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Green infrastructure and local implementation: (green) bridging the gap between research and practice

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“An organism that is too greedy and takes too much without giving anything in return destroys what it needs for life.”

Peter Wohlleben

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What a ride.

I vividly remember being encouraged to apply for a predoctoral position in the summer of 2018. A week after having been virtually interviewed by Steven and Jan from a dodgy Ecuadorian hostel room, I received the news that I'd start working on the Nature Smart Cities project from November onwards. When I arrived, I joined a team consisting of 6, maybe 7 doctoral researchers and 2 or 3 postdocs. Suddenly, it is 2023 and that small research group – now called EnvEcon - exponentially grew, counting over 40 members today. This dynamic and multidisciplinary environment made sure that several pseudo-apocalyptic events (e.g., dislocated shoulders, pandemics, buildings on fire) were effortlessly conquered.

Although *effortlessly* might be a slight overstatement. Every PhD student will (or should) acknowledge that it is at times frustrating, tiring, stressful and personally destabilising to commit to your research day in and day out, and that you often question yourself and what you are doing. The latter was a slight overstatement again, merely to please Steven. I know you think I'm a drama queen, Steven. And I have probably been in the past five years. Hence why your sober, pragmatic, and human approach to supervising me was extremely valuable. I want to thank you for your advice and support, your expertise, and for our regular exchange of views on football, cycling, and other sports. Further, I also owe a thank you to my other promotor, Jan. Jan, thank you for all the opportunities I got from working with you (like the Enabel assignments). I much appreciated the level of trust you put in me, especially regarding the Nature Smart Cities project.

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Wito Van Oijstaeijen
Antwerp, October 2023

Summary

Climate change is an ever-increasing threat to our planet, with urbanisation taking previously open spaces exacerbating the issue. The loss of open space leads to a decrease in ecosystem functions, which negatively impacts the liveability in urbanised environments, and beyond. The incorporation of green infrastructure (GI) into the built environment is acknowledged as an effective and multi-functional measure to make our living environment resilient and future-proof.

Green infrastructure conceptually encompasses (semi-)natural elements, often considered in urbanised environments. GI is known to deliver many benefits simultaneously and can therefore serve multi-purposes. Such benefits or services that nature provides, thereby contributing to human wellbeing, are named ecosystem services (ES). Ecosystem services that are typically targeted through urban green infrastructure are alleviating flooding risks, reducing urban heat island effects, or improving local air quality. Since aiming for one of these implies a wide array of co-benefits, GI is increasingly thought of as a cost-effective and systemic solution to increase landscape resilience.

Notwithstanding that the local level is essential for effective GI implementation, research into local decision making is very limited. This thesis therefore aims to address two significant gaps in the implementation of GI. The first objective is to bridge the science-policy gap by integrating scientific knowledge on ES and GI into local decision-making processes. In this context, the policy dimension within this thesis involves the process of translating overarching policy objectives into practical actions within local decision-making practices, abstracting from the intricacies of higher-level policymaking itself. The second objective focuses on the people-policy gap, which involves understanding stakeholders' perspectives and priorities regarding GI and its associated ecosystem services. By gaining insights into the demand, prioritisation, and provision of GI from the two most important stakeholder groups at the local level (residents and local decision-makers), this research aims to foster effective communication and alignment between public preferences and policy implementation. Ultimately, addressing these gaps will contribute to improved planning and decision-making practices related to green infrastructure. The overall goal of this thesis is to enhance the implementation of GI in the local political context, proposing pathways to facilitate and optimise investments in public GI.
Guaranteeing the cross-pollination between research and practice, parts of this work have been conducted in the context of the Interreg 2 seas Nature Smart Cities project (N° 2S05-048). For this research, Wito Van Oijstaeijen obtained an FWO-SB fellowship under contract n° 1S46420N.

To adequately address the multidisciplinary and participative dimensions to contribute to these research objectives, discrete choice experiments (DCE) are a key method in the research chapters of this thesis. A discrete choice experiment allows to model stakeholders' preferences and value attribution for GI characteristics. In this thesis, DCEs further allow to formalise the trade-offs in GI cost and benefit categories. The two stakeholder groups that are subjected to these DCEs are local decision-makers and residents. Apart from DCEs, another stated preference method is used to derive insights in the importance of GI attributes. In these best-worst scaling experiments, respondents indicate the best and the worst object in a limited list of GI attributes.

After the introductory chapter, introducing the reader to the research objectives and methods, the second chapter contains a literature review on toolkits valuing GI or ES. In this literature review we establish how toolkits respond to the specific needs and requirements that local officers in municipalities demand. Further, we also look at the role such valuation toolkits can play in GI planning and design. The results indicate that toolkits should emphasise lifespan assessments, include monetary arguments, and aim to display results in easily interpretable terms. The need for resource (time and expertise) efficient methods, leads to conclude that toolkits should mainly be used in early project stages.

The third component looks at local decision-makers and decision-making practices influencing GI implementation. Through DCEs with these decision-makers, a unique data sample of 568 local decision-makers was gathered. We look at the dimensions of ecosystem services knowledge and ecosystem services utilisation. The attributes in this DCE are highly similar to the arguments that would result from applying valuation toolkits. The analysis shows how local authorities' GI decisions are mainly influenced by short-termism and are highly cost sensitive. In the fourth chapter, a similar hypothetical scenario is used to reveal preferences of residents. By obtaining perceptions and views from a different stakeholder group, this research allows to identify (dis)similarities between both stakeholder groups, which leads to provide avenues to better align these perceptions. In that sense, this alignment can be considered to narrow the gap between people and policy.

In the last chapter, we harmonise the insights acquired in previous chapters. A novel toolkit for GI and ES valuation is proposed. The toolkit stands out from previous toolkits through its specific modules for assessing biodiversity and cultural ecosystem services. Further, the toolkit introduces cost estimations, besides the benefit valuations that toolkits traditionally execute. In the process of developing and validating the toolkit, co-design and collaboration were essential. Through this approach, the toolkit will better respond to what is needed in local practice. Hence, this last chapter narrows the gap between science and policy, while including residents' valuation, therefore bringing the people closer to decision-making (and consequently policy implementation) as well. Thus not only facilitating the integration of scientific knowledge into local decision making, but also providing opportunities for citizens to be more closely involved in making decisions around green infrastructure.

Samenvatting

Klimaatverandering vormt een steeds grotere bedreiging voor onze planeet, waarbij de verstedelijking van voorheen open ruimtes het probleem nog verergert. Het verlies van open ruimte leidt tot een afname van het functioneren van onze ecosystemen, wat een negatieve invloed heeft op de leefbaarheid in verstedelijkte omgevingen en daarbuiten. De integratie van groene infrastructuur (GI) in de bebouwde omgeving wordt gezien als een effectieve en multifunctionele maatregel om onze leefomgeving veerkrachtig en toekomstbestendig te maken.

Het concept van groene infrastructuur omvat (semi-)natuurlijke elementen die vaak betrekking hebben op verstedelijkte omgevingen. Men erkent hierbij dat GI veel voordelen tegelijk kan bieden en daarom multi-inzetbaar is. Dergelijke voordelen of diensten die de natuur levert en die zo bijdragen aan het welzijn van de mens, worden ecosysteemdiensten (ESD) genoemd. Ecosysteemdiensten die doorgaans worden nagestreefd met stedelijke groene infrastructuur zijn het verminderen van overstromingsrisico's, het verminderen van hitte-eilandeffecten of het verbeteren van de lokale luchtkwaliteit. Omdat het nastreven van een van deze diensten een breed scala aan bijkomende voordelen met zich meebrengt, wordt GI steeds meer gezien als een kosteneffectieve en systemische oplossing om de veerkracht van het landschap te vergroten.

Ondanks het feit dat het lokale niveau essentieel is voor een effectieve implementatie van GI, is het onderzoek naar lokale besluitvorming zeer beperkt. Dit proefschrift wil daarom twee belangrijke hiaten in de implementatie van GI opvullen. Het eerste doel is om de kloof tussen wetenschap en beleid te overbruggen door wetenschappelijke kennis over ESD en GI te integreren in lokale besluitsvorming. In deze context omvat de beleidsdimensie binnen dit proefschrift het proces van het vertalen van overkoepelende beleidsdoelstellingen naar praktische acties binnen lokale besluitvormingspraktijken, waarbij wordt geabstraheerd van de specificiteit verbonden aan beleidsvorming op hoger niveau. De tweede doelstelling richt zich op de kloof tussen burgers en beleid, waarbij het gaat om het begrijpen van de perspectieven en prioriteiten van verschillende stakeholders met betrekking tot GI en de bijbehorende ecosysteemdiensten. Door inzicht te verwerven in de vraag naar, prioritering en voorziening van GI van de twee belangrijkste stakeholdergroepen op lokaal niveau (bewoners en lokale besluitvormers), beoogt dit onderzoek effectieve communicatie en afstemming tussen publieke voorkeuren en beleidsuitvoering te bevorderen. Uiteindelijk zal het aanpakken van deze hiaten bijdragen aan verbeterde planning en besluitvorming met betrekking tot groene infrastructuur. Het algemene doel van deze dissertatie is het verbeteren van de implementatie van GI in de lokale politieke context, waarbij wegen worden voorgesteld om investeringen in openbare GI te vergemakkelijken en te optimaliseren. Om de kruisbestuiving tussen onderzoek en praktijk te garanderen, zijn delen van dit werk uitgevoerd in het kader van het Interreg 2 zeeën Nature Smart Cities project (N° 2S05-048). Wito Van Oijstaeijen ontving voor dit onderzoek een FWO-SB beurs onder contract nr. 1S46420N.

Om de multidisciplinaire en participatieve dimensies die bijdragen aan deze onderzoeksdoelstellingen adequaat aan te pakken, zijn discrete keuze-experimenten een belangrijke methode in de empirische hoofdstukken van dit proefschrift. Een discreet keuze-experiment maakt het mogelijk om de voorkeuren en waardering van stakeholders voor GI-kenmerken te modelleren. In dit proefschrift maken discrete keuze-experimenten het verder mogelijk om de afwegingen in GI-kosten- en batencategorieën te formaliseren. De twee groepen stakeholders die aan deze discrete keuze-experimenten worden onderworpen zijn lokale besluitvormers en bewoners. Naast discrete keuze-experimenten wordt ook een andere stated preference waarderingsmethode gebruikt om inzicht te krijgen in het belang van GI-attributen. In deze best-worst scaling experimenten geven respondenten het beste en het slechtste object aan in een beperkte lijst van GI-attributen.

Na het inleidende hoofdstuk, waarin de lezer kennis maakt met de onderzoeksdoelstellingen en methoden, bevat het tweede hoofdstuk een literatuuronderzoek naar wetenschappelijke waarderingstoolkits die GI of ESD waarderen. In dit literatuuroverzicht stellen we vast of en hoe deze toolkits inspelen op de specifieke behoeften en eisen die lokale ambtenaren in gemeenten stellen. Verder kijken we ook naar de rol die dergelijke waarderingstoolkits kunnen spelen in GI-ruimtelijke planning en ontwerp. De resultaten geven aan dat toolkits de nadruk moeten leggen op de impact op langere termijn, monetaire argumenten moeten bevatten en ervoor moeten zorgen dat de resultaten in eenvoudig interpreteerbare termen uitgedrukt zijn. De behoefte aan methoden die efficiënt zijn in de middelen die gebruik vereist (tijd en expertise), leidt tot de conclusie dat dit soort toolkits vooral in vroege projectfasen moeten worden gebruikt.

De derde component kijkt naar lokale besluitvormers en besluitvormingspraktijken die van invloed zijn op de implementatie van GI. Door middel van discrete keuze-experimenten met deze besluitvormers werd een unieke steekproef van 568 lokale besluitvormers verzameld. We bevraagden deze lokale besluitvormers naar hun kennis van ecosysteemdiensten en de rol van groene infrastructuur in klimaatadaptatie. De attributen in dit keuze-experiment komen sterk overeen met de argumenten die zouden resulteren uit het toepassen van waarderingstoolkits. De analyse laat zien hoe GI-beslissingen van onze gemeenten vooral worden beïnvloed door kortetermijndenken en bovendien zeer kostengevoelig zijn. In het vierde hoofdstuk wordt een vergelijkbaar hypothetisch scenario gebruikt om voorkeuren van bewoners te onthullen. Door percepties en standpunten van een andere stakeholdergroep te verzamelen, maakt dit onderzoek het mogelijk om overeenkomsten en breekpunten tussen beide stakeholdergroepen te identificeren, wat leidt tot mogelijkheden om deze percepties beter op elkaar af te stemmen. Deze benadering draagt daarom bij aan het overbruggen van de afstand die heerst tussen de benadering van het beleid en de percepties van de burgers.

In het laatste hoofdstuk harmoniseren we de inzichten uit de voorgaande hoofdstukken. Er wordt een nieuwe toolkit voor de waardering van GI en ES voorgesteld. De toolkit onderscheidt zich van eerdere toolkits door zijn specifieke modules voor het waarderen van biodiversiteit en culturele ecosysteemdiensten. Verder introduceert de toolkit kostenramingen, naast de batenwaarderingen die toolkits traditioneel uitvoeren. Bij het ontwikkelen en valideren van de toolkit, alsook doorheen dit hele onderzoek waren co-design en samenwerking essentieel. Door deze aanpak zal de toolkit beter tegemoetkomen aan de wensen van de gebruikers en zo niet alleen de integratie van wetenschappelijke kennis in lokale besluitvoering faciliteren, maar ook mogelijkheden bieden om burgers nauwer te betrekken bij het maken van die beslissingen rond groene infrastructuur.

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BGI	Blue-green infrastructure
BIBD	Balanced incomplete block design
BM	Business model
BWS	Best-worst scaling
CES	Cultural ecosystem services
CL	Conditional logit
CM	Choice modelling
DCE	Discrete choice experiment
ENS	Effective number of species
EDS	Ecosystem disservices
ES	Ecosystem services
ESK	Ecosystem services knowledge
GI	Green infrastructure
GIS	Geographical information system
HB	Hierarchical bayes
IIA	Independence of irrelevant alternatives
LA	Local authority
MCDA	Multi-criteria decision analysis
MEA	Millennium ecosystem assessment
MNL	Multinomial logit
NbS	Nature based solutions
NPV	Net present value
NSC	Nature Smart Cities
NSC-BM	Nature Smart Cities Business Model
RC	Retention coefficient
RUP	Ruimtelijk Uitvoeringsplan
RUT	Random utility theory
SoP	Share of preferences
SP	Stated preference
SuDS	Sustainable drainage systems
UGI	Urban green infrastructure
WTP	Willingness-to-pay

Contents

Chapter 1
Introduction

1.1 Setting the scene

Humans have always had a deep-rooted appreciation for nature. Where this appreciation is often latent, it resurfaced to become highly visible during the COVID-19 pandemic. In the light of a myriad of restrictions, people rediscovered nature by resorting to parks and natural areas, and by starting to vegetable garden. Researchers in the US, Germany, Australia and Norway all came to identical conclusions: urban parks were much more frequently visited during the period of COVID-19 lockdowns (Berdejo-Espinola et al., 2021; Derks et al., 2020; Rice & Pan, 2021; Venter et al., 2020). Moreover, research conducted globally found how governments responses (movement restrictions, workplace closures, *etc.*) were correlated with increasing park visitor number (Geng et al., 2021). Repeatedly, associations between green space availability, quality, abundance, or proximity and lower depression scores (Reid et al., 2022), lower anxiety scores, and better psychological wellbeing (Pouso et al., 2021) during the pandemic were found. This renewed human appreciation of nature's resources stipulates the current momentum for green space. Renewed, because the link between mental health and accessible green space extends far beyond the pandemic. Pre-pandemic research also showed how nature boosts creativity, sparks our imagination, brings a sense of peace to our minds, and generally positively influences our well-being (Nutsford et al., 2013; Plambech & Van Den Bosch, 2015; Taylor et al., 1998). Moreover, nature has been proven to enhance physical health (Pretty, 2004), as people turn to outdoor activities such as walking, running, and exercising in green environments (Mitchell, 2013).

Green infrastructure (GI) can be broadly interpreted as any (semi-)natural landscape element, collectively forming an interconnected *green* network. In that sense, green infrastructure is omnipresent, and examples of GI in practice are manifold: from forests and parks over green walls and roofs to permeable paving and individual trees (visualised in Figure 1)

Figure 1 Examples of green infrastructure types

GI is further understood to deliver a wide range of benefits simultaneously (Elmqvist et al., 2015). These benefits that green infrastructure, or nature in general generates to support life on earth are called ecosystem services (ES). Ecosystem services are organised into four categories by the Millennium Ecosystem Assessment (MEA), as depicted in Figure 2. Clearly, the significance of green infrastructure goes well beyond individual well-being. Pressing global issues are unequivocally linked to GI or ES. This thesis therefore cannot be separated from wider global trends such as the unprecedented rates and magnitudes of global climate change and biodiversity loss.

Figure 2 An oversight of the benefits from nature or ecosystem services organised into four categories: supporting, provisioning, regulating, and cultural.

