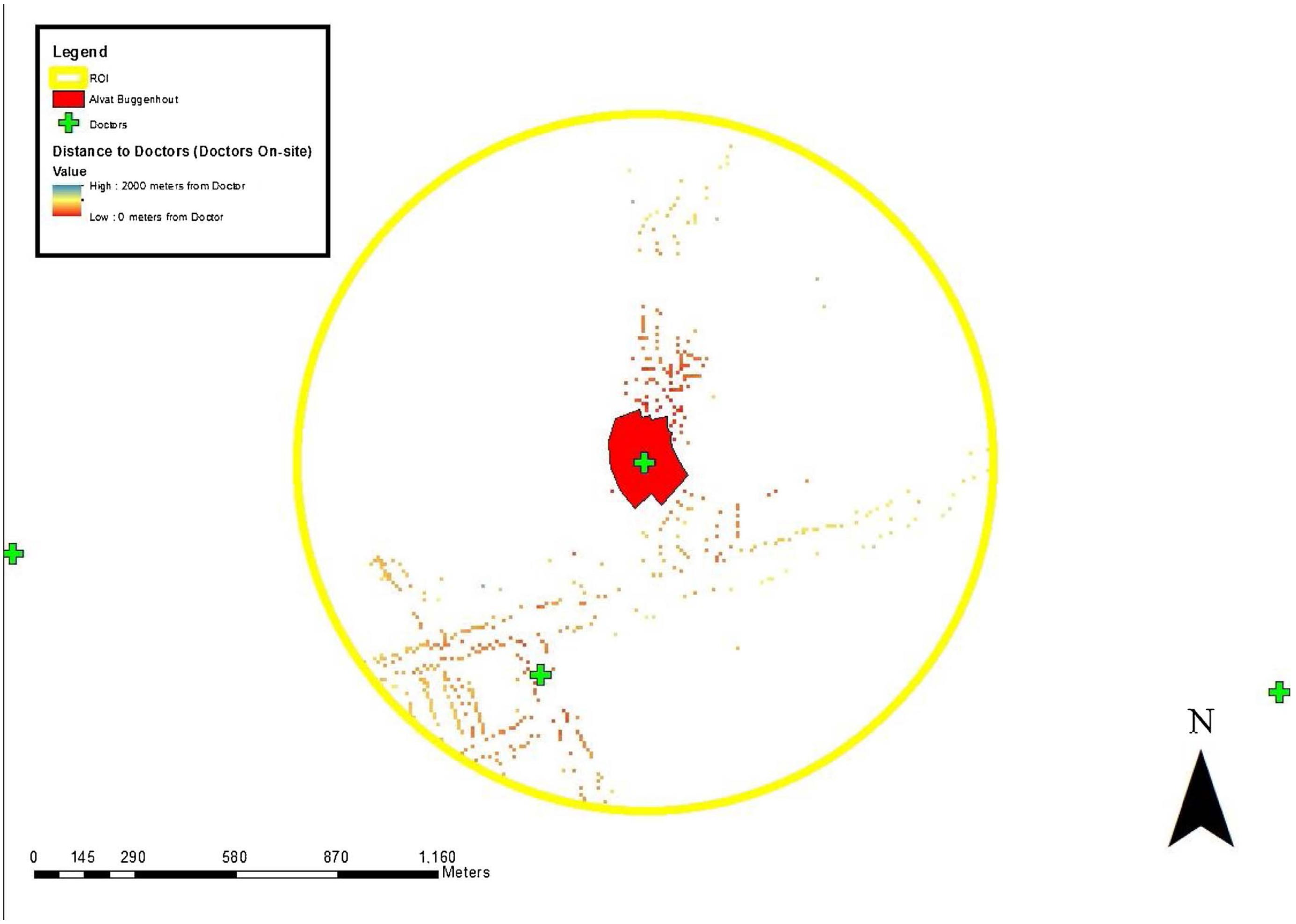


Fig. 5. Heat map representing the proximity of residents within ROI to doctors. The existing doctor and doctor on-site are represented by green crosses. Only raster cells where residents live are included. The colour of the raster cells represent distance to doctors along a scale from blue (which is 2000 m) through yellow to red (at zero meters). When comparing Fig. 4 to this figure (Fig. 5) it is clear that residents in the immediate vicinity of the brownfield site are brought closer to a doctor in terms of walking distance. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

