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RESEARCH ARTICLE

Valuation challenges of urban green infrastructure

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Abstract – The current article provides an overview of the benefits provided by urban green infrastructure (GI), as well as the application of the concept of total economic value and the relevance of the United Nations Sustainable Development Goals. Afterward, environmental valuation methods that can be used to calculate the benefits in monetary units are presented, highlighting the potential problems or biases. The relevance of cost-based, revealed, and stated preference methods are discussed. It is concluded that several case studies are available, however, the abundance of services provided and differences in measuring the GI services in natural units make monetary valuation ambiguous or challenging. Still, the growing number of people living in urban neighbourhoods makes it more and more expected to measure and valuate the benefits.

Keywords – urban green infrastructure, total economic value, SDGs, revealed and stated preference methods

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INTRODUCTION

The development and maintenance of city parks and other elements of urban green infrastructure (GI) can be very high and represent some easily measurable spending by the local municipalities. Extreme weather events can cause serious damages to GI, causing high maintenance or reconstruction costs. Furthermore, reconstruction cannot be complete, e.g. planting new trees cannot perfectly substitute for old ones. Such damages are becoming more and more likely, resulting in increased maintenance costs of the green infrastructure. While GI is considered as a major tool to help urban resilience, during the planning of future GI elements, changing climatic conditions should be taken into consideration (e.g., when selecting the species to be planted).

While costs are tangible and typically easy to be determined, especially after the negative changes, ex-post, the benefits or ecosystem services provided by GI are more difficult to quantify and monetize.

It is widely accepted that urban green spaces enhance the well-being of people (Elmqvist et al., 2015), but the total benefit is difficult to calculate because they are scattered. Beyond the local benefits, global impacts are also significant, e.g., the carbon sequestration of the flora. That is, some benefits are realized on macro-level and still, costs are born only by the local municipalities.

The present article introduces the characteristics of green infrastructure, comparing its attributes with that of the traditional, grey infrastructure. Afterwards, the concept of total economic value (Plottu, 2007) (TEV) is presented for urban GI, describing the significance of various value components, that is direct and indirect use value, option value, bequest and existence value. The relevance of UN SDGs in case of the management of urban GI is also discussed.

After presenting the specialties of GI, monetary valuation methods (cost-based, revealed and stated preference, benefit transfer) are analysed, focusing on their usefulness in case of valuing urban green infrastructure. In order to demonstrate the applicability of various methods, some international cases are presented and conclusions are drawn.

The findings of the study will help decision-makers to plan and manage GI more consciously. The monetary valuation of green infrastructure is important, considering the fact that

with a growing urban population (UN, 2014), the values will definitely increase.

ATTRIBUTES OF URBAN GREEN INFRASTRUCTURE

The characteristics mentioned in the introduction also indicate the relevance of the phrase "infrastructure" when describing "green infrastructure". The most important attribute is that it does not contribute directly to the economic production processes, however, it is needed in providing the background – the liveability of cities. The benefits are provided in the form of services, similarly to traditional infrastructure (Illés, 2008). E.g., recreational services of a park can only be enjoyed by visiting it. It is impossible or difficult to exclude those who don't contribute to the maintenance of it. The free-rider phenomenon is very common.

These characteristics explain why the development and maintenance are typically financed by the community and not by private companies. The long payback period also indicates public financing and using the Social Discount Rate when calculating the present value. Moreover, contrary to grey infrastructure, green infrastructure is not able to provide its maximum benefit after being completed, but needs years to reach its maximum potential (e.g. young trees planted). Partly as a result of this, estimating the benefits is less reliable than in the case of the traditional infrastructure.

Finally, similarly to grey infrastructure, it consists of interrelated elements, creating a network-like structure. Experts working on the development of urban GI are more and more aware of these characteristics and try to plan and manage the system as a whole. It is worth mentioning that together with lakes, ponds fountains, etc. many use the term "blue-green infrastructure". (With the increasing impacts of urban heat islands, the importance of "blue infrastructure" is also growing.)

EU emphasizes the role of GI in biodiversity conservation (European Union, 2010). The 2010 Biodiversity directive considers the concept very comprehensively. Most habitats within the EU have suffered some changes as a result of human activities and need active maintenance. Protected areas or other high-biodiversity areas also belong to green infrastructure. The Green Infrastructure Strategy defines GI as a "strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services" in both rural and urban settings (European Commission, 2013). In this context, urban green infrastructure forms a bridge between urban and rural areas, and the network-like attribute is present.