From: Mavsar et al. (2014)

The Intergovernmental Panel on Climate Change (IPCC) (2023) stressed that "(…) associated risks depend strongly on near-term mitigation and adaptation actions, and projected adverse impacts and related losses and damages escalate with every increment of global warming." The potential of green infrastructure to intervene on the risks associated with global warming is, therefore, twofold. Firstly, green infrastructure contributes to climate mitigation through capturing and storing CO_2. It further impacts GHG emissions through indirect effects: e.g., by reducing energy use resulting from local temperature mediation on hot summer days. Further, through the conservation and (re-)integration of nature or green infrastructure into the (urban) landscape, our living environment is better equipped to cope with the consequences of global warming (e.g., less vulnerable to floodings through better water infiltration). Thus, GI is an important tool for planned adaptation, and is often seen as a No Regrets strategy[1] towards climate resilience and climate adaptation (Depietri & McPhearson, 2017).

In 2022, at the COP15 UN Biodiversity Conference, the Convention on Biological Diversity exclaimed that biodiversity is still decreasing, rapidly approaching a point of no return (Maruma Mrema, 2022). As is seen in Figure 2, biodiversity is categorised as a supporting ecosystem service. A supporting ecosystem service is indispensable and essential for the generation of all other ecosystem services. Costanza et al. (2007) found that a 1% decline in biodiversity corresponds to a 0.5% change in ecosystem service values. It can thus unambiguously be said that sustaining any life on earth, requires the preservation and conservation of nature to safeguard biodiversity. GI – through its natural elements and connectivity aspect – provides opportunities for plant and animal habitat and species migration, also in traditionally *biodiversity-hostile* environments dominated by grey and built structures (Hostetler et al., 2011). Hence, GI as a concept is critical in addressing biodiversity preservation efforts and biodiversity should be an intrinsic consideration in GI implementation (Connop et al., 2016). Furthermore, both global pressures are highly interlinked and mutually reinforcing. Global warming negatively affects biodiversity, and biodiversity decline further aggravates global warming. At the intersection of both, GI plays a pivotal role.

All the previous highlights the significance of GI as an indispensable cross-disciplinary concept covering various disciplines, including public health, spatial planning, landscape resilience, biodiversity conservation, and climate adaptation. Therefore, also requiring systems thinking, embedding environmental, economic, and social perspectives.

Notwithstanding the capacity of green infrastructure to generate ecosystem services and combat beforementioned global pressures, urbanisation – among other threats such as resource exploitation - has threatened and continues to threaten the availability of greenery in our living environment. In economic language we could say that the demand for GI/ES (for various purposes) is extensive and increasing, yet the supply of these precious services is decreasing. While urbanisation is expected to continue rising globally, Europe's urbanisation trends differ from those in other regions due to historical factors and distinct patterns. European cities exhibit higher density compared to other parts of the world, with a prevalence of mid-sized cities rather than large metropolitan areas (European Commission, n.d.-c). Further, there is a European trend towards densification and compression of city cores (European Commission, 2022), which is also formulated as a strategy to slow down land take in the Flemish region (Vlaamse Overheid, 2022). Flanders, the northernmost region of Belgium stands out as one of the most densely built-up areas in Europe with a dense network of towns and cities. Because Flanders grapples with a range of spatial planning challenges, including

[1] A strategy that generates benefits or is worth implementing, regardless of future trends and climate scenarios (Heltberg et al., 2009).

ribbon development and urban sprawl (Vermeiren et al., 2018), which pressurises existing open space and natural resources even further. Given beforementioned spatial characteristics of the – already highly dense - Flemish landscape, against the backdrop of increasing urbanisation elsewhere in the world, Flanders provides a compelling case for examination. Therefore, in this dissertation, our focus will be on the region of Flanders. We aim to delve deeper into comprehending the means to safeguard and (re-) implement GI, addressing this is imperative for climate-resilient, biodiverse, and enjoyable living spaces. Because, while many policies and high-level ambitions to enhance the delivery of green space are formulated and discussed (see further in Section 1.2.2), the European Commission in 2019 concluded that the implementation of GI, and the prioritisation of green over grey remain issues (European Commission, 2019c).

By examining the case of Flanders and its ongoing efforts to address urbanisation challenges and promote GI, this research highlights the urgent need to implement sustainable development practices. Amidst these challenges, spatial planners and local decision-makers emerge as pivotal actors in shaping a sustainable future for Flanders. Moreover, the high share of land take requires active involvement and participation of citizens a well. It becomes evident that driving effective GI changes, requires engaging and involving different actors. This makes collaboration, co-creation, and public involvement integral parts of this thesis. Through exploring different stakeholder's perceptions and needs regarding green infrastructure, we aim to contribute to the discourse on shaping liveable and resilient cities for future generations. The subsequent sections of this introduction will delve into the incorporation of GI into (local) policy, provide a comprehensive overview of the research objectives and methods pursued in this thesis, and reflect on the research methods and their strengths and limitations.

1.2 The green infrastructure discourse

1.2.1 The foundations of green infrastructure

The term "green infrastructure" was supposedly first mentioned in scientific literature in 1995, with the early references likely relating to the Greenway movement in the US (Seiwert & Rößler, 2020). This movement started in 1987 in US landscape planning and architecture spheres (Fabos, 1995). **Greenways** are proposed as networks of green, explicitly competing with traditional network structures, such as railways and highway systems. In his introduction of a greenways issue in the Landscape and Urban Planning journal, Fabos (1995) already mentions how the term *greenways* was primarily used in North America. At that time, spatial planners in Europe appeared to be using ***green corridors***. From the start, the greenways concept led to publications on a variety of themes including open space planning, visual assessment, perceptions on environmental issues, sustainable development, growth management, and implementation issues (Fabos, 1995). In his "Greenways and the making of urban form", Walmsley (1995) concludes that: *"For an all-inclusive system serving the entire populace and joining downtowns and inner-city neighborhoods, through the suburbs to the countryside, the concept of a* ***green infrastructure*** *must be applied at all scales."*

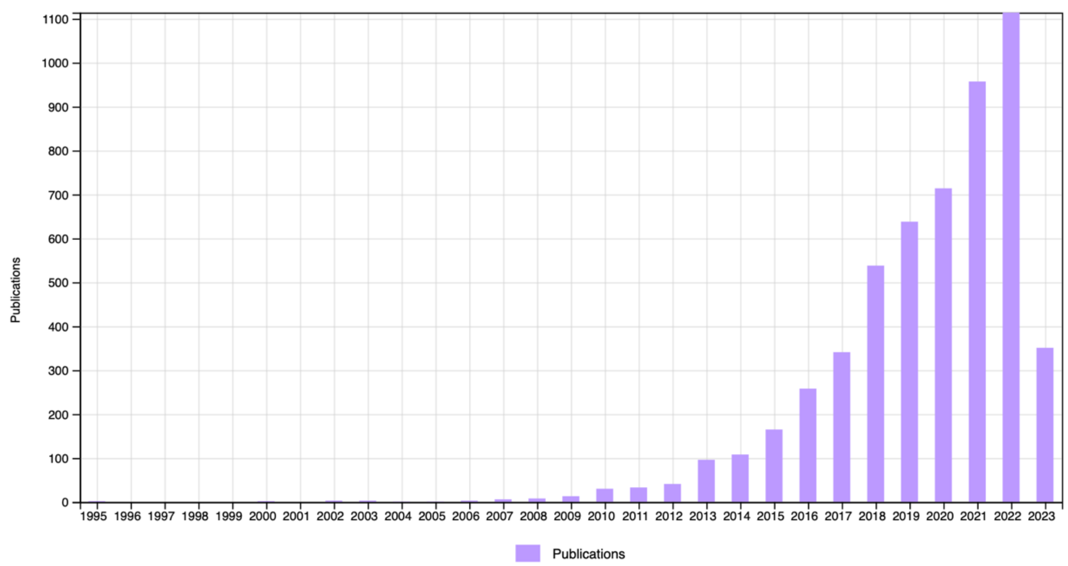
GI consequently evolved to become a *separate* research topic. Semantically, it benefits from the connotation of infrastructure, implying something "you need to have". This contrasts with **green space** for example, inherently implying something "nice to have" (Walmsley, 2006). This distinction between "nice" and "required" underscores the strategic component inherent to GI. Sandström (2002) introduces GI to emphasise the multi-benefits offered by green space, stating that the concept "has the same dignity as 'technological infrastructure' has had in traditional urban planning". In 2002, Benedict and McMahon (2002) compare greenways and GI to expose three fundamental differences between both:
"<u>Ecology vs. Recreation</u> - Green infrastructure emphasises ecology, not recreation.
<u>Bigger vs. Smaller</u> - Green infrastructure includes large, ecologically important hubs, as well as key landscape linkages.
<u>Framework for Growth</u> - Green infrastructure can shape urban form and provide a framework for growth. It works best when the framework pre-identifies both ecologically significant lands and suitable development areas."

Table 1 Green infrastructure and their proposed definitions

Source	Definition	Field
Benedict and McMahon (2002)	an interconnected network of green space that conserves natural ecosystem values and functions and provides associated benefits to human populations.	Ecological conservation
Davies et al. (2006)	Green infrastructure is the physical environment within and between our cities, towns and villages. It is a network of multi-functional open spaces, including formal parks, gardens, woodlands, green corridors, waterways, street trees and open countryside. It comprises all environmental resources, and thus a green infrastructure approach also contributes towards sustainable resource management.	Landscape planning
From Kambites and Owen (2006)	Green infrastructure is a network of multifunctional greenspace provided across the defined area. It is set within, and contributes to, a high quality natural and built environment and is required to deliver liveability for existing and new communities.	National environmental agencies
Mell (2010)	Green infrastructure are the resilient landscapes that support ecological, economic, and human interests by maintaining the integrity of, and promoting landscape connectivity, whilst enhancing the quality of life, place, and the environment across different landscape boundaries.	Spatial planning
Hostetler et al. (2011)	(…) protected natural open space and corridors (adjoining residential yards or sections)	Biodiversity conservation

Noticeably three main characteristics of GI reappear in the gradual shift from greenways to GI: natural elements, connectivity, and multifunctionality. Importantly, GI is said to include large elements, this does not exclude small interventions, however. In the early 2000s, several authors proposed definitions for GI, with nuances often relating to their respective fields (see Table 1). Consequently, the concept's definition(s) appear to be contested by scholars, and is in constant evolvement (Wright, 2011). One of the dynamics of this conceptual evolvement includes the gravitation towards including socio-economic issues to the originally predominantly environmental perspective of GI (Seiwert & Rößler, 2020). This evolution or gravitation contributes to GI increasingly being approached holistically, where the impact of greening is addressed in multi-disciplinary ways, delivering a wide array of **ecosystem services**. As can be seen in Figure 3 this has led to the exponential growth in studies on the topic of green infrastructure. The decrease in 2023 numbers is due to the data representing only part of the year.

Figure 3 Evolution in the number of "green infrastructure" publications (retrieved from Web of Science)



1.2.2 Green infrastructure in policy

Policymaking on GI and/or NbS is currently happening on different levels of decision-making. To highlight the present emphasis on GI and its associated ES within policy circles, a non-exhaustive overview of strategies and policy initiatives is presented. Particular attention is given to policies connected to the integration of GI in urbanised living spaces. This brief oversight starts from the overarching European level, from which we cascade down to the regional policy level.

The European Commission promotes GI in all EU policies and defines it as (European Commission, n.d.-a):

"*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, while also enhancing biodiversity."*

The three core ideas that were introduced in the previous section clearly recur in this definition. The Commission adopted GI in policy through the *EU Green Infrastructure Strategy* in 2013, to enhance Europe's **natural capital** (European Commission, 2013). In this EU GI Strategy, the Commission envisioned "(…) *that GI becomes a standard part of spatial planning and territorial development and that it is fully integrated into the implementation of the policies whose objectives can be achieved as a whole or in part through* ***nature-based solutions***". The EC reviewed the Strategy's progress in 2019 and concluded that challenges remain in the strategic deployment of GI at the EU-level. Also on the member state level, issues with implementation and prioritisation of green over grey infrastructure[2] remain (European Commission, 2019c). Further, green infrastructure - coupled to blue infrastructure[3] - is explicitly embedded into the *EU Biodiversity Strategy for 2030*, with specific reference to the Natura 2000 network[4]. In the Biodiversity Strategy, the Commission emphasises the role of systematically integrating GI and nature-based solutions into urban planning and design of buildings and their surroundings (European Commission, 2020). This focus on greening in urbanised areas was materialised in the EU call for European cities with at least 20,000 inhabitants to formulate ***Urban Greening*** *Plans* by the end of 2021, setting up an *EU Urban Greening Platform* in close cooperation with the *European Covenant of Mayors*. Over this course of action, it becomes clear that the EC shifts the focus of GI implementation more and more towards urbanities, and people's direct living environments. This aligns with Wright (2011) observation of a constantly evolving concept, introduced in the previous section.

On the Belgian national level, GI is incorporated in the *National Strategy for Pollinators 2021-2030* (Departement leefmilieu, 2021), mainly utilising GI quality to enhance biodiversity. This strategy is in line with the wider and overarching ambitions related to the European Green Deal (European Commission, 2019b). In Belgium, most authorities of the environment are assigned to the regional level. The Flemish institute for Nature and Forests (INBO) has issued its definition of GI (Van Reeth et al., 2018):

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[2] Grey infrastructure can be defined as engineered assets (often in concrete, steel, or other human-made materials) serving a specific function for society (e.g, a sewage system, a road, a pipe, *etc.*)

[3] Blue infrastructure is that (urban) infrastructure that relates to (flowing) water and water regulation. It can be both man-made, natural, or hybrid and encompasses blue elements such as ponds, rivers, wetlands, lakes, harbours, quays, *etc*.

[4] The Natura 2000 network stands as the largest integrated network of protected areas globally. This expansive network provides a refuge for Europe's most valuable and endangered species and habitats. Natura 2000 extends across all 27 EU countries, on land and at sea. (European Commission, n.d.-b)

"Green infrastructure is a network of quality natural and semi-natural areas and landscape elements that host natural processes. Its management and use aim to protect biodiversity and achieve other societal goals in both rural and more urbanised settings."

With regard to implementing policies, GI – broadly interpreted – is considered in three key strategies imposed by the Flemish government. The Flemish government reached an agreement on the concept note of the *building shift* in 2022 (Departement Omgeving, 2022). The concept note strives to safeguard open space in Flanders, therefore interpretable as a means to GI conservation. Targeted on GI implementation, two pillars for regional policy exist: the Climate Adaptation Plan 2030, and the Blue Deal. Both aim for further inclusion of climate mitigation and adaptation measures in spatial planning, the Blue Deal does this with the specific ambition of combatting water scarcity and droughts (Departement Omgeving, 2020; Vlaamse Overheid, 2022).

1.2.3 Green infrastructure in this doctoral thesis

In the previous two sections, the context of GI as a concept and as a policy instrument was drawn. We will refrain from proposing another definition to green infrastructure, since the ambiguity in the concept's meaning and its implementation in practice is already undeniable. The attentive reader will have noticed, the words in bold are names to what is intrinsically a quasi-synonym for GI, those concepts are all founded on similar grounds. This multitude of denominations is, however, often experienced as confusing. Notwithstanding subtle differences between them, the baseline of enhancing nature's values through conserving and implementing natural elements in our living environment is shared by all denominations (Escobedo et al., 2019; Pauleit et al., 2017). In that regard, "green infrastructure" in this dissertation can probably be used exchangeably with denominations such as *nature-based solutions*. Agreeing with Seiwert and Rößler (2020), this ambiguity of "green infrastructure" can be considered as a strength, offering i.a. flexibility. Through its wide applicability and scalability GI manages to reach policymakers and practitioners more than other concepts do, while simultaneously boosting multidisciplinary scientific research. However, I do believe that it is meaningful to define core principles of GI. In this thesis, we adopt core GI principles that have been proposed by Wang and Banzhaf (2018): sustainability, multifunctionality, connectivity, biodiversity targets, urban focus, and collaboration. Additionally, the strategic component described earlier is fundamental to understanding GI and might be its most distinctive feature.

1.3 Problem identification and research objective

In “the green infrastructure discourse” I deliberately introduced the reader to an extensive, but non-exhaustive array of strategies, plans and objectives that all aim at facilitating the uptake or adoption of GI. Those strategies, plans, and objectives have all emerged in a relatively condensed timeframe. Translating such policies to real-world applications evidently requires implementation of GI in practice. This implementation – be it part of a larger GI connected network – is most often the responsibility of local administrations (Slätmo et al., 2019). A first step for those local institutions towards physical implementation is the translation of these high-level plans into local practices. This often appears to be a hard-to-overcome hurdle. Research has revealed a substantial gap within (local) authorities, characterised by a disconnect between the strategic vision and the operational implementation dimension through local decision making. This gap indicates a lack of complete commitment to the high-level goals, objectives, and ambitions outlined in policies (Back & Collins, 2021; Bush, 2020; Raynor et al., 2017). Owing to the intricate nature of green infrastructure, the responses, and actions available at the local level are currently inadequate in addressing its complexities. Paradoxically, these complexities associated with green infrastructure arise from some of its inherent strengths:

- Multifunctionality: (urban) GI is a concept that encompasses various disciplines, as evident from the diversity of scientific fields involved. However, at the local decision-making level, the multidisciplinary nature of green infrastructure may not be adequately addressed. Resource constraints, (local) institutional siloes, and commitment to the *status-quo* contribute to this inability (Matthews et al., 2015; O’Donnell et al., 2017; Thorne et al., 2018). The lack of multidisciplinary responses limits the holistic integration of environmental, economic, and social perspectives in spatial decision-making, specifically with regard to urban greenery (Brink et al., 2016). These shortcomings result in incomprehensive value assessments, impeding on the competitiveness of GI with traditional, and commonly perceived as “safe”, grey infrastructure. Davies and Lafortezza (2019) state that this traditional and grey infrastructure remains deeply entrenched within institutional cultures (i.e., path dependence). In response to this, Bayulken et al. (2021) proposes the documenting of comparative costs and benefits to create support by engaging residents.