elementary and secondary schools. The population layer would then also have to reflect the number of students per household and education level. Proximity to employment also requires the consideration of capacity and of how the employment brought about on-site matches the community labour pool's general skill level and expertise. Proximity to employment would be more relevant in assessing the suitability of different commercial facilities on-site, particularly in areas with a surplus of unskilled labour. The more specific the skill and education level required by industry, the less likely it is that the local labour supply will match what is required.

5.3. Commercial and industrial land-uses

The proximity analysis approach defined here could also be applied to the evaluation of brownfield sites for potential commercial, light industrial and industrial land-use. Instead of considering amenities, the indicators could consider distance to suitable work force, access to navigable rivers, highways and train infrastructure on the one hand. On the other hand it could consider whether or not the site is at a sufficient distance from residents that would otherwise be impacted by air and noise emissions. Romano and Ercolano (2013) developed the environmental virtuosity index (UEVI), for measuring the general environmental quality of urban areas. The index measures, amongst other variables, the number of available air quality monitoring stations per 10,000 inhabitants, the number of noise monitoring stations per 10,000 inhabitants and the area of noise barriers. Human health is therefore accounted for as a factor of air quality and noise reduction. A friction grid raster representing vegetative barriers could be used to account for their buffering capacity and therefore provide an additional dimension to the *Community Health and Safety* indicator category.

5.4. Weighting

An additional weighting step allows for the relative importance between different amenities to be put into perspective. The ROI mean results can be further weighted by multiplying them by the average frequency of journeys per citizen to such amenities yearly. The results therefore remain as distance variables but reflect how local citizens are impacted by having the different amenities nearer in terms of their annual walking distances. However, the frequency of visits does not necessarily reflect the importance of having an amenity within close proximity. For example, having a doctor or emergency room nearby may be more important than having a shop or meeting place nearby, even though the shop and meeting place is frequented more regularly by local residents. Elderly residents and residents who are at higher risk of a medical emergency may feel more secure having a doctor in close proximity than a shop if indeed they would be mutually exclusive. The amenities included here are not necessarily mutually exclusive, however, on smaller sites a choice may have to be made between the different amenities. In this case, an additional weighting scheme could be