Treating GI as a type of infrastructure is useful, as it suggests that besides development the planning of maintenance is indispensable. Lessons learnt from the management of traditional infrastructure are useful for the management of green infrastructure

BENEFITS PROVIDED BY URBAN GREEN INFRASTRUCTURE

The benefits or ecosystem services provided by urban green areas typically include supporting, regulating and cultural services. Provisioning services are not significant, however, in the case of some special GI elements, such as community gardens, they can be important.

The most significant regulating service is microclimate regulation which has a direct impact on citizens' well-being. Reducing the heat island effect is becoming more and more important. Some studies estimate heat island reduction in natural units. For example, a study of Manchester revealed that a 10% increase in tree canopy has the potential to decrease the temperature by 3-4.8 C° (Gill et al., 2007). Another study, prepared in Terre Haute, Indiana, USA found that for each unit increase in the so-called leaf area index (LAI), the surface temperature was 1.2 °C lower (Hardin, Jensen, 2007). Microclimatic impacts imply the reduction of the use of energy and thereby contribute to lower urban carbon footprints (Akbari, 2002).

Water regulation is also significant (Pataki et al., 2011), as urban green spaces and open areas help combat the adverse impacts of flash-floods or heavy rains. This service is a good example of combining traditional grey infrastructure and green infrastructure services.

Green infrastructure contributes to pollution reduction and thereby has positive health impacts even on those who do not benefit from direct use value. There are several studies available on GI's health impact. According to a recent research project (Nowak et al., 2018), in 86 Canadian cities urban forests were estimated to remove 16,500 tonnes of various air pollutants in 2010, generating positive human health impacts worth 227.2 million Canadian dollars.

Finally, cultural services have to be mentioned (Elmqvist et al., 2015), since city parks provide important recreational opportunities and contribute to the preservation of human health.

After presenting typical ecosystem services, the concept of total economic value is interpreted for urban GI. The so-called total economic value is an extended concept of value, which can describe the value of natural resources. Some valuation methods are only able to measure parts of the TEV, while others can provide us information both about the use and non-use values.

Figure 1 is representing the concept of TEV in the case of urban green infrastructure. The width of the arrows is representing the importance of each value element.

Direct use value consists of two parts: the recreational and health preservation value which can be enjoyed by visiting the place (in situ direct use), and ex-situ value which means consuming or using extracted materials. Direct use value is very important in the case of city parks, that offer various

recreational opportunities. For example, Park Bikás in Buda offers entertainment opportunities for all generations, operating playgrounds, running track, outdoor gym, and playground for dogs. In the case of other types of green infrastructure, e.g. green roofs that cannot be visited, in situ use value is negligible. Ex-situ or extractive use value is typically low in the case of urban GI, except for urban community gardens. Furthermore, collecting biomass and using it for heat generation can be an example of ex situ value.

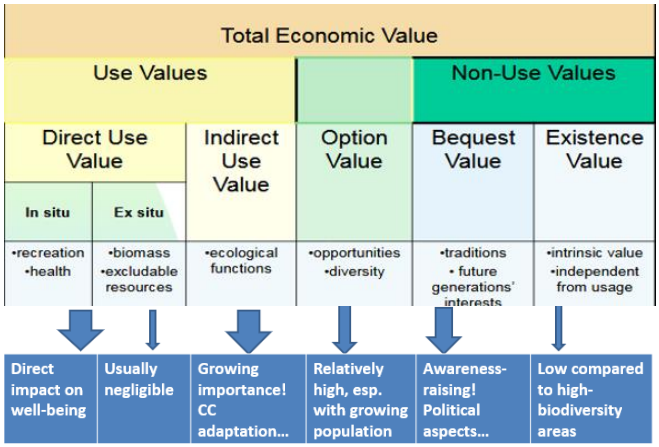

Figure 1: Total Economic Value of urban green infrastructure (Source: own, based on Munashinge, 1992)

Indirect use value is becoming more and more important. Considering urban green spaces as "green infrastructure" is a good indication of this tendency. Climate change adaptation is an increasingly important aspect of indirect use value. Carbon sequestration, the role in climate regulation and water management also belong here, as well as pollutant control and the role in noise prevention (Bolund, Hunhammar, 1999). It means tangible local or regional impacts.