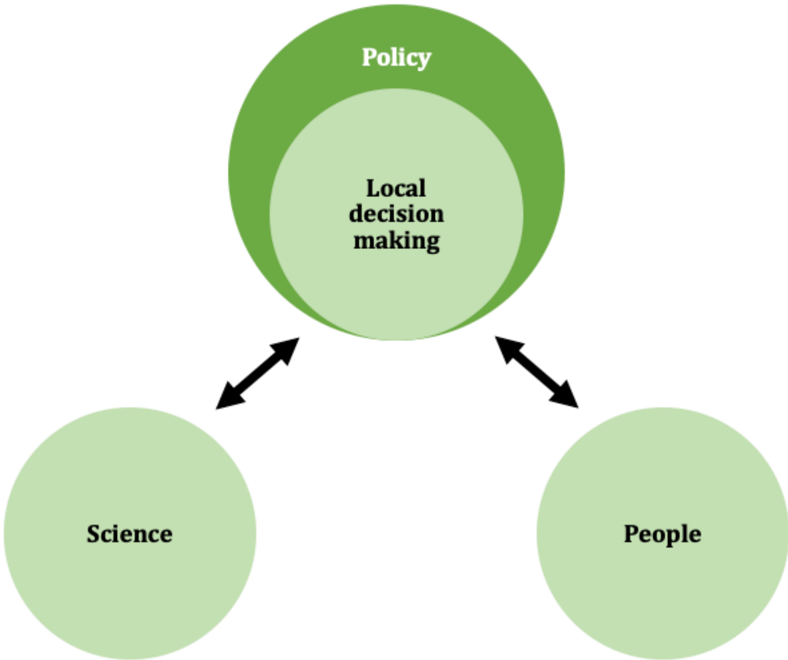
- Interconnectivity: partly by physically being a transboundary concept, partly by being at the intersection of global, continental, national, regional, and local issues, GI often faces challenges stemming from institutional inertia. Climate adaptation and GI requires connected responses, including many different actors (Juhola, 2019), which raises questions regarding the allocation of responsibilities and timelines for action (Hartzell-Nichols, 2011). This interconnectivity further emphasises the need for inter-actor collaboration. Collaboration takes on multifaceted dimensions, and within this dissertation, we situate these dimensions at the intersection of three key stakeholder groups: the scientific community, policy implementation (including local decision-making), and the residents.

While the focus of this thesis centres on the implementation of green infrastructure within the public domain, addressing the existing green GI implementation gap also involves residents, as the above two paragraphs indicate. The engagement and perspectives of local residents are pivotal in shaping the success and sustainability of GI projects. Their buy-in, active participation, and understanding of the benefits are crucial for the long-term viability of GI or NbS initiatives (Anderson & Renaud, 2021; Phillips et al., 2023). Therefore, addressing this implementation gap must encompass strategies that effectively communicate the value of GI to residents, involve them in decision-making processes, and consider their needs and preferences to create more inclusive and resilient urban environments.

Municipalities (i.e., the local decision-making level) have an acknowledged and important role in climate change responses (Giest & Howlett, 2013). Despite that, the current state of research regarding local governance of GI, along with the dynamics and processes of decision-making at the local scale, remains notably limited (Juhola, 2019). Notwithstanding the extensive accumulation of information on GI and its ecosystem services over the years (illustrated by Figure 3), Adem Esmail et al. (2022) revealed that scientific literature has had minimal influence on the adoption of greening practices in spatial planning. While significant attention has been devoted to studying the biophysical properties of green infrastructure, the socio-economic and political-institutional dimensions have been subject to comparatively less analysis (Matthews et al., 2015). Wickenberg et al. (2021) continue the discussion by stipulating this one-sided focus on experimentation in research at the local or urban scale, which fails to recognise formal planning. This also supports the conclusion drawn by Bayulken et al. (2021) that knowledge gaps between science and policy play a pivotal role in hindering the adoption of nature-based solutions or green infrastructure. de Groot et al. (2010) emphasise the significance of understanding stakeholders' perspectives on ecosystem services as crucial for implementing appropriate management practices, highlighting that these perspectives are frequently comprehended insufficiently.

In tackling challenges related to the multifunctionality and connectivity of GI, utilisation of tools has been suggested as a method to incorporate ecosystem service knowledge into decision-making processes (Juhola, 2019). While ecosystem services are conceptually designed to facilitate the dissemination of knowledge on complex natural processes to different actors, its potential to function as a boundary object relies on its adoption by societal actors and its integration into local environmental governance processes (Schröter et al., 2014). Nevertheless, there exists a noticeable gap in the actual application of the ES concept in local decision-making, despite the availability of such tools and methods (Cortinovis & Geneletti, 2018).

Figure 4 Schematic representation of the three main stakeholder groups involved in the dimensions of the green infrastructure implementation gap studied in this work



The aforementioned observations contribute to the formulation of the research objectives of this thesis. Schematically, the research in this dissertation on the GI implementation gap is approached as presented in Figure 4. In this section, the relevance of every one of these stakeholders was established. The main actor under investigation is the local decision-making level and we established how this is subject to operate within a certain space that is defined by the higher-level policies that are imposed. We break down the existing implementation gap (i.e., translation from strategic visions to GI realisation) in two distinct gaps:

- Science-policy gap: this thesis aims to enhance the comprehension of the current science-policy gap. With science-policy gap, we imply the gap between science on the one hand and the translation of strategies and ambitions (see 1.2.2) from the policymaking level to the decision-making level. This thesis aims to improve the comprehension of the prevalent science-policy gap and eventually enhance informed decision-making practices. We aim to do this by revealing potential heuristics or political behaviour in local GI decision making. We further objectify the integration of qualitative and quantitative evidencing of GI in spatial planning processes, researching this in a highly participative way and tailoring solutions to local authorities' needs. Particularly, the focus is directed towards local decision-making.
- People-policy gap: One of the fundamental prerequisites is the capacity and willingness of society or *the people* to put into effect policies, plans, and implementation strategies aimed at enhancing the uptake of GI. Bayulken et al. (2021) propose that democratising access to the economic, social, and environmental benefits is essential to convince and

engage people, implying a knowledge gap that relates to the multi-functionality of GI. On the other hand, the connectivity aspect of GI requires collaborative responses, as mentioned before. Authors have stressed how the GI implementation gap can only be resolved through inclusive, multi-actor, and public engagement. The lack of alignment between people and policy in spatial planning (and in this dissertation specifically on green infrastructure implementation) is characterised by a disconnect between the priorities and expectations of local communities and the decision-making processes at the municipal level. Often, spatial planning decisions related to green infrastructure may not adequately reflect the specific needs and preferences of residents (i.e., the demand for GI), leading to mismatches in resource allocation and project implementation (i.e., the supply of GI).

In this dissertation, we aim to contribute to bridging (elements of) these science-policy and people-policy gaps that shape the GI implementation gap through facilitating and tailoring access to GI/ES knowledge. In Chapter 2, we explore the role of valuation tools and how the interplay between science and policy can be improved through tools. In Chapters 3 and 4, GI perceptions and valuation of two different stakeholders are revealed and compared: local decision-makers and residents. This alignment of knowledge, and creating a mutual understanding is essential and van Delden et al. (2011) names it a pivotal step in the development of a decision support tool. In Chapter 5, many elements of the stakeholders' perspectives are harmonised, and a novel decision-support tool is introduced. The tool can both serve as a planning and design supporting tool, and a communication vehicle. With this research approach, we foster a comprehensive and unique understanding of the intricate interplay between the demand, prioritisation, and provision or supply of GI, as emphasised by Mosleh et al. (2023).

1.4 Research outline

1.4.1 Chapter 2: Reviewing existing green infrastructure valuation tools

Research question 1: What are the challenges and opportunities associated with existing valuation tools for urban green infrastructure in the context of urban planning and decision-making, and how can straightforward valuation tools be designed to better support the development of green infrastructure in urban areas?

In the second chapter, we start from the observation in GI literature that its implementation is hampering. While several variables contribute to this delayed uptake, many of those variables appear to stem from a fundamental issue, i.e., it is not trivial to demonstrate the added value of adopting GI. In response, authors have proposed the use of tools, toolkits, or methods for local authorities to (more explicitly) unveil the benefits of GI (Haase et al., 2014; Pauleit et al., 2019). These tools are meant to facilitate comprehensive valuation practices at the local level, enabling the demonstration of socio-economic and biophysical impacts of GI. Several of such tools have been developed over the course of the past decade, with the ambition to narrow the gap between scientific insights and ES knowledge utilisation in policy- and decision-making. However, it so appears that those tools are rarely used by local authorities. To understand why, this chapter conducts a literature review examining a selection of these GI or ES valuation tools. This examination is carried out from two perspectives. Firstly, we scrutinise the tools by analysing functionalities, underlying assumptions, and scientific validity. Secondly, we explore the needs and expectations of local authorities regarding those tools, along with the potential roles of those tools in spatial planning and local decision-making processes. The latter is not solely reliant on a literature review but is complemented by the perceptions of local practitioners through guided focus groups. In this chapter we aim to address the limitations of current (scientific) tools and explore the potential for improving decision-making in UGI implementation using appropriate valuation tools. This approach allows to identify the (mis)matches between the scientific toolkits and practice.

1.4.2 Chapter 3: A discrete choice experiment to analyse the science-policy gap in green infrastructure

Research question 2: What are key factors in local decision-making processes that influence the implementation of green infrastructure in Flemish municipalities? How is ecosystem services or green infrastructure knowledge used in practice in local decision-making?

Chapter 3 draws upon the findings presented in chapter 2. The application of toolkits generates knowledge on ES and GI in general. However, the practical application of this information within the political and economic context of local authorities remains unclear. Valuation studies often assume that the generated information will seamlessly inform decision-making processes (Primmer et al., 2018). Nevertheless, scholars have highlighted the pervasive inaccuracy of this premise, emphasising the presence of irrational and non-systematic decision-making practices despite the availability of comprehensive information (Kieslich & Salles, 2021; van Stigt et al., 2015). Local planning decisions are characterised by trade-offs, strategic knowledge utilisation, and compromises (Haines-Young & Potschin, 2014; McKenzie et al., 2014). Turkelboom et al. (2018) have argued for the lack of insight into these trade-offs and the potential benefits of understanding them for effective management decisions. While qualitative research with practitioners into ES has been conducted (Mekala & Hatton MacDonald, 2018; Mosleh et al., 2023), this chapter introduces a quantitative approach to assess trade-offs at the decision-making level in Flemish municipalities. The objective of this chapter is to examine the existence and reasons behind the science-policy gap pertaining to GI. Recent research by Wei and Zhan (2023) states that the science-policy gap is also shaped by a lack of research on the decision-makers' perspective, and the impact of their logic of action and political behaviour. Through a discrete choice experiment (DCE) that involves decision makers, it is discerned how spatial planning practices at local levels value GI or ES attributes. Further, this quantitative evidence is complemented with qualitative evidence collected from our unique sample gathered from decision makers. The above enables the identification of structural barriers in the implementation gap and facilitates an understanding in why knowledge is (dis)regarded in planning processes.

1.4.3 Chapter 4: A discrete choice experiment to analyse the people-policy gap in green infrastructure

Research question 3: How do residents value and prioritise ecosystem services from green infrastructure? How do these stakeholder perceptions and priorities regarding ecosystem services in green infrastructure shape the people-policy gap?

In chapter 4 delves into exploring the people-policy gap in GI. Since chapter 3 offered us an insight on the perceptions at the *supply* side of GI, this chapter addresses the *demand* side. From a planning perspective, it is critical to couple public values with climate adaptation strategies for effective implementation (Ordóñez Barona, 2015). Recognising that citizens can play a significant role in driving greening initiatives and enhancing urban systems' climate adaptability (Bayulken et al., 2021), it becomes crucial to analyse people's perceptions, priorities, and trade-offs regarding GIs ES. To achieve this, a sequential experimental approach was adopted, commencing with a best-worst scaling (BWS) experiment followed by a discrete choice experiment (DCE). The BWS experiment aimed to capture the public's value orientation (Parvin et al., 2016) by assessing their preferences for attributes or ecosystem services associated with a hypothetical green infrastructure case. The insights gained from the BWS experiment informed us for the design of the subsequent DCE through facilitating attribute reduction and defining of attributes. Note that this DCE bears considerable similarities to the one conducted with local Flemish decision makers in Chapter 3, therewith enabling the inclusion of complementary stakeholder perspectives. Consequently, the setup of this chapter offers a unique opportunity to analyse and bridge potential divergences in perceptions and preferences among different stakeholder groups (Depietri, 2022), determine how valuation tools might help, ultimately contributing to active citizen engagement and participation (Kronenberg et al., 2021). Given the importance of public involvement in climate adaptation ambitions and strategies, active citizen engagement becomes vital in achieving predefined targets. By enhancing our understanding of stakeholder perspectives and narrowing the existing people-policy gap, this chapter contributes to fostering effective communication, collaboration, and alignment between public preferences and policy decisions in the context of GI. Further, these insights allow us to reflect on the role valuation toolkits can play in bridging said gap.

1.4.4 Chapter 5: A novel tool to reveal green infrastructure costs and benefits: the Nature Smart Cities business model

Research question 4: How does the implementation of the Nature Smart Cities business model for valuing GI benefits and costs contribute to the effective planning and decision-making processes of local authorities in small to medium-sized cities?

Chapter 5 synthesises some key insights and findings derived from the preceding chapters. This chapter also introduces a novel tool designed to evaluate the benefits and costs of GI specifically tailored for local authorities. The development of this tool has been an integral part of the Nature Smart Cities project, which aimed to facilitate the implementation of GI in small to medium-sized cities. The tool's creation involved extensive collaboration, emphasising co-development and co-design processes. Recognising the significance of engaging local practitioners, constant collaboration between scientific researchers and practitioners was deemed crucial for successful uptake within this target group. In this chapter, a case study is presented to familiarise readers with the tool and its primary features. The Nature Smart Cities tool is intended for use during the early stages of project planning and design. It includes a comprehensive assessment of ecosystem services through qualitative, quantitative, and monetary approaches, coupled with the inclusion of green infrastructure cost data. This enables local officers to assess the potential impact of a green infrastructure project in a straightforward and timely manner. Moreover, the tool facilitates the presentation of results in easily interpretable formats, effectively addressing the information needs of decision makers.

1.5 Introduction to research methods

A combination of research methods is employed to address the primary research question of each chapter and, furthermore, to narrow the identified gaps discussed in 1.3. These methods are outlined in 1.4. Every method was carefully chosen and serves particular purposes. In the following subsections, these methods will be introduced and elucidated, with a (non-exhaustive) examination of strengths and limitations. Methods are critically analysed and discussed in greater detail in the following chapters.

1.5.1 Ecosystem service valuation

The concept of ecosystem services is long-existing, initially devised with the intention to underline societal dependence on ecological functions (Costanza et al., 1997; Norgaard, 2010). Its origins frame within a socially still relevant and reactionary debate on the disillusionment of economic growth and the coping capacity of our earth's system, so called planetary boundaries (e.g., Raworth (2017)). Increasing anthropogenic pressure and demands on nature's services and biodiversity were (and are) seen as large threats causing environmental disruption (Rockström et al., 2009). Ecological economists therefore metaphorically expressed nature as a *natural capital stock* sustaining a flow of ecosystem services (Costanza & Daly, 1992). According to Norgaard (2010), some conservation biologists embraced this market metaphor to build support for conservation and to raise awareness among an audience often uninformed about natural processes.

The concept of ecosystem services began to gain momentum within science-policy environments following the publication of the MEA in 2005 (Millennium Ecosystem Assessment, 2005) evolving into an established framework for analysing social-ecological systems (Carpenter et al., 2009). As a result, there was a proliferation of studies assessing environmental goods and services. The concept of ecosystem services and the consequent practice of ecosystem service valuation have been the subject of ongoing debate. In fact, the ethical-philosophical side to the debate has a much longer history within the field of natural conservation, starting in the early 1900s with Muir and Pinchot (Smith, 1998). Proponents and opponents have expressed their perspectives regarding the valuation of natural resources. Ecosystem service valuation (ESV) is a bottom line throughout the thesis, and to the concept of GI. Thus, following is a concise overview of the most recurring arguments in favour and arguments against ES(V).