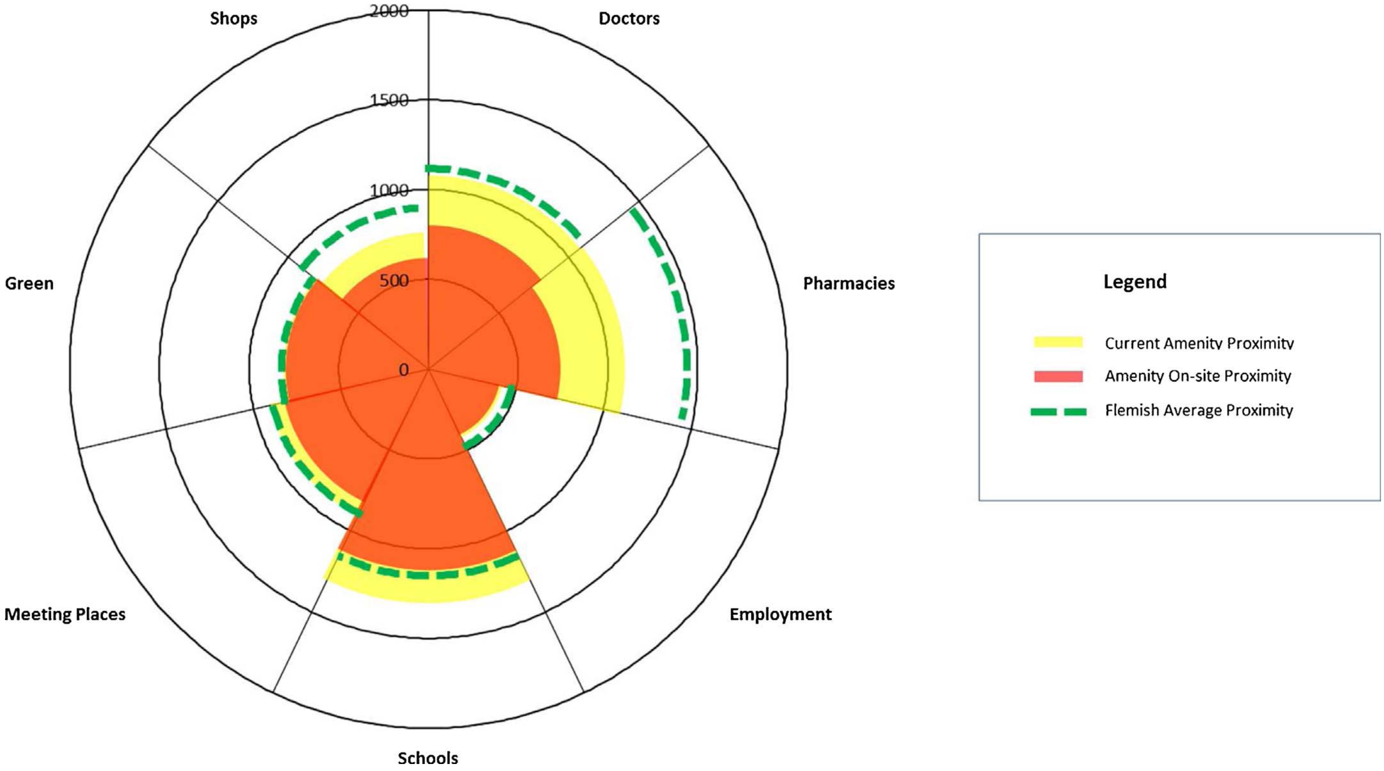


Fig. 6. Radar diagram representing all social amenity indicators together. The axes represent the distance to the nearest amenities in meters for residents within the ROI. The yellow wedges represent the mean walking distance for local residents in the ROI for the present idle site scenario. The orange wedges represent the mean walking distance for local residents in the ROI when the different amenities are included on-site. The green broken line represents the mean walking distance for the Flanders region. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

adopted that would reflect the specific preferences of local stakeholders. The various impact categories can also be weighted according to their importance to local stakeholders.

5.5. Future land-use change

The approach presented here is a step in the direction toward thinking about decision support tools for urban intensification and compact urban development with the benefit of reduced walking distances (Laprise et al., 2015; Talen et al., 2013). An important next step would be to integrate predicted future land-use changes and to consider to what extent changes on-site would shape the landscape of the surrounding area in the future. An important question is whether or not and to what extent eventual redevelopment plans will service the