Option value is high and increasing as the number of people living in cities is growing. Preserving the opportunities is important. Bequest value is about the preservation of resources for future generations. The traditions and cultural values are also important constituents of bequest value. The bequest value of emblematic city parks can be especially high. Finally, the existence value in the case of urban GI is relatively low, compared to other high-biodiversity areas, as the number of species living in urban ecosystems is limited.

Bequest value is relatively high, as preservation is important for future generations. A growing population also increases bequest value. There are some traditional places (e.g. old city parks) with high cultural values, too. Awareness-raising can increase bequest value.

Existence value is relatively low, compared to other, high-biodiversity areas. To sum up, the most important value elements are: direct in situ value, indirect use value, option and bequest values, while ex situ use value and existence value are not significant.

The United Nations Sustainable Development Goals (UN, General Assembly, 2015) provide a widely accepted option for the assessment of sustainability. Urban GI first of all support SDG 11: Make cities and human settlements inclusive, safe, resilient and sustainable. As urban green infrastructure is a public good, its benefits are available for all members of the community. However, if we consider the value of properties as influenced by the availability or accessibility to city parks, it is observed that not all citizens have similar access to certain elements of GI. As mentioned earlier, GI has a significant role in biodiversity conservation, that is SDG 15 "Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss" is supported, too. SDG 9, "Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation" is also relevant, as green infrastructure can help build resilient infrastructure. Urban green infrastructure may also assist SDG 13, "Take urgent action to combat climate change and its impacts" considering its role in CC mitigation and adaptation. Finally, SDG 3, "Ensure healthy lives and promote well-being for all at all ages" is also more and more relevant, taking into consideration the growing number of people living in cities.

APPLICABILITY OF ENVIRONMENTAL VALUATION METHODS – COST-BASED METHODS

Cost-based methods can be applied if some environmental service is lost or damaged and needs to be restored or substituted. The benefit of cost-based methods is that they are more known and accepted among decision-makers than the other techniques.

As more and more information is available on the development and maintenance cost of urban green infrastructure, the application of cost-based methods is more and more relevant.

It is an important limitation of cost-based methods that they typically focus on the use value elements of TEV (Marjainé et al., 2005). Since the use value of GI is high, cost-based methods are able to measure a significant section of TEV.

APPLICABILITY OF ENVIRONMENTAL VALUATION METHODS – HEDONIC PRICING

Hedonic pricing (HP) is a revealed preference method, measuring value based on individuals' revealed preferences. It uses the property market to gain information on how environmental characteristics influence prices.

Overviewing international literature, there are several attempts to use hedonic pricing for the valuation of green infrastructure, city parks, open spaces or forests. Wu et al. conclude that the positive impact of green areas on property prices is because of recreational opportunity and the nice view (Wu et al. 2004). Irwin (2002) mentions that an additional benefit of these spaces is that they are not developed and contribute to avoiding over-crowdedness.

Overviewing several earlier studies, using hedonic pricing, Walter and Schläpfer found that beautiful landscapes and the proximity of green areas have a positive impact on the value of properties (Walter, Schläpfer, 2010). The proximity of protected areas usually, open spaces and forests frequently and agricultural lands sometimes increase the value of nearby properties. 46 journal articles introducing 53 regression analyses, prepared between 1986 and 2009 also revealed that: studies prepared for a bigger territory and urban and suburban areas are more likely to find a significant positive impact.

Analysing earlier primary surveys draws our attention to some practical problems, too. Environmental characteristics are measured differently in the case of various studies, which makes it difficult to transfer the results to other sites and to use "benefit transfer".

How can we measure the proximity of green areas, for example? Usually, there are three opportunities for that (Walter, Schläpfer, 2010):
• Accessibility: how far is the nearest green territory from the property concerned?
• Share of green territory: what is the share of green areas around the property (within X meters) concerned?
• Binary variable: is there a green area around the property concerned?

There are big differences, regarding the impact on prices depending on how we measure the positive impact of green spaces, e.g. we measure the distance from green spaces or the share of green. A recent study for Cologne found that if we consider the distance, one meter less will increase the value by 0.0038%, while if the share of green areas is higher by 1% within 500 m, it will increase the value by 0,1% (Kolbe, Wüstemann, 2015).