Proponents' arguments in favour of ES(V):

- Gómez-Baggethun and Ruiz-Pérez (2011) states that 40 years of conservation failed in reversing the decline of ecological life-support systems and biodiversity. Especially in the world's poorest areas, the mere consideration of intrinsic value is insufficient to support ecological conservation (Reid et al., 2006). As a response to the critique of ES being an anthropocentric concept, advocates argue that environmental ethics also includes anthropocentric values (Reid et al., 2006). Advocates state that the ES concept is founded to complement biocentric arguments, not replace them, offering means to integrate intangible and noneconomic values (Chan et al., 2012; Luck et al., 2012). Therefore, anthropocentric values introduces supplementary arguments that need to be addressed in order to effectively confront the ongoing ecological crisis. (Schröter et al., 2014). Armsworth et al. (2007) underscore the conservationists' inability to reverse the decline in biodiversity, given the persistent existence of the issue. They argue that the notion of valuing nature for its own sake appeals primarily to those who are already convinced of its intrinsic value. Further, they contend that the ecosystem services concept is a more inclusive approach that can engage and empower individuals with diverse interests who may not have previously felt connected (or were unable to) to the conservation rationale (Armsworth et al., 2007).

- By articulating ecosystem services and valuing them, it provides tangible (economic) incentives for conservation efforts (National Research Council, 2005). This approach addresses market failures that result from externalities, non-excludability of ES, inadequate property rights, and insufficient knowledge and information (Tietenberg & Lewis, 2018). As a consequence of these market failures, the depletion of natural capital exceeds what would be socially optimal (Engel et al., 2008). ES make environmental externalities more explicit, facilitating the design of policy instruments aimed at internalising the value of these externalities in market transactions and decision-making processes (Jax et al., 2013). Advocates recognise the inability of making exact value estimations, but state that that complete accuracy is not always necessary when making decisions, especially in cases where the benefits significantly outweigh the costs (Daily et al., 2000). It is suggested that monetary values should not serve as a substitute for ethical, ecological, or other nonmonetary considerations and arguments (De Groot et al., 2012; Schröter et al., 2014).

- The concept of ecosystem services has led to the development of integrated ecological-economic-social approaches for managing ecosystem assets, demonstrating significant potential (Daily et al., 2000). By incorporating reciprocal feedback between humans and their environment, the concept of ecosystem services provides a comprehensive understanding of the social-ecological system in which we exist, promoting a more holistic perspective (Raymond et al., 2013). Not only does ES promote interdisciplinary science but it also serves as a bridge between science and practice, demonstrating its transdisciplinary nature. This holistic approach, utilising integrative methods, recognises that traditional narrow approaches, based solely on economic, political, or scientific solutions, fail to adequately address the sustainable use of natural ecosystems (Wang et al., 2013).

Opponents' arguments against ES(V):

- The concept is ethically questioned for its fundamentally anthropocentric approach. "With scant evidence that market-based conservation works, the time is ripe for returning to the protection of nature for nature's sake" (McCauley, 2006). McCauley (2006) expressed his concerns on the commodification of nature that results from the ecosystem services concept, highlighting the challenge of safeguarding natural areas that do not align with human interests or demonstrate direct benefits. This perspective implies that nature's conservation value should not be solely determined by its profitability, as it possesses inherent worth that transcends monetary evaluation. Such critiques have been echoed by other authors who reject the utilitarian justification for conservation that is implied with the ES concept (Child, 2009; Peterson et al., 2010). These philosophical and utilitarian arguments against the perceived commodification of nature are further reinforced by equity concerns associated with uneven distribution of access to benefits and burdens arising from the protection of ecosystem services. This argument arises due to the inadequate consideration of context sensitivity within the general ES concept (Corbera et al., 2007).

- The ES framework is just one framework for ecologists to understand the complexity of nature, emphasise the limits of ecology to define ecosystem services. This complexity does not allow to thoroughly describe the tradeoffs underlying uses of ecosystem services, yet (Norgaard, 2008, 2010; Ridder, 2008). Since ecologic research rarely addresses human well-being and ecologists' methods do not necessarily reduce to stock-flow models or *production functions* that underly ecosystem services (Norgaard, 2010; Vira & Adams, 2009). Consequently, the ecological underpinnings that support ecosystem services are frequently regarded as weak, even among ecologists who endorse the concept (Daily et al., 2000).

- To value ES, researchers often conduct studies using a partial equilibrium model. Economically, the partial equilibrium theory framework that is often used for valuation is troublesome, when considering the biologically and institutionally complex context (Norgaard, 2010). In a partial equilibrium model, analyses are done assuming other things are equal, including market factors. For example, measures of willingness to pay for use-based ecosystem services are influenced by changes in the demand for complementary market goods (Carbone & Smith, 2010). Howarth and Norgaard (1992) found that transitioning to a sustainable development trajectory leads to an increased appreciation of environmental services and a lower rate of interest. Consequently, in a sustainable economy, the marginal value of an ecosystem is inflated, and future values are discounted to a lesser extent due to the reduced rate of interest. Such considerations are not accounted for in a partial equilibrium model.

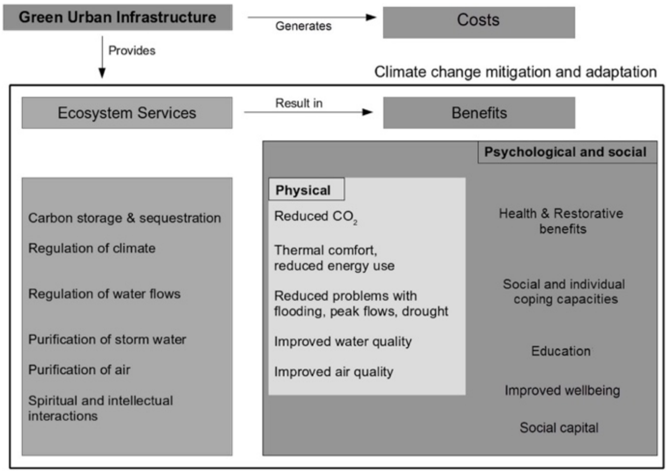
- Not particularly an argument against ESV, but rather a reflection on the current practice of ESV research is the limited consideration of ecosystem disservices (EDS). EDS are defined as negative impacts of natural and ecosystem resources on humans (von Döhren & Haase, 2015). Examples of ESD are allergies, block of views, introduction of invasive species, decreases in air quality (e.g., in street canyons), and costs resulting from maintenance or damage (von Döhren & Haase, 2015). GI generates these disservices simultaneously with the ecosystem services that are extensively studied. Some authors therefore advocate for a holistic ES-EDS approach when assessing the impact of GI on social-ecological systems, including both effects both research and policy (Blanco et al., 2019; Shackleton et al., 2016; Wu et al., 2021).

Ecosystem service valuation in this thesis

The objective of this thesis is not to engage in further debate on the ecosystem services concept. Instead, the acknowledgement of the contrasting perspectives advocating for and against the concept serves as a pertinent backdrop to proceed with caution, balancing anthropocentric and ecocentric perspectives (Benedict & McMahon, 2002). As supported by Gómez-Baggethun and Ruiz-Pérez (2011), the strategic endorsement of ES and ecosystem service valuation (ESV) serves as a pragmatic approach to effectively communicate the value of natural and ecological systems. Moreover, many of the debates surrounding the concept primarily revolve around concerns related to biodiversity conservation and larger-scale natural resources, whereas this thesis focuses more specifically on small-scale and urbanised ecosystem services (visualised in the framework in Figure 5). This aligns with shifts in research and practice, emphasising the generation of urban ecosystem services and investigating climate adaptation within urban contexts (Bolund & Hunhammar, 1999; Gómez-Baggethun et al., 2013; Rosenzweig et al., 2010). Thus, the ES concept is applied more towards the integration of natural resources in urban settings, extending beyond mere conservation objectives.

Further, the use and novelty of our work in ecosystem service valuation relies on improving the link between research and practice. In this thesis, we research how ES knowledge can be accessed more easily to be used in local GI decision-making processes. We further make the liaison between different stakeholder's value orientations and perceptions to go beyond the state-of-the-art by developing a tool that encapsulates these different perspectives and distinguishes itself from previous attempts through the participative and empirical approach of integrating different stakeholder needs in GI and ESV tool development.

Figure 5 Framework for ecosystem services delivery by urban green infrastructure (adapted from Demuzere et al. (2014))



1.5.2 Stated preference valuation

Stated preference (SP) or direct methods are employed as a means to elicit preferences for a particular good or service. SP methods rely on individuals' explicit statements about their hypothetical behaviour to derive preferences. This contrasts with revealed or indirect valuation methods, which involve observing actual consumer behaviour to develop choice models. Throughout this thesis two stated preference methods are used, in Chapters 3 and 4: discrete choice experiments and a sequential best-worst scaling - discrete choice experiment respectively.

In Chapter 3 we use discrete choice experiments to shed a light on the investor or supply side of GI provision. This innovative approach extends beyond the conventional application of DCEs, which typically focus on examining the demand side of a product or service. Traditionally, DCEs have been employed primarily to explore consumer preferences and choices by presenting hypothetical scenarios where respondents make choices based on various attributes of a product or service. In our research, however, we shift the focus to the supplier's perspective, seeking to unravel the intricate decision-making processes and preferences of those responsible for investing in and providing GI solutions. The unique and large sample of decision-makers that participated in the sample allows us to break new ground in the field of green infrastructure research, providing a deeper understanding of how investments in GI are prioritised and allocated. Previously, research involving decision-makers was limited to small-sample qualitative research. This approach acknowledges the role of supply-side considerations and bottlenecks with local decision-makers in shaping the availability and accessibility of GI within communities.

These communities, or local residents and their GI preferences are researched in Chapter 4 through a two-stage stated preference approach. This innovative methodology has been seldomly applied in the existing literature, making it an addition to the state-of-the-art in GI and ES research. This approach stands out for its dynamic and flexible nature. By combining BWS and DCE, we gain a deeper understanding of what communities truly value when it comes to GI. This deeper understanding is instrumental in acknowledging the perspectives of local residents and ensuring their preferences are genuinely integrated into the decision-making processes at the local level.

Discrete choice experiments

A discrete choice experiment (DCE) is a form of stated preference valuation method commonly used for non-market valuation. The technique was introduced by Louviere and Hensher (1982) and Louviere and Woodworth (1983), stemming from transportation and marketing research. DCEs have gained prominence and surpassed contingent valuation as the most widely practiced and frequently cited stated preference technique for environmental goods (Mahieu et al., 2014). In a DCE, respondents are presented with hypothetical scenarios that include various attributes and corresponding levels. The underlying theory of the DCE is based on the assumption that respondents' choices among alternatives reflect the utility they derive from each alternative, following the principles of Lancaster's characteristics of value theory (Lancaster, 1966) and underpinned by random utility theory (RUT) (Louviere et al., 2010). RUT posits that an individual's relative preference for object A compared to object B can be attributed to the relative frequency with which A is chosen as better or preferred over B (McFadden, 1973). As such, RUT assumes that individuals make choices stochastically, incorporating a certain level of error or randomness (Louviere et al., 2013). The researcher presents the respondent with multiple choice sets, each containing a set of alternatives. The respondents are then asked to select their preferred alternative based on the context of the hypothetical scenario. DCEs typically involve the presentation of 2 or 3 choice alternatives to respondents, alongside a status quo or opt-out alternative. This design complies with the principles of utility maximisation and demand theory, ensuring that respondents are not coerced into selecting alternatives they do not genuinely desire (OECD, 2018). By analysing the choice behaviour of respondents across the repeated choice tasks, valuable insights can be obtained regarding the trade-offs individuals make between different attributes or levels within the alternatives. The response data collected from the choice sets are then modelled using a benefit (or utility) function, which enables the assessment of the importance of specific attributes, the relative significance of these attributes, the willingness of individuals to trade-off between different attributes, and the overall utility scores associated with alternative choice options (Ryan et al., 2001).

DCEs offer the following strengths:

- In comparison to revealed preference methods, DCEs offer the advantage of being able to assign values to products or services and their attributes even in the absence of real-life data. By employing hypothetical scenarios, researchers and policymakers can gain insights into people's behaviour concerning non-marketed attributes and effectively value pre-market goods, services, or programs (Srivastava, 2019). This capability of DCEs to assess preferences and assign economic values to intangible or non-existing attributes provides a valuable tool for decision-making processes and resource allocation, especially in contexts where actual market data is limited or unavailable. Especially in the context of valuing ecosystem services (see 1.5.1), which are predominantly non-marketable, DCEs could therefore provide a useful mechanism to reveal stakeholder preferences and values.

- DCEs are appreciated for their efficiency. Due to the repetitive nature of respondents expressing preferences towards a good and its attributes, DCEs offer a high level of informativeness. Additionally, since it offers the ability to elicit and analyse preferences through in a controlled and structured manner, without the need for multiple surveys or extensive field experiments, DCEs have favourable cost-effectiveness (Hoyos, 2010).

- DCEs are well-suited for addressing environments involving multidimensional changes and trade-offs between different dimensions or attributes. In comparison to contingent valuation, DCEs excel in quantifying the marginal value of alterations in attributes of products, services, or programs. This also facilitates a deeper comprehension of the trade-offs among these attributes. From a management and policy perspective, this focus on understanding the multifaceted changes and associated trade-offs often proves more valuable than exclusively examining the overall gain or loss of a good or fixating on a singular discrete change in its attribute (which would be technically feasible with contingent valuation) (OECD, 2018).

- Within the context of climate change and adaptation, stated preference and discrete choice experiments in particular are a very useful tool. Given the uncertain context of climate change, which constantly evolves, DCEs can set the hypothetical scene that allows us to investigate how future impacts or risks would be perceived by certain stakeholders. This further enables researchers to identify effective climate policies and communication pathways, incentivising desirable behavioural changes affecting climate mitigation and adaptation.

DCEs include the following limitations:

- Like other stated preference methods, DCEs are susceptible to hypothetical bias. Since respondents are presented with hypothetical scenarios, their choice behaviour in a DCE may diverge from their actual behaviour when faced with real-world, economic situations (Hausman, 2012). It is commonly observed that respondents tend to exhibit less price sensitivity in hypothetical scenarios compared to real-world contexts. This phenomenon can lead to an overestimation of the willingness-to-pay values derived from DCEs, as the hypothetical nature of the exercise may inflate the observed levels of stated preferences (Bjørnåvold, 2021).

- When dealing with multiple complex choices involving bundles consisting of numerous attributes and levels, respondents often experience a cognitive burden. This might lead to complexity-induced inconsistencies (Hoyos, 2010). While obtaining data for a large number of choice sets may be statistically advantageous, respondents tend to fare better when presented with a smaller number of simpler trade-offs. Balancing the need for comprehensive data collection with respondents' cognitive load is crucial. (OECD, 2018) Respondent efficiency is related with the complexity of the choice tasks, the experimental design, familiarity with the researched good or service, and motivation to participate in the experiment (Ryan et al., 2008; Severin, 2001). This limitation applies to DCEs for ESV in particular, where respondents are not always equally informed about specific ecological processes. This imbalance in background knowledge could lead to an information bias. This limitation links up with the concern of oversimplification that is discussed in the limitations of ESV in 1.5.1.

- A notable observation in DCEs is the occurrence of a disproportionate number of respondents selecting the status quo or opt-out alternative, potentially indicating the presence of a status quo bias (Meyerhoff & Liebe, 2009; OECD, 2018). This bias can arise from various sources, including inertia, biased perceptions, cognitive limitations, uncertainty, and distrust in institutions (Meyerhoff & Liebe, 2009; OECD, 2018). The inclination to stick with the status quo option may be influenced by individuals' resistance to change or their perception that the existing state provides a certain level of familiarity, stability, or security.

- DCEs, like stated preference methods in general, are very sensitive to the experimental design (Hoyos, 2010) (e.g., omitting certain variables affects estimates and variance (Islam et al., 2007)). This might limit the generalisability of DCE results (Rakotonarivo et al., 2016), and SP results by extension.

- DCEs typically assume relatively stable preferences to some extent. However, in the context of climate change, climate adaptation, and - in our case - the adoption of GI, preferences may be subject to variation due to evolving environmental conditions, public narratives, and emerging risks. This mere observation was already briefly mentioned in 1.1, where we mentioned a *renewed* appreciation of GI. Hence, temporal stability of preferences is often questionable (Wunsch et al., 2022).

Best-worst scaling

Best-worst scaling (BWS) was introduced in 1992 by Finn and Louviere (1992). Like discrete choice experiments, it is a stated preference valuation method that is underpinned by random utility theory (Louviere et al., 2013). The initial motivation for BWS was obtaining more respondent specific data, since DCEs do typically not allow to make statements about individual respondents (Flynn & Marley, 2014). BWS is an extension to pairwise comparisons, which involves presenting individuals with sets of two objects and requesting them to choose the best object from each pair. This method was first introduced by Thurstone (1927). McFadden (1973) generalised the method, establishing a relationship between choices made from sets of multiple objects and an underlying latent scale value linked to each individual object. Recognising that collecting solely the "first" or "best" choices provides limited statistical estimation information, BWS capitalises on the simultaneous collection of information on the "worst" object as well (Louviere et al., 2013). BWS assumes that individuals can reliably and validly make choices on the two most extreme objects within a choice set (Louviere et al., 2013). Analytically these are treated as the attribute pair to be furthest apart on this latent utility scale (Flynn et al., 2007). Like in DCEs, respondents are presented multiple comparison sets. These comparison sets consist of a minimum of three objects, as the inclusion of only two objects would result in a paired comparisons experiment. Unlike DCEs, BWS focuses on preferences for attributes, rather than scenarios (OECD, 2018).