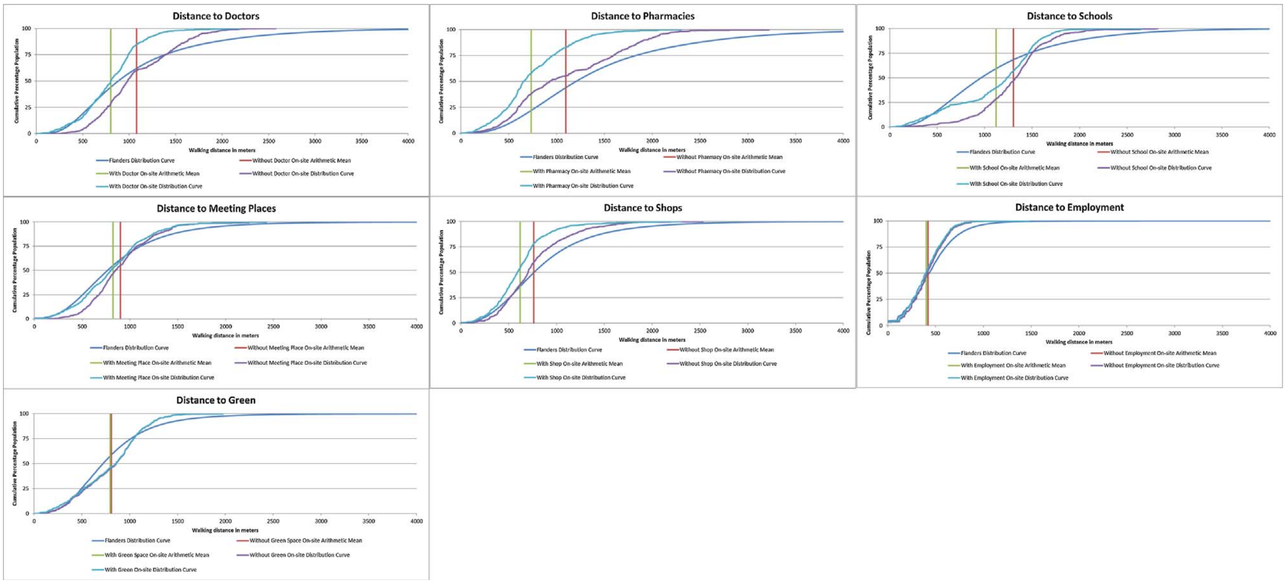


Fig. 7. Radius of influence results. The distance to the specific amenities is represented for each indicator showing a shift in walking distances from an idle site to including the amenity on-site. The mean walking distance to the amenity shifts (from red vertical line to green vertical line) along the distribution curve for Flanders (dark blue). The distribution curve for people in the ROI around the site (from purple to light blue) in terms of their walking distances to amenities. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

community. Further work on the approach could also include the integration of land-use change predictions that account for increases or decreases in the local population around a site.

5.6. Applicability in the brownfield context

The approach presented here can be used for any urban space located in an urban setting, in which the future land-use is open. The existing methods and their proximity indicators were described here to demonstrate that the scope of consideration in terms of access to amenities is limited. In this sense the proposed approach builds on existing *decision support systems for brownfield redevelopment*. None of the existing methods address the question "to what extent do local residents benefit from the redevelopment scenario?" Instead they either focus on the best scenario for those that will inhabit the site or they focus on selecting a site form a range of possibilities in a larger area. The approach presented here addresses the question of how local communities around a given site can benefit from what is on the site. The approach can therefore also be an addition to the existing methods.

Compact urban development is arguably the basis upon which cities and urban landscapes can be more sustainable (Van Bueren, van Bohemen, & Visscher, 2012). Compact urban areas allow for shorter travel distances and therefore less dependence on different travel modalities and the associated energy use and air pollution emissions. Compact areas also allow for greater energy efficiency, in terms of heating and the sharing of grid infrastructure (Slavin, 2011; Van Bueren et al., 2012). Cities can ultimately provide their residents with better employment opportunities, access to services that are not available in rural areas and ultimately higher living standards (Rydin et al., 2002; Shäffler & Swilling, 2013). Spatial proximity analysis allows for the degree to which urban zones are compact to be evaluated. Brownfields and areas requiring renewal provide the opportunity for more compact urban planning where spatial proximity analysis can play an important role in determining which amenities are already available and which amenities can be brought closer to residents.

6. Conclusions

The approach presented allows for comparisons based on walking distance, which can be easily understood by stakeholders and experts alike. The approach provides the user with insights into the impact of eventual redevelopment scenarios in a straight-forward manner where the calculation steps can be easily understood. The approach can be added to existing methods or used as a standalone tool.

The Alvat Buggenhout case study illustrates that although all amenities are brought closer to the local residents by including them onsite, certain amenities are brought closer to some residents than others. The approach and considering the distribution of distances across the site ROI, shows that using spatially explicit indicators provides the necessary detail for informed decision making. The spatial indicators in the existing tools simply consider whether or not an amenity is within walking distance from the site in question, overlooking the large variations in walking distances that actually exist for local residents.

Spatial proximity considerations support efforts toward more compact urban areas. Compact urban areas in turn provide a foundation for reduced dependency on travel, greater energy efficiency and the prevision of essential services to residents. Brownfield redevelopment provides the opportunity to utilise underproductive land resources. The approach presented here is a first step towards identifying appropriate future land-use scenarios in terms of reducing residents walking distances.