The impact of green spaces on property prices can be measured using further indicators, too. In the case of a Spanish survey (Morancho, 2002), the following indicators were used: is there a park/ public garden visible from the property? How far is the closest public park from the property and how big is this park? Data of 810 properties from Castellón city were analysed using regression analysis. It was found that the most important variable influencing property prices is the size of the property. If the distance from the closest park is growing, the value of the property is decreasing. The other two variables: visibility of the park and size of the park, did not influence the price.

Besides the challenges of measuring the impacts of certain variables, it is also a problem that some variables are not linearly independent from each other. For example, if we would like to measure the impact of air quality and GI on property prices, the two factors are not independent of each other. (As one of the positive impacts of GI is the positive impact on air quality.)

Finally, the last methodological problem worth mentioning is the problem of the availability of all the important variables which potentially influence property prices. In the case of the study prepared in Cologne, experts found it a problem, that they did not have information about small city parks, only about the large ones. They also complained that they had no information about the quality of green spaces, although it could influence nearby property prices. (Kolbe, Wüstemann, 2015).

In spite of the difficulties, hedonic pricing can be expected to play an important role in the valuation of GI, as property values can be measured objectively, contributing to the acceptance of this approach, compared to the so-called hypothetical methods, introduced next.

APPLICABILITY OF ENVIRONMENTAL VALUATION METHODS – HYPOTHETICAL METHODS

In the case of hypothetical methods, a hypothetical market is constructed. In the framework of a questionnaire survey, we would like to know how much people would be willing to pay for some environmental services which are originally available for free (Szlávik, 2006). As green infrastructure is typically a public good, hypothetical methods can valuate it. The most simple and well-known hypothetical method is the contingent valuation method (CVM). When using CSM, we ask "willingness to pay" directly.

As a consequence of several potential biases, this method receives a lot of criticism (Eberle, Hayden, 1991). Since the 1990s the so-called indirect stated preference methods receive more and more attention. The risk of strategic bias (when the respondent states a higher WTP to influence the decision) will not be eliminated but it can be decreased (Bristow, Wardman, 2004). The two most well-known indirect methods are "choice experiment" and "contingent ranking".

It is an important advantage of hypothetical methods that we can prepare ex-ante valuation before the beginning of development projects in the phase of planning.

Hypothetical methods have been used to valuate urban and suburban green infrastructure or GI situated close to large cities. To demonstrate the latter, a case study from Italy is presented (Vecchiato, Tempesta 2013). In the Veneto region, the size of forests has decreased significantly since the 19th century. The demand for the establishment of recreational areas has increased recently. To meet this demand, it was decided to establish a forest close to the city of Venice. The high cost of the project made it important to calculate the benefits in monetary terms. It was an important question if people preferred planting trees or having meadows as well as forest areas. Based on the questionnaire survey among local inhabitants it was found that most people prefer the latter one. The average WTP for the realization of the forest development project was 51 €/family/year. WTP decreased with the age of the respondent but even the WTP of older respondents was relatively high. Finally, those who lived closer to the development size had higher WTPs. It suggests that use values are more important than the non-use values in this case.

The Valuing Attractive Landscapes in the Urban Economy (VALUE) project − which was implemented in the framework of Interreg − resulted in several case studies. One of the cases was realized in Manchester city. Using the contingent valuation method (CVM) they analysed how various groups of people (local people, commuters and owners of local businesses) would support the planting of trees and improvement of green spaces in Whitworth Street (which is located in the crowded city centre). The questionnaire survey concerned four topics: attitudes regarding green spaces, green infrastructure development (planting small or big trees), willingness to pay and the opinion about current GI services provided by the local municipality. 512 questionnaires were completed in the framework of personnel interviews. It was found that 75% percent of respondents would pay for the development, accepting a new local tax to finance the development. The larger project alternative was typically supported, the WTP was 1.46 to 2.33 pounds. Analysing stakeholder groups, it was concluded that the highest WTP belongs to local inhabitants, and commuters or those who work here have a 12-15% lower WTP.

A newly developed large city park was valuated in Thessaloniki, Greece. The project was demonstrated using maps and visual design and the benefits of the park were described. According to the plans, local citizens would have to pay a local tax, every second month. Using double-round dichotomous choice questions WTP was measured. The questionnaire contained some additional, related issues. It was found that citizens are not satisfied with existing green areas. The most important benefit they expect is "in situ" use value, that is recreational services (walking, outdoor sports), and the aesthetic value and positive impact on air quality are also significant. Negative impacts were not high, one potential negative consequence of the establishment of the park is higher crime rates. WTPs of respondents with higher income and educational level proved to be higher, as expected. Those who expected more benefits had relatively higher WTPs, too, and also those who lived closer to the park.