BWS offers the following strengths:

- BWS overcomes the limitations associated with rating-based methods by providing a means to measure preferences on a difference scale with known properties (Marley & Louviere, 2005). Unlike rating scales, which rely on respondents' subjective interpretation of scale labels (Lee et al., 2008; Louviere et al., 2013). Further, it addresses several biases commonly observed in rating scale research, including social desirability bias, acquiescence bias, and extreme response bias (Lee et al., 2008). These biases often arise when respondents provide ratings or scores on subjective scales, which can be influenced by factors such as the desire to conform to social norms, a tendency to agree or disagree with statements, or a propensity to select extreme response options. In contrast, BWS choice sets present respondents with the task of making discriminating choices between objects (Cohen & Markowitz, 2002), resulting in a more realistic representation of market choices.

- BWS build on the assumption that it is cognitively simpler to identify the extremes in a list of options. Being cognitively intuitive, it provides a clear advantage over ranking scales, that have the same objective of ranking objects. Choice design and choice tasks are less complex for BWS than those of DCEs (Flynn & Marley, 2014). The simplicity of choice tasks also results in significantly lower time requirements to collect respondents' information (Lee et al., 2008).

- BWS strikes a balance between the need for question parsimony and the desire to simulate real-life decision-making processes (Louviere et al., 2013). While paired comparisons become increasingly burdensome as the number of objects to compare grows, BWS offers an optimal design that minimises the number of questions while still capturing meaningful preference information (Louviere et al., 2013). This advantages BWS in that it can assess many objects, without significantly toughening the cognitive task.

BWS includes the following limitations:

- Three of the limitations that were mentioned when discussing DCEs reapply: hypothetical bias, sensitivity of results to the experimental design, and the temporal stability of preferences.

- Through best-worst scaling experiments, researchers are not able to provide monetary valuation for the subject under research (OECD, 2018). Even more, the results of BWS yield relative values, comparing different objects or attributes and the tradeoffs between them, but they have no absolute values (Louviere et al., 2013). This limits the options to replication and generalizability of results even further.

1.6 Overview of publications

Having introduced the subject, research background, research objectives, and the theoretical foundations of this thesis, this thesis is structured into four chapters, each comprising individual papers. Each paper includes an introduction, methods section, results section, discussion and limitations, and conclusion. Consequently, there may be instances of content repetition, particularly in the literature reviews. It is important to note that some of these papers have been published in peer-reviewed journals. The articles on which this thesis is based are as follows, and they align with the narrative established in this introduction:

Chapter 2: Van Oijstaeijen, W., Van Passel, S., & Cools, J. (2020). Urban green infrastructure: A review on valuation toolkits from an urban planning perspective. *Journal of Environmental Management, 267*, 110603. doi:https://doi.org/10.1016/j.jenvman.2020.110603

Chapter 3: Van Oijstaeijen, W., Van Passel, S., Back, P., & Cools, J. (2022). The politics of green infrastructure: A discrete choice experiment with Flemish local decision-makers. *Ecological Economics, 199*, 107493. doi:https://doi.org/10.1016/j.ecolecon.2022.107493

Chapter 4: Van Oijstaeijen, W., Van Passel, S., & Cools, J. (2023). Residents' perceptions on ecosystem services from green infrastructure: results from a sequential best-worst scaling and discrete choice experiment approach. *Working paper.*

Chapter 5: Van Oijstaeijen, W., Silva, M. F. e., Back, P., Collins, A., Verheyen, K., De Beelde, R., Cools, J., Van Passel, S. (2023). The Nature Smart Cities business model: A rapid decision-support and scenario analysis tool to reveal the multi-benefits of green infrastructure investments. *Urban Forestry & Urban Greening, 84*, 127923. doi:https://doi.org/10.1016/j.ufug.2023.127923

In Chapter 6, the general findings and remarks are presented. This chapter serves as a summary of the main findings and observations from the previous chapters. It provides a concise overview of the key insights and conclusions that have been derived from the research.

Chapter 2
A review of existing green infrastructure valuation tools

In this second chapter, we delve into one of the challenges hindering green infrastructure implementation, recognising that one fundamental issue is the difficulty in demonstrating its added value. To address this, various tools and methods have been proposed to help local authorities unveil the benefits of GI. Despite these efforts, these tools are underutilised. In this chapter, we conduct a comprehensive literature review of selected GI and ES valuation tools. We examine their functionalities, assumptions, and scientific validity while also exploring local authorities' needs and expectations, as well as their potential roles in spatial planning and decision-making. This chapter seeks to identify areas for improvement in tool development and in decision-making practices, within the larger aim of bridging the gap between science and policy, as it was defined in 1.3. We obtain an understanding of how valuation tools would theoretically fit within the local decision-making processes, and how they can be improved. These results feed both development of a novel tool (presented in Chapter 5) and the articulation of scenarios and attributes for the stated preference valuation techniques that empirically apply these insights with the most important local stakeholders employed in Chapter 3 (local decision-makers) and 4 (the residents).

Parts of this chapter have been published in : Van Oijstaeijen, W., Van Passel, S., & Cools, J. (2020). Urban green infrastructure: A review on valuation toolkits from an urban planning perspective. Journal of Environmental Management, 267, 110603. doi:https://doi.org/10.1016/j.jenvman.2020.110603

2.1 Introduction

Within the reality that the impacts of climate change are affecting people on a more frequent basis every year, climate change adaptation has become a key topic in environmental sciences. On the same hand, rising urbanisation causes cities to become increasingly dense and wide, most often at the expense of green areas. However, humans are still dependent on nature for their livelihood (Bolund & Hunhammar, 1999) and human well-being and health is closely related to the availability of nature (Ward Thompson, 2011). The benefits of nature are often defined as the ecological functions it performs, where the ecosystem services concept then contributes to placing value on these functions (Ahern, 2007). Since the publication of the MEA in 2005 (Millennium Ecosystem Assessment, 2005), there has been continuous debate for the protection of ecosystem services provision. As a result of human dependency on ecosystem services and intensive urbanisation, a paradox emerged between the supply and demand of ecosystem services. This led to the expansion of the ecosystem services debate from farmlands and ecosystems to cities and urban ecosystems (Rosenzweig et al., 2010). In our densely populated urban areas, where the demand for ecosystem services is the highest, the supply is close to nothing. This economic supply/demand perspective was introduced in Chapter 1 and is central in this dissertation. In Chapter 3 the role of ES/GI suppliers is investigated through DCEs with local decision-makers, and Chapter 4 sheds light on the ES/GI demand side by gauging residents' perceptions.

Evidently, (urban) green infrastructure (UGI) and the ecosystem services it provides, are important to increase the resilience of cities against the impacts of climate change and natural hazards such as droughts and floods. UGI are means to reduce the urban heat island effect, improve limited water retention and infiltration capacity in densely urbanised areas, while at the same time enhancing biodiversity and human wellbeing. The aspect of human wellbeing not only results from healthier living environments, but also from the capacity of urban green to produce greater social capital. Coutts and Hahn (2015) state that GI is found to improve "neighbourhood social ties" and the togetherness of the local community and leads to more social support and less self-reported loneliness. The increasing number of cities engaged in international gatherings such as C40 (C40 Cities Climate Leadership Group Inc. , 2019), 100 resilient cities (100 Resilient Cities, 2019) and the Covenant of Mayors (Covenant of Mayors for Climate & Energy, n.d.) are creating momentum to practically invest in GI.

GI can be defined as the concept of (semi-)natural structures, strategically structured in networks and characterised by their multi-functionality (i.e., multitude of ecosystem services provided)(Benedict & McMahon, 2012). Examples of urban green infrastructure were introduced in 1.1 and can take many shapes, such as permeable vegetated surfaces, green roofs, public parks, green walls, urban forests, green alleys and streets, community gardens and urban wetlands (Gill et al., 2007), also visualised in Figure 1 (1.1). Sustainable Drainage systems (SuDS) can also be considered an element of GI. UGI is a mean to deliver valuable ecosystem services within the urban environment, this is illustrated by Figure 5 in 1.5.1. Consequently, UGI can be described as landscape elements that can provide environmental, economic, and social benefits simultaneously. In this thesis, the term 'co-benefits' refers to this wide range of benefits that often surpasses the narrower purpose of a UGI element.

Table 2: Overview of current barriers towards green infrastructure uptake as identified by previous research

Barriers	Source
Multifunctional GI spans different community agencies and their roles (e.g., water, transport infrastructure, buildings, …), uncertainty about the delivery of benefits from GI, concerns about social acceptance with citizens.	(Thorne et al., 2018)
Biophysical character of the built environment, planning systems, institutional frameworks and governance structures, perceptions, and values of urban residents.	(Byrne & Jinjun, 2009)
Path dependency, characterising a situation in which institutions gradually conform to specific circumstances and practices, resulting in a reluctance to adapt to newly emerging imperatives. In that way creating lock-in effects.	(Matthews et al., 2015)
Uncertainties in cost and performance, lack of engineering standards and guidelines, fragmented responsibilities, lack of institutional capacity, lack of legislative mandate, funding constraints, resistance to change.	(Roy et al., 2008)
Lack of economic argument, roles and responsibilities, municipal organisation, urban densification, legislation, political interest, time, and workload	(Wihlborg et al., 2019)
Reluctance to support novel approaches, lack of knowledge, funding and costs, ineffective communication, issues with partnerships, maintenance, and adoption, identifying/quantifying/monetising the multiple benefits, legislation.	(O'Donnell et al., 2017)

The term *(urban) green infrastructure* itself is relatively new to academic literature, however the idea is long existing. As mentioned in 1.2.1, its origins lie in the greenway movement. Despite recent growing academic interest, the implementation of UGI into practice remains slow (Dhakal & Chevalier, 2017). The reasons for the hampering uptake of UGI are diverse. Where initial GI research was focused on bio-physical dimensions, the momentum is starting to shift towards socio-cultural, institutional, and political conditions. This led to various studies identifying barriers for GI uptake, a non-exhaustive oversight is provided in Table 2.

'Green infrastructure' implicitly argues for an equal treatment to 'grey infrastructure', critical to the strategic significance elucidated in 1.2.3. This is illustrated by the European Strategy on Green Infrastructure. In this strategy, the European Commission urges member states to "ensure that the protection, restoration, creation and enhancement of green infrastructure becomes an integral part of spatial planning and territorial development whenever it offers a better alternative, or is complementary, to standard grey choices" (European Commission, 2019a). In practice, comparing alternatives is often based on their relative costs and benefits.

One reason for the limited implementation of green infrastructure is the lack of knowledge on cost, benefits, and impact (see Table 2). Multiple authors stress that the mainstreaming of UGI not only requires evolutions in urban design principles, also urban governance and thus budgeting processes and structures are to be rethought (Andersson et al., 2014; Shackleton et al., 2018). The latter relates to the first barrier depicted in Table 2. Valuation practices at city scale are rare, leading to uncertainty of economic benefit and impact and multidisciplinary performance. Assessing and quantifying the impacts of UGI is essential in composing economic value, since there is often no observable market value. In literature, valuation is often defined in bio-geophysical terms, while economic and social valuation is seldom applied (Brink et al., 2016). As it appears, the transition to economic and financial aspects of urban green infrastructure is not well researched. Economic valuation, e.g. a societal cost-benefit analysis are typically done at a larger scale (Millennium Ecosystem Assessment, 2005). There is a need for economic cost to benefit/utility analyses of urban green elements, addressing all its uses and co-benefits (Lee et al., 2015). Methods and tools to economically assess the value of urban green while also bridging to planning, financial and implementation aspects are needed (Wild et al., 2017).

Valuation of investment projects is a key part of the return-on-investment calculations and eventually decision making. In the MEA the necessity for economic valuation was intensively argued, because it provides decision makers and the public with numbers that are readily understandable (Carpenter et al., 2006). However, resource constraints (especially in small city governments) led to the latter being skipped far too often. Valuation of traditional, grey, or built infrastructure is more straightforward because such infrastructures mainly serve a specific purpose e.g., an apartment building (for living) or a highway (for transportation). This contrasts with green infrastructure and its co-benefit production. Therefore, in contrast to grey infrastructure, where added value is much more tangible, local authorities (LAs) appear to experience green infrastructure investments as non-performant. Because of that, especially smaller cities are not willing to take the 'risk' (Wihlborg et al., 2019). Evidence in Europe states that investments in urban green infrastructure are scarce and limited to individual, small-scale projects, often the result of active citizenship (van der Jagt et al., 2019), on the other hand subsidies provide another incentive to invest in UGI. Typically, if (innovative) investments (e.g. vertical greening) occur, these are mostly limited to larger cities (Pauleit et al., 2019). Subsidies offer concrete opportunities for (smaller) cities to invest in UGI but are also limited in scale. The lack of economic valuation currently impedes on credible business case development and thus on informed decision-making for local authorities. Notwithstanding the fact that solutions based on GI prove to not only be environmentally and socially desirable, but also economically superior to their grey alternatives in recent studies (Elmqvist et al., 2015). Thus, for green infrastructure to become economically viable, local authorities need to see the economic rewards to fully commit in green infrastructure on a strategic urban management level.

With the strategic and planning concept of urban green infrastructure, the domain of landscape ecology attempts to integrate the ecological network concept within urban environments

(Ahern, 2007). To assess the value of UGI, it is necessary to elaborate on elements that determine the ecological and social functions of GI in cities specifically. Firstly, in cities, the consideration of appropriate scales, rooting in hierarchy theory is important and requires a multi-scaled approach for assessments (Ahern, 2007). Existing literature on valuation exercises does not incorporate the importance of the relevant spatial scale. Most often, studies opt to assess green infrastructure on a spatial scale of choice. In order for results to be transferable to other cases, the spatial sensitivity of attributes plays an important role, very often overlooked in non-market benefits today (Lizin et al., 2016). Demuzere et al. (2014) argued that defining the scales of benefits is advantageous on different levels (individual and political and administrative decision making). Secondly, UGI and its value is highly dependent on the co-benefits that are generated during the life-span of the GI structure (Hansen et al., 2019). Existing valuation literature mostly offer partial analyses, focusing on single ecosystem services or values (Gómez-Baggethun & Barton, 2013). Thirdly, natural structures in urban space typically generate urban ecosystem services, which require additional assessment exercises (Bolund & Hunhammar, 1999).

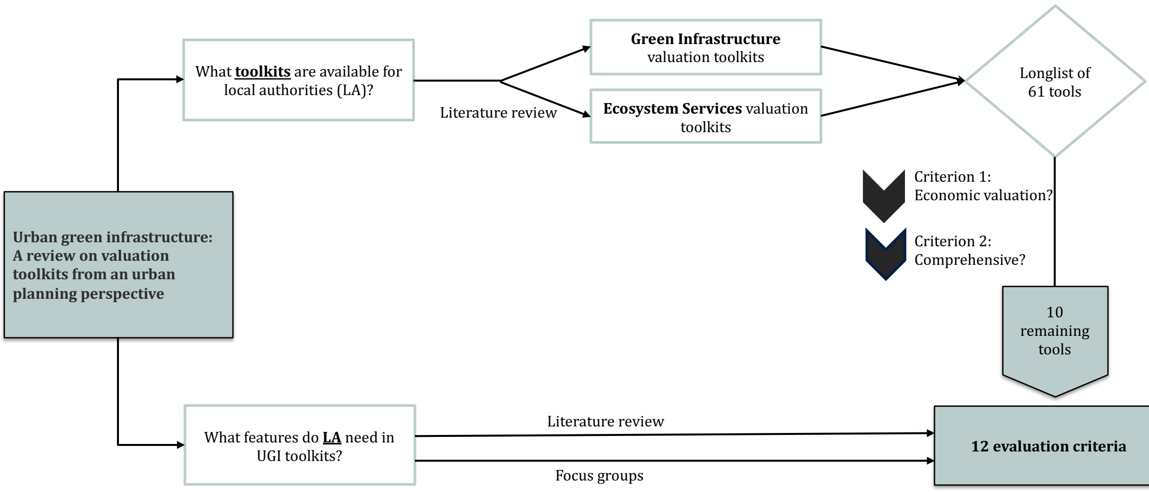
All the previous strengthens the relevance of an integrative assessment identifying and analysing the multi-scale co-benefits that are to be gained from UGI projects. For local authorities to compute socio-economic and biophysical value of GI, valuation tools are emerging. These valuation tools have the potential to help local authorities to overcome (some of) the previously mentioned barriers to UGI implementation. The objective of such tools should be to comprehensively assess the multi-scale and multi-functional benefits of UGI. Application of valuation tools could save local authorities a considerable amount of resources – which is especially relevant for smaller cities and communities – while still providing scientifically supported evidence that monetarily expresses the added value of an envisioned project (in the assumption that local authorities aim for fully informed decision making). Although these objectives highlight the potential, exploratory research indicated that local authorities are not using such tools.