The approach is however in the early stages of development and the key potential improvements include the consideration of the capacity of amenities, more specific amenity sub-categories and the addition of a stakeholder preference weighting procedure or scheme. The line of reasoning adopted in the approach could also be applied to industrial sites with different indicators. Further developments could also include predictive modelling in order to evaluate the long-term sustainability of different redevelopment scenarios.

Acknowledgements

The authors are grateful to the Flemish Public Waste Agency (OVAM) for providing the case study data. The authors would like to thank the reviwers for helping to substantially imporve the quality of the article. The authors would also like the thank Jeremy De Valck for reviweing the use of langauge in the manuscript and for his helpful suggestions.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.landurbplan.2017.12.003.

References

Ahn, K. H., & Palmer, R. (2016). Regional flood frequency analysis using spatial proximity and basin characteristics. *World environmental and water resources congress,* 329–338 2009, July.

Bardos, R. P., Bone, B. D., Boyle, R., Evans, F., Harries, N. D., Howard, T., & Smith, J. W. (2016). The rationale for simple approaches for sustainability assessment and management in contaminated land practice. *Science of the Total Environment, 563*, 755–768.

Bauer, R. (1967). *Social indicators.* Cambridge, MA: MIT press.

Berleant, A., & Carlson, A. (2007). *Introduction: The aesthetics of human environments. The aesthetics of human environments*. Broadview Press.

Bulmer, M. (1978). *Measuring social well-being: A progress report on the development of social indicators*OECD, Paris: OECD Social Indicator Development Programme no. 3 213 pp. 1976.

Chan, J., To, H. P., & Chan, E. (2006). Reconsidering social cohesion: Developing a definition and analytical framework for empirical research. *Social Indicators Research, 75*(2), 273–302.

Colantonio, A., Dixon, T., Ganser, R., Carpenter, J., & Ngombe, A. (2009). *Measuring socially sustainable urban regeneration in Europe. Oxford Institute for Sustainable Development (OISD).* School of the Built Environment, Oxford Brookes University.

European Environmental Agency (EEA) (2015). *Environmental Terminology and Discovery Service.* Available at: http://glossary.eea.europa.eu/terminology/concept_html?term=social%20indicator [Accessed on 16 June 2015].

European Commission Directorate-General for Regional Policy (2009). *Promoting sustainable urban development in Europe: achievements and opportunities.* Brussels. Available at: http://ec.europa.eu/regional_policy/sources/docgener/presenta/urban2009/urban2009_en.pdf [Accessed on 05 May 2015].

Freeman, C. (1999). Development of a simple method for site survey and assessment in urban areas. *Landscape and Urban Planning, 44*, 1–11.

Hartmann, B., Török, S., Börcsök, E., & Oláhné Groma, V. (2014). Multi-objective method for energy purpose redevelopment of brownfield sites. *Journal of Cleaner Production, 82*, 202–212.

Hayek, U. W., Efthymiou, D., Farooq, B., von Wirth, T., Teich, M., Neuenschwander, N., et al. (2015). Quality of urban patterns: Spatially explicit evidence for multiple scales. *Landscape and Urban Planning, 142*, 47–62.

Herbst, H., & Herbst, V. (2006). The development of an evaluation method using a geographic information system to determine the importance of wasteland sites as urban wildlife areas. *Landscape and Urban Planning, 77*, 178–195.

Huff, D., & McCallum, B. M. (2008). *Calibrating the huff model using ArcGIS business analyst.* Redlands, CA: ESRI.

Huff, D. L. (1963). A probabilistic analysis of shopping center trade areas. *Land Economics, 39*, 81–90.

Laprise, M., Lufkin, S., & Rey, E. (2015). An indicator system for the assessment of sustainability integrated into the project dynamics of regeneration of disused urban areas. *Building and Environment, 86*, 29–38.

Leighton, L. R., & Schneider, C. L. (2004). Neighbor proximity analysis, a technique for assessing spatial patterns in the fossil record. *Palaios, 19*(4), 396–407.

Loukaitou-Sideris, A. (2006). Is it safe to walk? 1 neighborhood safety and security considerations and their effects on walking. *Journal of Planning Literature, 20*(3), 219–232.