It was an important result of the questionnaire survey that as it was prepared twice, so it was possible to analyse the changes. WTP in 2013 was cc. 20% lower than in 2010. This is in harmony with the change of the GDP. On the other hand, the number of those, whose WTP was positive increased from 48,8% to 56,5%. It is very likely, that it was the result of the media coverage of the proposed development. This phenomenon can be considered as a form of informational bias, that is the more the respondents know about the projects, the more likely they will support it. Despite of the crisis, the WTP did not change significantly, and most people would support the establishment of the city park.

Choice experiment was applied in Dublin (Bullock, 2008) in order to learn, which characteristics of green spaces are important for local citizens, and how the development and maintenance can be cost-effective, taking into consideration the expectations of local people.

The survey intends to reveal how satisfied are local people with the existing green infrastructure and what kind of development projects would be desirable. The survey was focusing on the direct use values. Four focus groups were completed and a pilot survey among 100 citizens was completed to learn which are the characteristics that influence the value of city parks. In the next phase, personnel interviews were prepared with a sample of 500. Respondents had to choose between two scenarios in eight hypothetical situations. The characteristics were as follows: size (small local parks, large park), maintenance (moderate maintenance, high maintenance), trees (few trees, mixture of open areas and trees, more wooded areas), water (shallow pond with paved banks, natural-looking ponds/lakes, riverside), Play Facilities (no playground, small modern playground, adventure play park and Paths/Seating (few benches, paths and seating, ample seating and paths, plenty of seating, paths, trails and cycle paths).

Regarding the payment vehicle, the entrance fee was considered but refused as citizens are used to freely available city parks and too many would have refused to pay an entrance fee. The cost of using the park was measured as the travel cost needed to visit it. It was discovered that different characteristics are important in the case of big and small city parks. In the case of small parks, playgrounds are important and the availability of quiet and more busy areas. In the cases of large parks, adventure play park, paths and seating and natural-looking ponds are important. It was also discovered that people are willing to travel a lot to reach big parks (presumably because they don't visit those frequently). The estimated total, aggregated value of city parks is 20 million Euro/year which exceeds the amount of money spent on the maintenance of city parks.

CONCLUSIONS

The services provided by urban green infrastructure are significant and forecast to be increased shortly on the global level. Both the size and the population of cities are growing and, with the consequences of climate change, urban resilience is more and more expected. Green infrastructure has the potential to contribute to both adaptation and mitigation.

Overviewing the total economic value of urban GI it was found that indirect and direct in situ use value as well as option value are relatively high. Consequently, methods that measure use values: cost-based methods or hedonic pricing can be applied successfully to estimate a significant portion of TEV.

Although several case studies are available, more primary research is also needed. It is a serious barrier of transferring values that the benefits provided by GI are measured in several ways, following various approaches.

Most of the case studies focus on city parks, therefore more research is needed on the value of other GI elements or the

values of green infrastructure as a whole. As it was seen in the cases presented, all the potential methods have their advantages and limitations, therefore the application of several methods is desirable.

Besides determining the value, the application of environmental valuation methods helps more conscious development and management of GI in cities. For example, stated preference methods can be used to gain information about the preferred development options.

In the case of international studies, researchers formulated some recommendations. In the case of the Spanish City, Castillon, as it was found that the size of the park is not important, only the distance from the closest one. Therefore, it was suggested that the establishment of several small parks would be desirable instead of a few big ones. (Morancho, 2002). In the case of forestation around Venice, the preferences of local people were considered, and they decided the development of mixed areas of grassland and forest.

We can conclude that there are several methods to valuate urban green infrastructure. Measuring benefits will help to offset the undervaluation of green infrastructure compared to traditional grey infrastructure (Mella et al., 2013).

It is a great advantage of stated preference methods that they represent a form of involvement of local people, thereby contributing to the acceptance of development projects (Latinopoulosa et al, 2016). Questionnaire-based methods enable the analysis of the impact of personnel characteristics on the willingness to pay. Such analysis will enable us to forecast how changes − e.g., in size and composition of the population − will influence the expectations, the preferences and the WTP.

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