In scientific research, biophysical properties of GI have been studied extensively, while socio-economic and political-institutional dimensions are far less subject to thorough analysis (Matthews et al., 2015). In this review paper we combine those previously mentioned dimensions (political-institutional, socio-economic, and biophysical) of UGI in an assessment of existing valuation toolkits for UGI. The objective of this research is to explore the readiness and scientific soundness of a selection of GI/ES valuation toolkits. Concretely, we will assess the suitability and functionality of said tools from the perspective of urban planning and urban land management using a set of indicators/criteria. On the other hand, from guided focus groups and published, peer-reviewed literature, local authorities' needs and expectations are addressed. This way, we aim at identifying how these tools can be of added value and in which stages of an urban planning process. Finally, this will allow to identify why valuation tools are currently not used by local authorities and how the future development of valuation tools can be improved to become a key component in facilitating informed urban planning for sustainable and resilient cities. This way we aim at contributing to what O'Donnell et al. (2017) formulated as the main strategy for overcoming existing barriers to GI implementation: "promotion of multifunctional space and identification and assessment of the multiple benefits".

2.2 Method

A three-fold approach was adopted for reviewing potential evaluation toolkits for green infrastructure. A graphical oversight of these three steps is given by Figure 6. In the top half of the figure, the process of selecting valuation tools is shown. The bottom half of the figure visualises how the evaluation criteria were defined. At the intersection of both in the bottom right corner of the figure, is Step 3: the comparative tool analysis.

Figure 6 Graphical presentation of the three-stage methodological approach: selection of valuation tools, definition of evaluation criteria, and the comparative tool analysis

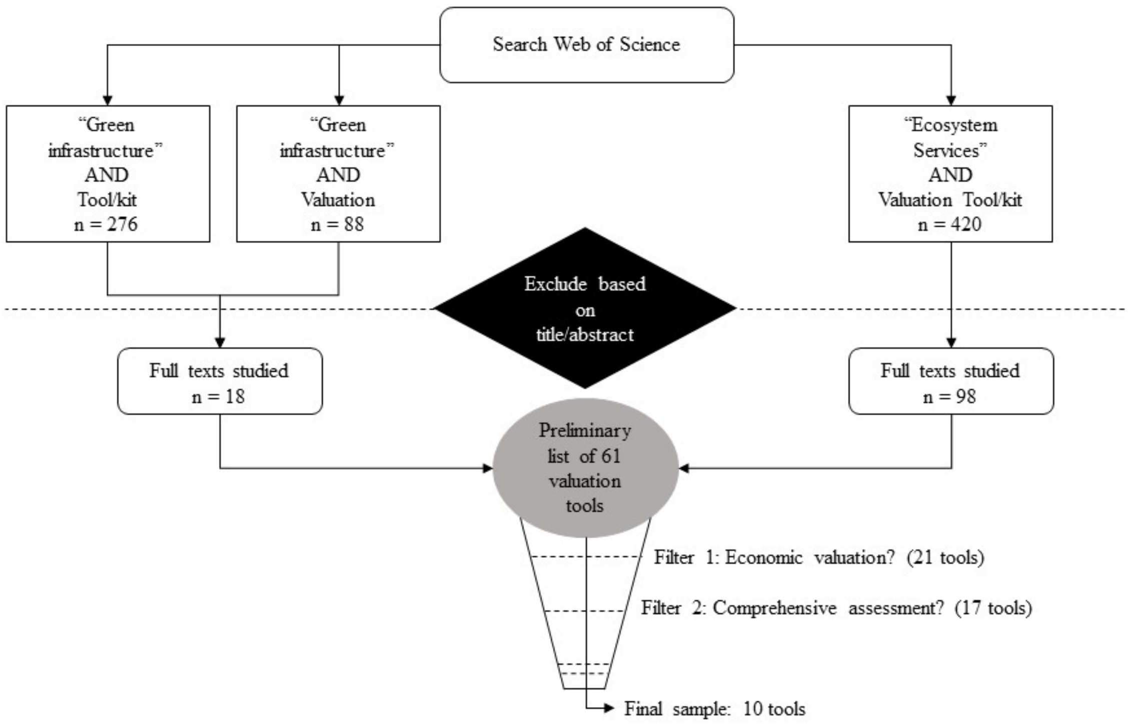


In the following, an elaborate explanation of these three stages is provided: selection of valuation tools, identification of evaluation criteria and eventually the comparative assessment of valuation tools based on these evaluation criteria.

2.2.1 Selection of valuation tools

For this part of the study, a systematic literature research (Figure 7) was conducted. Articles published on ISI Web of Science Core Collection were examined in accordance with the following queries: "Green infrastructure" AND ("Tool" OR "Toolkit"), "Green infrastructure" AND "Valuation". Because absence of the term "green infrastructure" does not necessarily mean that the underlying concept is missing, the queries: "Ecosystem Services" AND Valuation AND ("Tool" OR "Toolkit") were added. To proceed to the next step, only articles mentioning the use of quick assessment methods in their title or abstract were included for the next stage. Thus, the extensive list of 784 articles was reduced to 116 articles that were subjected for further analysis. The latter sample led to the identification of a preliminary selection of 61 toolkits that have been used in literature to quantify, map or model green infrastructure or ecosystem services. Since local authorities are the principal customers for such tools in this assessment and given their resource constraints, it is assumed that only toolkits that are free-to-use are suited for widespread use. The extensive list of 61 toolkits and their respective reasons for exclusion can be found in Appendix 2-A.

Figure 7 Schematic representation of the selection method for green infrastructure or ecosystem services evaluation toolkits



After compiling this list from academic literature, all 61 toolkits were individually reviewed through their respective manuals. Given the objective of this comparative study, additional filtering criteria were identified to reach a final sample of toolkits that anticipates application in the context of this paper's objectives. The first filter identifies tool(kit)s that attempt or at least objectify a partial monetary valuation of ecosystem services or green infrastructure assets. Thus, the list of tools was reduced from 61 to 21. The second filter covers the nature of the assessment: does the toolkit address the appraisal of one or a few ecosystem services, or does it proposes a comprehensive valuation exercise? Only toolkits ambitioning the latter were considered for further investigation, reducing the list to 17 tools. As GI solutions are characterised by multiple co-benefits, the evaluation of a single goal perspective does not cover the complexity of the net-benefits that are actually generated (Alves et al., 2019). Finally, after excluding valuation toolkits based on several additional determining factors (e.g., toolkits that are out-of-use, predecessors of other toolkits, toolkits that are not publicly available (yet)), the final shortlist was composed of 10 valuation tools designed to value green infrastructure or ecosystem services.

2.2.2 Evaluation criteria

After the identification of the tools that are to be assessed, a list of evaluation criteria was composed. The approach for selection and defining the criteria relies on a two-staged approach. On one hand existing literature contributed to determine current limitations and gaps in both decision-making processes and readiness of tools. Based on this first stage, the second stage – consisting of guided focus groups – was conducted. Two focus groups took place, consisting of 15 individuals active in different layers of urban planning and decision making in local authorities. The focus groups took place in April and September 2019. These focus groups were organised and led by academics from the institution of the lead author. In practice, they were organised through discussions with local authorities' officers from Belgium, The Netherlands, France, and UK. Concretely, the discussions in the first focus group contributed to identifying critical elements in actual decision making and perceptions on the application of quick assessment methods. This input was utilised to create the criteria mentioned below. Moreover, literature review highlighted existing shortcomings and limitations in decision-support tools, that were translated into additional criteria defining the functionality of a tool. The second focus group served to allow participants to validate the criteria as defined. This qualitative research contributes to the applicability of the research in practice, thus realising impact in actual decision making, advancing towards urban planning and development based on scientifically supported methods. City stakeholders identified additional concerns for toolkits to be widely applicable.

2.2.3 Comparative tool analysis

After composing the list of tools to review and the criteria that could define their applicability, an assessment was made for every tool separately. The assessment of performance on the proposed evaluation criteria was considered through analysing the user guides, peer-reviewed literature, case studies and eventually through trials of hypothetical scenarios with each of the toolkits. For accessibility reasons, the scoring of a toolkit on all criteria was simplified into a scoring table using a 5-point scale. This 5-point scale ranges from being highly suitable or functional to serve as a decision-support tools within the defined objectives (++) over acceptable (0) to highly unsuitable of dysfunctional to serve as a decision-support tool in the scope of this paper (--). In Appendix 2-B the motivations behind assigning scores for each criterion are elaborated.

2.3 Results

Resulting from the literature review, Table 3 presents an overview of the shortlist of valuation toolkits. These toolkits are thus all designed to contribute to calculating an economic value of green infrastructure elements and aim at the valuation of a wide range of benefits.

Local authority's officers that took part in the focus group identified several key elements in the process, while academics provided complementary advice to support the scientific credibility of tools. The outcome of the focus groups and literature review is processed in defining 12 criteria that determine the functionality and suitability of decision-support tools in the specific context of urban planning and decision-making processes. These criteria are displayed in Table 4.

After composing the list of tools to review and the criteria that could define their applicability, an assessment was made for every tool separately. While Table 5 introduces a summary of the performance on the most important evaluating features for every criterion, the full qualitative assessment can be found in Appendix 2-C. Table 6 was designed to provide an intuitive overview, facilitating to draw conclusions from the qualitative assessment.

Table 3: Shortlist of the valuation toolkits assessed in this review

	Developer	Type a	Type b	Type c	Type d	Objective	Last version**	Literature references
Nature Value Explorer (NVE)	VITO, BE	x				Demonstrate the impact of various land use scenarios on the value and generation of ecosystem services	2018	(De Valck et al., 2019; Liekens et al., 2013)
i-Tree eco	USDA Forest Service, US			x		Uses field data from trees and air pollution and meteorological data to quantify environmental effects and value to society	2019	(Blair et al., 2017; Kim et al., 2018; Ozdemiroglu et al., 2013)
Green infrastructure valuation toolkit (GI-Val)	The Mersey Forest, UK				x	Establish the value of existing green assets or proposed green investments, using a set of calculator tools	2015	(Jayasooriya & Ng, 2014; Ozdemiroglu et al., 2013)
A guide to value Green Infrastructure	Center for Neighbourhood Technology (CNT), US		x			To inform decision-makers and planners about green infrastructure benefits and guide them in valuing potential green infrastructure investments	2011	(Ozdemiroglu et al., 2013)
Toolkit for Ecosystem Service Site-based Assessment (TESSA)	Birdlife int., UK		x			Guidance on how to evaluate the benefits human receive from particular natural sites, generating information to support decision making	2017	(Birch et al., 2014; Liu et al., 2017; Martino & Muenzel, 2018)
Integrated Valuation of Ecosytem Services and Tradeoffs (InVEST)	Natural Capital Project - Stanford University, UK			x		Facilitate quantification of trade-offs associated with different management choices and identify areas where natural capital investments enhance development and conservation	2018	(Arcidiacono et al., 2016; Isely et al., 2010; Ozdemiroglu et al., 2013; von Essen et al., 2019)
EcoPLAN Scenario Evaluator (SE)	University of Antwerp, BE			x		Evaluate the supply of ecosystem services to alternative scenarios in spatial development projects	2017	(Maebe et al., 2019)
Green Infrastructure Benefits Valuation Tool	Earth Economics, US				x	A quick, screening assessment of the potential costs and benefits of different green infrastructure investment options	2018	(Toledo et al., 2018)*
Capital Asset Value of Amenity Trees (CAVAT)	London Tree Officers Association (LTOA), UK				x	A strategic tool and support for decision making when the value of the tree stock, or of a single tree needs to be expressed in monetary terms	2018	(Ozdemiroglu et al., 2013)
Benefits Estimation Tool (B£ST)	Construction Industry Research and Information Association (CIRIA), UK				x	Evaluate and monetise economic, social and environmental benefits of blue-green infrastructure to support investment decisions and identify stakeholders for potential funding routes.	2019	(R. Ashley et al., 2018; R. M. Ashley et al., 2018)

[a] Webtool, [b] Textual guide, [c] Computer program, [d] Spreadsheet

*Case study relies on Ecosystem Services Valuation tool by Earth Economics, exclusively available to members, alternatively the free GI benefits tool from Earth Economics was studied. ** Last version before November 2019

Table 4: Full list of definitions of the evaluation criteria for comparative analysis of the valuation toolkits

Type of GI	Different types of GI generate different benefits. Most common types of urban GI: permeable vegetated surfaces, green roofs, public parks, green walls, urban forests, street trees, green alleys and streets, community gardens and urban wetlands.
Subject of valuation	What does the toolkit attempt to valuate? Tools could aim at valuating the range of 'ecosystem services' that are provided by GI, but other tools define their own selection of 'benefits', other tools use even different determinants to compose value. Because toolkits are specifically researched on their capability of being used in urban areas, the inclusion of specific problems that densely populated and concreted places bring forth is important (urban heat islands, pollution, noise, climate resilience, …)
Time requirement	Time that is required to go through the whole process proposed by a tool.
Expertise requirement	Are subject-matter experts required throughout different steps of the process of valuation with a certain tool?
Quantification	Does the tool provide immediate quantification or is the explicit quantification left to the user? Is the quantification focused on biophysical units, monetary outputs, or both? Where quantification is complicated, does the toolkit provide qualitative support? LA officers pointed out that economic evidence is currently lacking and strengthens the business case for UGI.
Biophysical soundness	The biophysical drivers that co-define the added economic, environmental, and social value need to be measured and assessed accurately to provide reliable input. The methods that are used to biophysically express and predict the impacts of certain types of green infrastructure need to comply with academic standards. Moreover, including data on city-specific ecosystem services is highly relevant.
Economic soundness	To be treated on the same level as grey infrastructure, green infrastructure needs clear ways of expressing the total economic value. Because of the multi-functional nature of GI, toolkits apply different valuation techniques to monetise the stream of benefits. Critically assessing these techniques and the assumptions made, while using recent peer-reviewed literature as a benchmark will improve the accuracy and replicability of valuation exercises. Except for valuation techniques, it is also important to avoid double counting and thus overstating economic value.
Adaptability	Can a toolkit be tailored to local context? Can calculation mechanisms be altered, or just input data?
Scalability	Toolkits can be developed to be applied from landscape to parcel scale. LAs emphasise that UGI investments mostly exist of retrofitting, where the size of a project can vary from a single tree up to a wide urban park. Moreover, academics concluded that capturing the key 'network' aspect of GI requires flexibility in scale from a tool.
Generalizability	Ideally, a toolkit would be applicable across different socioeconomic, environmental, and geographical circumstances. Many tools are bound to specific regions, which reduces the possibility of transferring the application to other areas. On the other hand, detailed region-specific properties can result in more accurate local estimations.
Uncertainty	Given that infrastructure costs and benefits within urban environments are highly sensitive, further the generation of co-benefits is also volatile. Tools that include sensitivity into modelling and estimating are preferred. Tools that just provide point values lead to distrust.
Scenario analysis	To be applied as a strategic decision-support toolkit, a toolkit must be able to calculate different spatial planning scenarios and compare this to the current state of the urban landscape. This way, one can straightforwardly observe how projects affect the stock of ecosystem services. It also offers the opportunity to improve participatory decision making with local stakeholders.