Maantay, J. A., & McLafferty, S. (Vol. Eds.), (2011). *Geospatial analysis of environmental health: Vol. 4*Springer Science & Business Media.

Malczewski, J. (1999). *GIS and multicriteria decision analysis.* John Wiley & Sons.

Marans, R. W. (2015). Quality of urban life & environmental sustainability studies: Future linkage opportunities. *Habitat International, 45*, 47–52 Part 1.

Morris, J. M., Dumble, P. L., & Wigan, M. R. (1979). Accessibility indicators for transport planning. *Transportation Research Part A: General, 13*, 91–109.

Newman, P. W. G. (1999). Sustainability and cities: Extending the metabolism model. *Landscape and Urban Planning, 44*, 219–226.

Nohl, W. (2001). Sustainable landscape use and aesthetic perception: Preliminary reflections on future landscape aesthetics. *Landscape and Urban Planning, 54*, 223–237.

Noll, H. H. (2004). *Social indicators and quality of Life research: Background, achievements and current trends. Advances in Sociological Knowledge*. Springer151–181.

Norrman, J., Volchko, Y., Hooimeijer, F., Maring, L., Kain, J. H., Bardos, P., et al. (2016). Integration of the subsurface and the surface sectors for a more holistic approach for sustainable redevelopment of urban brownfields. *Science of The Total Environment, 563–564*, 879–889.

Oliver, L., Ferber, U., Grimski, D., Millar, K., & Nathanail, P. (2005). The scale and nature of European brownfields. CABERNET 2005 -scale and nature of European brownfields. *CABERNET 2005 -international conference on managing urban land*.

Ostrom, E. (2000) Social capital: a fad or a fundamental concept. Social capital: A multifaceted perspective, 172(173), 195–198.

Pediaditi, K., Doick, K. J., & Moffatt, A. J. (2010). Monitoring and evaluation practice for brownfield: Regeneration to greenspace initiatives A meta-evaluation of assessment and monitoring tools. *Landscape and Urban Planning, 97*, 22–36.

Philipp, R. (2001). Aesthetic quality of the built and natural environment: Why does it matter? In W. Pasini, & F. Rusticali (Eds.). *Green cities: Blue cities of Europe* (pp. 225–247). Rimini: WHO Regional Office for Europe.

Phillips, R., & Stein, J. (2013). An indicator framework for linking historic preservation and community economic development. *Social Indicators Research, 113*, 1–15.

Rall, E. L., & Haase, D. (2011). Creative intervention in a dynamic city: A sustainability assessment of an interim use strategy for brownfields in Leipzig, Germany. *Landscape and Urban Planning, 100*(3), 189–201.

Ramsdem, P. (2010). Workshop on re-using brownfield sites and buildings. *Regions for economic change conference* Available at: http://ec.europa.eu/regional_policy/archive/conferences/sustainable-growth/doc/rfec_brownfield_en.pdf [Accessed on 04 May 2015].

Repetti, A., & Desthieux, G. (2006). A relational indicator set model for urban land-use planning and management: Methodological approach and application in two case studies. *Landscape and Urban Planning, 77*, 196–215.

Romano, O., & Ercolano, S. (2013). Who makes the most? Measuring the urban environmental virtuosity. *Social Indicators Research, 112*, 709–724.

Roseland, M. (2000). Sustainable community development: integrating environmental, economic, and social objectives. *Progress in Planning, 54*(2), 73–132.

Ryan, R. L. (2011). The social landscape of planning: Integrating social and perceptual research with spatial planning information. *Landscape and Urban Planning, 100*, 361–363.

Rydin, Y., Bleahu, A., Davies, M., Dávila, J. D., Friel, S., De Grandis, G., et al. (2002). Shaping cities for health: Complexity and the planning of urban environments in the 21 st century. *The Lancet, 379*, 2079–2108.

Schädler, S., Morio, M., Bartke, S., Rohr-Zanker, R., & Finkel, M. (2011). Designing sustainable and economically attractive brownfield revitalization options using an integrated assessment model. *Journal of Environmental Management, 92*, 827–837.

Schädler, S., Morio, M., Bartke, S., & Finkel, M. (2012). Integrated planning and spatial evaluation of megasite remediation and reuse options. *Journal of Contaminant Hydrology, 127*, 88–100.