Table 5: Summarised assessment of valuation tools, with evidence of the main characteristics for every evaluation criterion

	GI[a]	SV[b]	TR[c]	ER[d]	Q[e]	BS[f]				ESn[g]			A[i]	S[j]	G[k]	U[l]		SA[m]
						AR	T	Fb	UC	AR	DC	EA[h]				R	QRA	
NVE	x	ES	2	NE	Both	x	x		x	x		YB	Id	x	SE	x		x
i-Tree eco		ES	4	M	Both		x		x	x		Und.	Id	x	BT			
Gi-Val	x	B	2	C	Mon				x		x	TEV/NPV	Id	x	BT			x
CNT	x	B	2	C	NQ	x			x	x	x	YB	Id,Meth,Sub		BT			x
TESSA		ES	5	C	NQ	x				x		BB	Id,Meth,Sub		BT			
InVEST		ES	4	P	Bio	x				x		BB	Id		SE			x
EcoPLAN-SE		ES	3	P	Both	x		x	x	x		YB	Id	x	NG			x
GI Benefits valuation	x	B	1	NE	Mon	x	x			x		NPV, IRR, BCR	Id		BT			x
CAVAT		O	4	M	Mon		x		x			TEV	Id	x	BT			
B£ST	x	B	3	NE	Both	x	x			x	x	TEV, NPV, BCR	Id,Meth,Sub	x	BT	x	x	x

[a] GI = Green infrastructure.
[b] SV = Subject of valuation. ES = ecosystem services; B = benefit categories; O = Other.
[c] TR = Time requirement. Varying from 1 (quick assessment) to 5 (extensive time requirement)
[d] ER = Expertise requirement. C = expertise needed for calculations; P = expertise needed for programming; M = expertise needed for measurements; NE = no need for specific expertise
[e] Q = Quantification. Bio = Output in biophysical units; Mon = Output in monetary units; Both = Output in Bio and Mon units; NQ = No explicit quantification
[f] BS = Biophysical soundness. AR = Academic referencing; T = Time horizon of benefits; Fb = Feedback between ecosystem services/benefits; UC = Urban character.
[g] ESn = Economic soundness. AR = Academic referencing; DC = Acknowledges double counting; EA = Economic analysis
[h] YB = yearly benefits, TEV = total economic value; NPV = net present value; BB = benefits compared to baseline scenario; IRR = internal rate of return; BCR = benefit cost ratio; Und. = undefined
[i] A = Adaptability. Id = Input data for calculations adaptable; Meth = Methods to valuate adaptable; Sub = Subjects of valuation adaptable; NA = Not adaptable.
[j] S = Scalability – transferable over different spatial scales.
[k] G = Generalizability. SE = need spatially explicit data; BT = With benefit transfer methods; NG = Not generalizable.
[l] U = Uncertainties. R = Ranges for value; QRA = Quantitative risk analysis.
[m] SA = Scenario analysis

Table 6 Summarised overview of toolkit performance, where all tools are scored on the evaluative criteria on a five-point scale from best (++) to worst (--)

	Type of GI	Subject of valuation	Time requirement	Expertise requirement	Quantification	Biophysical soundness	Economic soundness	Adaptability	Scalability	Generalizability	Uncertainties	Scenario analysis
NVE	++	++	+	++	++	+	0	0	++	+	0	++
i-Tree eco	--	++	-	--	+	-	0	0	++	-	--	--
GI-Val	++	--	+	0	0	-	-	0	++	-	--	++
CNT	++	--	+	0	--	+	+	+	0	-	--	++
TESSA	--	++	--	0	--	0	+	+	0	-	-	++
InVEST	--	++	-	--	-	0	0	0	--	+	0	++
EcoPLAN	--	++	--	--	++	+	0	0	++	--	--	++
GI benefits tool	++	--	++	++	0	-	+	0	0	-	--	++
CAVAT	--	--	-	--	0	--	--	0	++	+	--	--
B£ST	++	--	0	++	0	+	++	+	++	-	+	++

2.4 Discussion

The specific objective of this literature review is to assess the possibility for widespread use in urban areas. Since urban areas bring forth specific challenges, it is necessary for a toolkit to take account of this city-specific context in order to be recommendable. Apart from this, the target customers that are considered in this review – local authorities – introduce additional requirements for the applicability of such toolkits. As can be concluded from reviewing the existing literature, the number of green infrastructure/ecosystem services toolkits including economic valuation practices is very limited, especially when it is compared with the number of biophysical and hydrological modelling tools. However, it must be stressed that the shortlisted tools are the result of literature reviews based on specific keywords, as explained in the method. Further, the tools that are studied in this chapter, are all scientific tools – or tools originating from academic research. Admittedly, other tools (e.g., from research firms or consultants) have been developed and used in practice. However, such tools would probably not pass our initial selection criterion of freely available decision-support tools. Still, where many tools facilitate modelling and planning (urban) environments and their biophysical features, the lack of economic valuation and comprehensive assessments stipulates a current gap in research. Nevertheless, aside from the usefulness of biophysical assessments, local authorities' decision makers and planners indicated that economic value is often required in order to convince relevant stakeholders, and thus a key component towards mainstreaming investments in urban green infrastructure. The results and discussion as they are presented, are most relevant to urban contexts in developed countries. Because the nature of green infrastructure investments in developed countries relies mostly on retrofitted solutions, this has been a key point of view in conducting the assessments of the valuation tools.

Since the assessment is based on the definition of 12 criteria, sometimes further simplified in indicative subcriteria, it must be stressed that the results as they are shown can be subject for discussion. It is for example self-evident that the assessment of biophysical soundness exceeds the limited selection of subcriteria as they are shown in Table 4 and Table 5. However, in order to support the interpretability and harmonise the objectives of this review with findings from literature, such tables provide a valuable oversight. Moreover, the criteria as they are defined, cannot be seen as independent parts of a comprehensive assessment. Criteria are often interdependent, given that handling a certain toolkit requires a lot of expertise, this will also result in higher time requirement for example.

These interdependencies are a key element in discussing GI/ES valuation toolkits. The interdependence and interference of ecosystem services, complicates accurately capturing the economic value, since it introduces the risk for double counting. Only three toolkits (Gi-Val, CNT and B£ST) provide users specific guidance in coping with this issue. InVEST on the other hand generates source for double counting in providing a multitude of different models, without consideration of interdependencies. Other toolkits often indicate to provide conservative estimates or omit the concept of double counting in general. The source for this lack of consideration of double counting on the economic side, may reflect the lack of considering feedback loops in ecosystem services production from the biophysical side. A clear oversight of the linkages between the ecosystem services that green infrastructure generates, as well as an oversight of the relationships between the social and ecological systems could benefit the reliability in economically assessing the value. This also relates to self-defined benefit categories as observed with Gi-VAL, CNT, GI Benefits Tool and B£ST. Deferring from published categorisations provides additional source for double counting.

Analysing the first two columns in Table 6 sets another concern for using current toolkits. Where half of the toolkits are specifically designed to facilitate green infrastructure valuations, only one of these utilises the ecosystem services approach to conduct the valuation exercise. Sticking to the ecosystem services approach is valuable since the concept is generally accepted and research in this field is improving rapidly. Gi-Val, CNT, GI Benefits tool, and B£ST all apply self-defined benefit categories. From literature research it shows that these roughly defined

categories provide additional source for double counting. This does not imply that the ecosystem services approach is free of double counting, through the interrelations of ES, complexity and non-linearity is inherent (Bennett et al., 2009; Raudsepp-Hearne et al., 2010). This results in temporal and spatial trade-offs (Rodríguez et al., 2006) and synergies (Bennett et al., 2009) that ought to be identified (Rodríguez et al., 2006), ideally toolkits are capable of this. Another argument to opt for the valuation of ecosystem services is its capability to conduct targeted studies. Furthermore, since most of the toolkits are a 'living mechanism' and subject to regular improvements, leaving the emerging field of ecosystem services is not advisable.
Toolkits that mention adaptations for densely populated areas and explicitly elaborate on urban issues are preferred. On this matter, there is extensive room for improvement. From the quantitative toolkits only Nature Value Explorer, i-Tree Eco and EcoPLAN-SE consider adaptations for the specificities of urban areas and are thus desirable within the scope of this review. However, since the urban environment often requires creative use of public space, inclusion of as many green infrastructure elements (e.g., green walls, green roofs) significantly contributes to the applicability. On this latter criterion, i-Tree eco is less convenient since it only evaluates urban trees/forests. EcoPLAN-SE on the other hand doesn't provide built-in features for green infrastructure types.

Regarding the time and expertise requirement, important trade-offs need to be made. Toolkits that can be performed fast and without experts, typically make use of default values. While default values are convenient – especially in initial planning phases - one must not forget that these can only provide initial indicative values in a project development process. In the urban planning and developing process, it is required that these valuations are performed by competent and critical people that understand the underlying valuation methods and the consequences of using default values and benefit transfer systems. After all, benefit transfer is an inevitable and precious technique for data/resource scarce environments, but one must account for the correspondence issues that will arise if this type of valuation is not applied with care (Plummer, 2009). Moreover, several tools that were studied (eg. Gi-VAL, NVE, …) claim that further research is required on the impact of green infrastructure types and the contributions of urban ecosystems. Given the current research gap, this underlines the fact that in applying benefit transfers one should be conscious of generalisation errors. It was found that toolkits relying on geographical information system (GIS) can provide a stronger scientific basis, while shortening the time requirement for data collection. Evidently, utilising geographically specific data improves the performance of quantification without requiring the user to provide many additional measurements. Moreover, including GIS analyses aids to identify areas where GI intervention is relevant, by layering data on different ecological functions (Hansen et al., 2019). Narrowing down the selection based on GIS, only Nature Value Explorer, EcoPLAN-SE and InVEST are left. The CAVAT tool on the other side is hardly applicable in the urban planning context that is considered in this review, especially if ex-ante valuation would be considered.

EcoPLAN-SE indicates that the methods have been designed for the Flanders region specifically and InVEST does not provide economic valuation for many ecosystem services. Thus, to perform a general basic valuation exercise, Nature Value Explorer appears to be the most reliable toolkit, for local authorities in Flanders (Belgium). Theoretically, this toolkit could be generalisable too if GIS data are provided by the user. This does however not imply that such generalised experiments would induce reliable results. Since most of the calculations are made with numbers specific to the Flanders region, spatially explicit data need to be provided to support accuracy. The limited suitability of generalizability limits the ability for widespread use. The values provided give an indication of the ecosystem services that are relevant to consider in making a GI investment. However, the manual also indicates that a few topics require more elaborate methods and expert analysis to generate accurate results. It is also noticed that Nature Value Explorer does not cover all ecosystem services. Especially in terms of cultural ecosystem services – although valuation methods are sometimes subject of debate – the model can still use improvements. The biggest shortcoming for Nature Value Explorer is the lack of explicit monetisation of temperature regulating services. Studies of energy savings resulting from green roofs and green walls indicate that monetary benefits from reduced energy demands comprise approximately 50% of the total monetary benefits (Foster et al., 2011). A single 8m tall tree could reduce annual residential heating and cooling costs with 8-12% (McPherson & Rowntree, 1993). Although these numbers are highly sensitive to the climate zone that is considered, they demonstrate the concern to consider the monetisation of this ecosystem service when it is aimed to perform a comprehensive monetary valuation of an urban green infrastructure investment.

A critical shortcoming that vastly influences the outcome of UGI is the notion of life-span assessments. In comparing grey and green infrastructure, it is noticeable that the advantage of GI clearly lies in the generation of multiple co-benefits. These co-benefits should be assessed on the lifespan of GI structures, which extends beyond current valuation practices for all toolkits. Moreover, social and environmental gains – although often hard to monetise – are likely to bring forth substantial benefits, especially when considering the number of beneficiaries in urbanised environments, which contribute to justifying UGI investments. In this regard, significant short-term social and environmental benefits could justify a potential long-term return on investment. Regarding scalability, most toolkits allow valuation of projects across varying landscape scales. Additionally, toolkits might benefit from including a spatial-temporal scale for different processes/ecosystem services in order to support appropriate assessment and decision making in the urban context, similar to the approach taken by Papadimitriou and Mairota (1996) for rural policy planning.

Another critique on the actual valuation tools is the lack of consideration of the cost-side. Like the net present value (NPV) in grey infrastructure, the costs need to be introduced to make a realistic argument for green infrastructure. In this regard, three essential parts that compose the (societal) cost-side to GI investments are to be taken into account: investment costs, maintenance costs (see Table 2: current barriers to GI adoption), and ecosystem disservices (not addressed in any of the tools). Only B£ST really elaborates on developing the economic case for green infrastructure. In the field of urban planning and management, terms as 'return on investment' are critical in decision-making. A guided example of cost calculation, depreciation and discounting regarding urban green infrastructure can aid local authorities in developing a credible business case, equivalent to what is common practice in grey infrastructure investments, the maintenance costs need to be included as well. Moreover, it should be taken into account that urban greening not only features ecosystem services, but also generate ecosystem disservices. The discussion on ecosystem disservices is emerging and especially important in urban greening management contexts (Lyytimäki & Sipilä, 2009). Especially in densely populated cities, some ecosystem disservices may introduce substantial value deductions through the number of beneficiaries (e.g., allergies), thus require attention. At the moment it is noticed the toolkits in this review either focus on biophysical assessments and provide quick economic guidance on the side, or either focus on monetising ecosystem services and neglect the biophysical foundation. Ideally, applying a toolkit would provide local authorities with the biophysical, economic, and social arguments that support the business case for urban green infrastructure. This includes scientifically sound valuations of biophysical, economic, and social impacts, and also at least a qualitative overview of 'invaluable' ecosystem services. Furthermore, the (limited) cost side of valuation toolkits illustrates a gap in actual research. Where the benefit side is often scientifically motivated by peer-reviewed default value data, no such practices are common in cost calculation. To make credible business cases for green infrastructure project development, both benefit and costs are expected to be scientifically motivated. On this matter, unit values on infrastructure and maintenance costs could improve the performance and field of application of valuation toolkits significantly.

To support realistic business cases, valuation toolkits are required to spend considerably more amount of caution on the uncertainties that are faced. By only providing point values, toolkits give the impression that we can perfectly predict future value. In what is discussed before, many elements that introduce uncertainty can be identified. First the interdependencies of ecosystem services, which have been explained to cause double counting. Secondly, the wide array of valuation techniques that are used to value ecosystem services and include limitations (e.g., travel cost method or contingent valuation studies). Thirdly, it was observed that executing valuations with the toolkits in other geographical areas entails the application of benefit transfer methods. Given the uncertainty that these practices generate for a valuation exercise, it is critical to have insight into the risks.

From another point of view, focus groups with officers involved in the urban planning and decision-making process highlighted shortcomings from their side. Where valuation toolkits put effort into scientifically supporting the case for GI investments, this scientific approach is less mainstream within local authorities, especially when it comes to the added value of urban green. Often, when offering green investments there is a sense of 'false satisfaction'. This perception of 'green is good enough' limits the potential added value of such investments, and this is a fundamental breaking point with grey infrastructure decision making processes and structure. In order to make public space management more evidence-based, guides for valuation of green infrastructure could be of value (CNT, TESSA). As stated in Matthews et al.

(2015) by a senior executive local government policy planner and urban designer: “demonstrating the multiple benefits of green infrastructure will build the support with developers and the public that is needed”. Whilst TESSA is not advised to put numbers on GI projects and is not adapted for urban assessments, it introduces an easily accessible and step-by-step elaboration on scientific evidence of the whole process in assessing a GI investment. Moreover, it is useful in conducting at least qualitative assessments that precede translation to monetary values, and as a mean of capacity building with non-experts, especially in the near future, when they plan to release an urban guide. In consulting with local authorities and conducting literature reviews, it was found that some toolkits are developing updated versions specific for urban contexts (e.g., InVEST, Nature Value Explorer, ECOPLAN) and other toolkits are under development (ARIES, Greenkeeper). The advancement towards tools specifically designed to serve as urban decision-support tools can only be supported. Both ARIES and Greenkeeper have indicated to release publicly available prototypes by the end of 2020, and both will use big data for ecosystem services valuation. Greenkeeper defines the use of big data as adopting: “a researched and layered range of data sources, combining freely available data sources with specifically commissioned smart data (e.g. mobile phone location data) and emerging research findings” (Greenkeeper, 2019). This transition towards big data applications in ecosystem services valuation may help to reduce the uncertainties and time/expertise requirements that were identified in this research. Importantly, these toolkits should be subject to a constant review and update. Current toolkits are often the result of research projects that phase out once the project period terminates. It is critical that these toolkits are developed in cooperation with their target customers (local authorities).

Building on the discussions in Chapter 1 regarding the limitations of ecosystem service valuation practices, particularly in decision-support tools, it is crucial to recognise that perceptions and values associated with GI can be socially constructed and vary significantly among different communities. Therefore, an integrated approach should emphasise community engagement and the incorporation of socio-contextual evidence, such as surveys, interviews, and participatory planning. This approach ensures that GI projects align with and accurately reflect the values, preferences, and needs of the local community, ultimately leading to more sustainable and socially accepted GI interventions. Even with these considerations, it's important to view valuation tools as complementary instruments that help initiate a constructive dialogue between decision-makers and the community. To acknowledge this aspect of GI valuation, Chapter 4 elaborates on the appreciation of local residents, which complements the decision-makers’ views that are studied in Chapter 3. We believe that including elements of different stakeholders’ GI value appreciation in a valuation tool adds to its practical applicability.

All the previous highlights factors that hamper the uptake of the decision-support tools in practice. We reveal how the science-policy gap is not solely caused by shortcomings from the scientific community and their toolkits, nor solely by shortcomings from local authorities’ decision-making processes. Therefore, aligning the needs of local authorities with the scientific methods to support informed decision making should be the fundamental idea to improve quick assessment toolkits for UGI. This must be an important objective for future green infrastructure research in general: bridging theoretical, scientific insight with the practical side of urban planners, developers, and decision makers. In Chapter 3, we do exactly this. By zooming in on local GI decision-makers, studying which arguments are (dis)regarded in the process of GI decision-making (potentially resulting from the political game), lessons are learned to incorporate in the development of a novel valuation tool that is introduced in Chapter 5.

2.5 Conclusion

In the rising urgency of building resilient and healthy urban environments, one of the main obstructions in making green infrastructure investments, is the lack of acknowledgement of the added value such investments generate. Since local authorities are restricted in resources, committing to time and money intensive valuation processes is not feasible on a project-scale. In an attempt to overcome this problem, valuation toolkits have emerged to provide the instruments for developers to conduct such valuation exercises. Nevertheless, it is noticed that such toolkits are not employed today, resulting in slow implementation of urban green infrastructure. In consequence, local authorities have no sense of value and are thus discouraged to make such investments and instead rely on subsidies.