Schädler, S., Finkel, M., Bleicher, A., Morio, M., & Gross, M. (2013). Spatially explicit computation of sustainability indicator values for the automated assessment of land-use options. *Landscape and Urban Planning, 111*, 34–45.

Schneidewind, U., Haest, P. J., Atashgahi, S., Maphosa, F., Hamonts, K., Maesen, M., et al. (2014). Kinetics of dechlorination by Dehalococcoides mccartyi using different carbon sources. *Journal of Contaminant Hydrology, 157*, 25–36.

Shäffler, A., & Swilling, M. (2013). Valuing green infrastructure in an urban environment under pressure: The Johannesburg case. *Ecological Economics, 86*, 246–257.

Shearmur, R. (2011). Innovation, regions and proximity: From neo-regionalism to spatial analysis. *Regional Studies, 45*(9), 1225–1243.

Slavin, M. (2011). *The Triple bottom line: Sustainability principles, practice, and perspective in America's cities.* Washington, DC: Island Press.

Smardon, R. C. (1988). Perception and aesthetics of the urban-environment – Review of the role of vegetation. *Landscape and Urban Planning, 15*, 85–106.

Smith, T., Nelischer, M., & Perkins, N. (1997). Quality of an urban community: A framework for understanding the relationship between quality and physical form. *Landscape and Urban Planning, 39*(2-3), 229–241.

Southworth, M. (2005). Designing the walkable city. *Journal of Urban Planning and Development, 131*(4), 246–257.

Stedman, R. C. (1999). Sense of place as an indicator of community sustainability. *Forestry Chronicle, 75*, 765–770.

Talen, E., Allen, E., Bosse, A., Ahmann, J., Koschinsky, J., Wentz, E., et al. (2013). LEED-ND as an urban metric. *Landscape and Urban Planning, 119*, 20–34.

Thomas, M. R. (2002). A GIS-based decision support system for brownfield redevelopment. *Landscape and Urban Planning, 58*, 7–23.

Thornton, G., Franz, M., Edwards, D., Pahlen, G., & Nathanail, P. (2007). The challenge of sustainability: Incentives for brownfield regeneration in Europe. *Environmental Science & Policy, 10*, 116–134.

United Nations World Commission on Environment and Development (UNWCED) (1987). *Our common future (the brundtland report)*Oxford, UK: Oxford University Press.

United States Environmental Protection Agency (USEPA) (1996). *Support of regional efforts to negotiate Prospective Purchaser Agreements (PPAs) at superfund sites and clarification of PPA guidance.* Available at: http://www.epa.gov/superfund/programs/reforms/docs/ppa_clar.pdf [Accessed on 04 May 2015].

Van Bueren, E., van Bohemen, H., & Visscher, H. (2012). *Sustainable urban environments. An Ecosystems Approach*. Dodrecht: Springer.

Van Esch, L., Poelmans, L., Engelen, G., & Uljee, I. (2011). *Landgebruikskaart voor Vlaanderen en Brussel, studie uitgevoerd in opdracht van MIRA, Milieurapport Vlaanderen (Land-use map for Flanders and Brussels, study commissioned by MIRA, the Environmental Report of Flanders). MIRA/2011/09*Mechelen: Vlaamse Milieumaatschappij Available at http://www.milieurapport.be/nl/publicaties/mira-onderzoeksrapporten/ [Accessed on 21 January 2017].

Van Kamp, I., Leidelmeijer, K., Marsman, G., & De Hollander, A. (2003). Urban environmental quality and human well-being: Towards a conceptual framework and demarcation of concepts; a literature study. *Landscape and Urban Planning, 65*(1), 5–18.

Wedding, G. C., & Crawford-Brown, D. (2007). Measuring site-level success in brownfield redevelopments: A focus on sustainability and green building. *Journal of Environmental Management, 85*, 483–495.

Zhang, Z., Tan, S., & Tang, W. (2015). A GIS-based spatial analysis of housing price and road density in proximity to urban lakes in Wuhan City, China. *Chinese Geographical Science, 25*(6), 775–790.