This literature review has the objective to explore which valuation toolkits are available for local authorities at the moment to value urban green infrastructure investments, as well as identify the shortcomings and limitations of these tools. We can conclude that while some valuation toolkits operate from a strong scientific base, most of these toolkits are more concerned about simplicity. Because of this, tools are currently only fit for use in the early project development stages to get a sense of the ecosystem services that would be generated from the project. Ideally, the tools are the first step, followed by an in-depth and spatially explicit assessment of the most important ecosystem services. In the future, the development of toolkits that make use of big data could possibly contribute to overcome this requirement. However, this also implies the need for further research into current data gaps on urban ecosystems, urban green infrastructure and their ecological/socio-economic impacts.

Importantly, it must be stressed that this review does not attempt to undermine the biological and ecological importance of nature by reducing it to monetary values. Since it is objectified to support credible business cases for urban green infrastructure that can compete with grey infrastructure in a competitive context of urban space, monetary values are an inevitable instrument towards mainstreaming such investments. Having these numbers, endorsed by qualitative input on the ecological functions and processes, must be the main objective for profound assessments.

The threats of urbanisation often push back the quantity of urban green, hence the need for optimal quality. To benefit from locally optimal solutions, tools should be applicable at project-scale to landscape-scale and in different geographic and socio-economic environments. Because of this, we advise future GI tools to be GIS-based and open-source, so that local authorities can input their proper GIS-data and adapt methods if necessary. With the objective of building the business case for GI, future tools should pay additional attention to life-span assessments of UGI structures, the cost-side, and indicators of economic performance. To make the tools more realistic, a quantitative risk analysis should be included. In order to provide local authorities with the basis for business cases that objectify equal treatment with 'grey infrastructure', these are the minimum requirements. Ideally, tools would even be able to distinguish between the beneficiaries of the ecosystem services that are generated through urban green, which could mean a next step towards sustainable financing of such projects. Finally, another critical outcome of this review is the trade-offs that are to make by valuation toolkits. Since the evaluative criteria are often correlated, valuation toolkits must find balances (e.g., simplicity – scientific soundness). In our opinion – and relevant for toolkit developers - this requires valuation toolkit developers to utilise participative approaches to design such instruments. In consulting local authorities and identifying their specific hurdles and requirements, scientists can compose frameworks that are tailor-made and readily usable to be put into practice and contribute to the attractive, healthy and climate resilient urban landscapes of tomorrow.

Further research should aim at filling the gaps that are demonstrated in this literature review. By acknowledging the specific requirements and insights and the shortcomings of actual valuation toolkits, it should be objectified to compile advanced valuation methods with a thorough scientific base. Eventually, studying the total economic value and its beneficiaries, appropriate finance methods should be introduced. Since it is observed that valuation toolkits are in constant development, we are convinced that the insights from jointly (academic and local authorities) delivering these cases will provide the opportunity for current toolkits to be validated, appropriately updated, as well as for toolkits that are under development to add significantly to the actual state-of-the-art.

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Chapter 3
A discrete choice experiment to analyse the science-policy gap in green infrastructure

In this chapter, we study the use of ecosystem services knowledge in policy implementation, more specifically in the local GI decision-making processes. In Chapter 2 we described how valuation tools have been proposed to enhance the uptake of GI. Yet, it is noticed that such scientific tools are barely used by local authorities – the supplier of public green infrastructure. To deepen our understanding of employing these GI/ES valuation tools in practice, this chapter aims to identify how ES knowledge (as would be generated by such a tool) would be used in a decision-making process. In this chapter, we use a discrete choice experiment to provide insights into how decision-makers expect a hypothetical GI case to be valued in their municipality. A unique sample of 568 local decision-makers in Flanders, Belgium, collects evidence and provides unprecedented insight in the local GI decision-making practices, and how the local political game influences which arguments are (dis)regarded. Because local decision-makers are ought to serve the community, this chapter provides a basis for comparison in Chapter 4, where we explore (dis)similarities between residents and decision-makers' GI perceptions and priorities. By delving into the dynamics of local decision-making, this chapter enhances our comprehension of current common practices which facilitates the customisation of solutions (see Chapter 5) that bridge the knowledge gap between science and policy.

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3.1 Introduction

Humans appreciate green space. This statement became abundantly clear during the covid-19 pandemic. People retreated to local parks, rediscovering natural areas in urban peripheries, and attempting to flee the city. In the aftermath of a period of lockdowns, working from home, and social constraints, many countries record rising property prices, especially for homes with gardens and properties in the vicinity of publicly accessible green space (Marsh, 2020; "Price of homes with gardens hits 4-year high," 2021). This behavioural shift provides clear examples of how people directly attribute (monetary) value to natural areas, illustrating the economic side to ecosystem services research. Multiple studies have demonstrated that people are willing to pay more to live close to nature and have green elements in their vicinity (Kong et al., 2007; Łaszkiewicz et al., 2019; Zhang et al., 2020). The practice of ecosystem services valuation is gaining importance in recent literature. In fact, many studies economically approach the demand-side for GI elements, expressing willingness-to-pay (WTP) or socioeconomic benefits that accrue to citizens from (public) investments in green infrastructure (e.g., Tian et al. (2020); Kolimenakis et al. (2021); Latinopoulos et al. (2016); Manso et al. (2022); Mell et al. (2016)). In public decision-making processes, it would thus make sense to incorporate these values people attach to and benefits people gain from green elements in their living environment.

The topics of (monetary) ecosystem services valuation (ESV) and utilisation are however debated (Stephenson & Shabman, 2019). Given the incommensurability of different ecosystem services' impacts, the appropriateness of such valuation exercises can be questioned. One additional critique on current ecosystem services valuation practices is the underlying assumption that serves as one of the main motivations for executing valuation exercises. Many ESV applications objectify knowledge acquisition as such, which is then expected to lead to desirable and informed decision-making on spatial planning and development issues (Primmer et al., 2018). The starting point of this argument is that valuation studies will feed into decision-making as a mean to recognise trade-offs (de Groot et al., 2010), or that it will facilitate scenario comparison through cost-benefit analyses. However, studies highlight that the assumption that decisions are made in rational and systematic ways based on the available information, is often invalid (Kieslich & Salles, 2021). In reality decisions are the result of trade-offs that often don't result from mere linear-rational decision processes (Cowell & Lennon, 2014). Decisions on spatial planning are instead likely to result from iterative processes, strategic knowledge utilisation and finding compromises between different stakeholder groups (Haines-Young & Potschin, 2014; McKenzie et al., 2014). Sometimes decisions can even be overly political (Cairney & Oliver, 2017). This dimension of policy design and knowledge utilisation is underrepresented in the current 'supply-driven' ESV literature (Marre & Billé, 2019), where we assume that more knowledge straightforwardly impacts decisions. According to van Stigt et al. (2015) little is known about how decision-makers perceive knowledge to be of use in planning processes.

On many occasions, design plans for public spaces focus on grey infrastructure, subsequently complemented by fragmented GI elements as an afterthought, rather than as an essential component (Mell et al., 2016). Nevertheless, cities play a key role in responding to climate change (Giest & Howlett, 2013), and the authority to implement GI practices is with local administrations

(Slätmo et al., 2019). This leaves responsibility for climate adaptation largely with local governments, who rely on local capacity and competence (Bowen & Lynch, 2017). Thus, much depends on the willingness and ability to invest the available resources at municipality-level. After all, holistic valuation assessments of GI are often complex and time consuming (Ian C Mell, 2017; Smith et al., 2019), due to the wide range of benefits or ecosystem services that can be delivered through GI. It is unrealistic to assume that municipalities have the capacity to base all their decisions on such assessments, meaning that they often have incomplete understanding when they make strategic choices. These resource allocations are implicitly linked to trade-offs in public decision-making processes.

The notion of the importance of trade-offs in spatial planning, leading to land-use or management choices with their resulting impact on the delivery of ecosystem services is thoroughly described by Turkelboom et al. (2018). They argue that knowledge on trade-offs within decision-making bodies is lacking and that insights in the causes and mechanisms behind such trade-offs would eventually lead to "more effective, efficient and credible management decisions". Decisions on smaller-scale spatial planning initiatives happen within local governments, subject to the above issues. In this study we build further on this argument, approaching our analysis of trade-offs and decision-making processes from a political and economic viewpoint. To reveal the trade-offs that take place within local authorities, a discrete choice experimen was initiated. DCEs have been conducted in previous research related to willingness-to-pay for green space (Bronnmann et al., 2020; Liu et al., 2020) While several papers have approached urban green infrastructure (UGI) to assess added value by interviewing local residents, tourists or other *users of UGI* (Derkzen et al., 2017; Shr et al., 2019), this research empirically studies experiences and perspectives with the intended *target users of ESV*: local authorities (McKenzie et al., 2014). Until now, studies on LAs' behaviour are limited to identifying barriers to uptake of UGI at differing institutional levels (Back & Collins, 2021; Matthews et al., 2015; O'Donnell et al., 2017; Thorne et al., 2018; Wihlborg et al., 2019) and determinants of adoption (Carlet, 2015). This is the first study to combine qualitative and quantitative evidence from actual GI decision makers in local authorities, to provide insight into the decision-making processes at the supply side of GI.

The choice experiment is based on five attributes expressing both the costs and benefits of a fictitious scenario of a neighbourhood park. Thus, we move beyond the approach of ES trade-offs to realistic GI decision-making trade-offs combining resource restrictions and benefits. Since previous research with decision-makers has indicated that ES are often considered in alternative wording, we opted to frame our ES as benefits to serve respondents in a realistic and consistent scenario. By challenging respondents to anticipate the views of all the stakeholders within their municipality and their positions on the green infrastructure scenario, we try to move respondents away from the mere subjective to an expression of intersubjectivity within the organisation (Klauer et al., 2013). Moreover, Klauer et al. (2013) argue that successful decision-making is the result of this power of judgment to reach well-balanced decisions, which requires suitable heuristics to bridge these different visions. In this paper we have attempted to expose some of these existing heuristics in local green infrastructure decision-making.

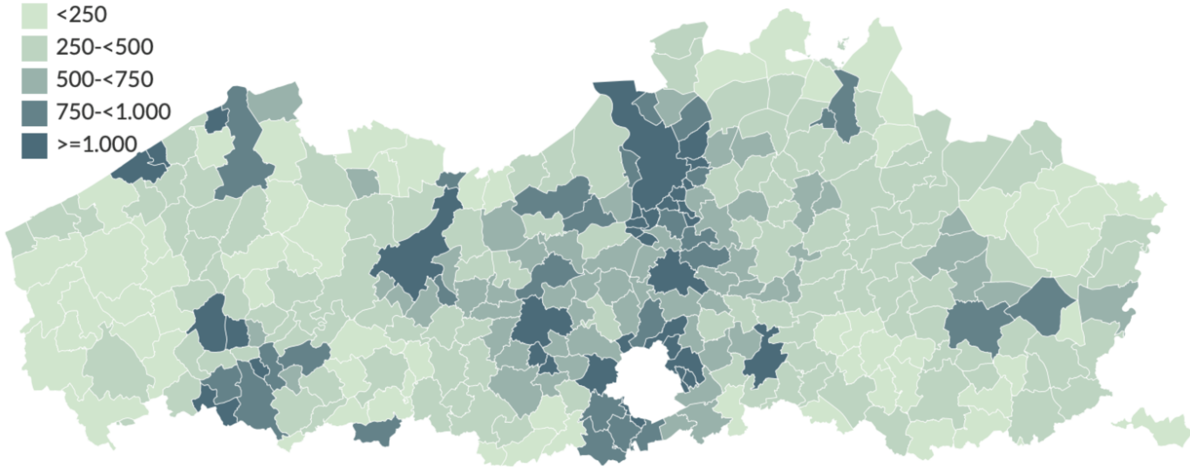
We research how the availability of information from ecosystem service valuation is expected to be used in local authorities today, by people involved in the day-to-day government. This way, we are able to identify structural hurdles in the current implementation gap (Levrel et al., 2017), their implications and how the role of ecosystem service valuation could be redefined. On the other hand, we also provide reflections on the policy design and its impact on GI decisions. Lastly, overarching bodies that are often encouraging investment in greening solutions, will be able to target campaigns or financing instruments specifically towards current bottlenecks for GI investments, so that LAs would be more inclined to consider them. To our knowledge, this is the first paper to execute a discrete choice experiment about public GI decision making, with decision-makers and to directly assess (strategic) knowledge utilisation regarding GI within local authorities. Additionally, as Haines-Young and Potschin (2014) mentioned, studies should also explain why knowledge is occasionally disregarded, where we try to make the bridge with political-psychological hurdles characteristic of GI investing. This study will therefore offer a complementary part to previous exploratory, qualitative studies of how ES/GI knowledge (ESK) is affecting decision-making (Mekala & Hatton MacDonald, 2018).

3.2 The Institutional Context

This research was conducted in Flanders, Belgium. Flanders is characterised as one of Europe's most densely built regions. Flanders has a surface of 13.625 km^2, for 6,6 million inhabitants, so the average population density is 487 inhabitants/km^2 (Statistiek Vlaanderen, 2021a). Significant regional differences in urbanisation and population densities exist. Figure 8 represents the population density of the Flemish region. Apart from the largest cities (Antwerp and Ghent) and their agglomerations, we observe high population densities in the diamond Antwerp-Ghent-Leuven-Brussels. This diamond, which covers parts of the northern province of Antwerp and the East Flanders and Flemish Brabant provinces. Easternmost Limburg province and westernmost West Flanders province clearly show lower population densities.

A classification system for Flemish municipalities based on demographic, economic, spatial and natural indicators and the Flemish Spatial Structural Plan was established in the *VRIND-classification (Statistiek Vlaanderen, 2021b)*. This classification subdivides the 300 Flemish municipalities into nine classes with similar characteristics. The distribution of the different classes over the five Flemish provinces which provide an indication of the structural regional variation can be found in Appendix 3-A.

Figure 8 A map displaying the population densities in the region under investigation, Flanders, Belgium



Politically, local authorities are at the most decentralised governmental level in Flanders. These local administrations consist of two bodies with different responsibilities, the College of Mayor and Aldermen (executive power) and the local council (legislative power) (Vanneste & Goeminne, 2020). Legislative cycles last 6 years. In the Flanders region, a spatial structural plan (RUP – Ruimtelijk Uitvoeringsplan) guarantees the land use on different scales of the territory. Regional, provincial, and municipal spatial structural plans exist that secure the spatial design and management, authorised activities and planning regulations for areas that belong to these respective levels. In our discrete choice experiment a neighbourhood park is examined, which would fall under the authority of the municipal level. To avoid a part of the (highly political) discussion on land use, we assume for the hypothetical scenario that the designation of this land as green space has been agreed upon and is already captured in the spatial implementation plan.

One of Flanders' biggest challenges is urban sprawl, with over 33% of its territory occupied by settlement area, characterised by a high degree of ribbon development and urban sprawl (Peeters et al., 2017; Vermeiren et al., 2018); there is little unclaimed land in Flanders. Moreover, the high population density, urban sprawl and a highly privatised housing market mean that competition for unclaimed land is fierce and many stakeholders are involved (Bergmans et al., 2017). Scattered development requires 4,5 times more sealed surface per building compared to buildings in urban centres. This loss of open space results in losses in ecosystem services that are 4,5 times higher than when people would centre in urbanities, so that the benefits in terms of ecosystem services of preventing further landscape fragmentation and reopening surfaces amount up to 250 to 400 million euros per year by 2050 (Vermeiren et al., 2019).

These findings illustrate the significant gains in ecosystem services that can be reaped from integrating green infrastructure in the public domain. The responsibility to initiate such interventions lies with local governments. However, it has never been studied what the main determinants for decision-making within these local authorities are, especially regarding greening projects or projects aiming at reopening sealed surfaces. The case of Flanders provides an interesting example of how densification and urbanisation should be executed carefully and sustainably to prevent the actual threats from happening. Actually, Flanders aims to protect open spaces through the highly debated "building shift", which was introduced as the "concrete stop" in 2016. Coming from a daily average of 6-7 ha of land being taken in 2018, the Flemish Government plans to reduce this number to zero by 2040 (Buitelaar & Leinfelder, 2020). This should lead to densification of residential areas and safeguard existing open spaces. According to the Association of Flemish Cities and Municipalities (VVSG) the responsibility to reach these targets will be highly dependent on local authorities, with considerable financial implications (Debast, 2020).

3.3 Method

3.3.1 Theoretical background

Choice modelling (CM) is a stated preference technique to explicit preferences towards characteristics or attributes of certain goods. CM relies on the idea that any good can be described in function of its attributes (or characteristics) and their levels (Bateman et al., 2002). Unlike contingent ranking/rating and paired comparisons methods, discrete choice experiments can provide welfare consistent estimates according to Bateman et al. (2002). In this context, DCEs are adopted for valuing non-market goods and services. In a DCE, a hypothetical setting is created, where respondents are confronted with multiple choice tasks. In a choice task, a respondent is expected to choose out of a limited amount of choice alternatives for their preferred alternative. Every choice alternative is composed of a combination of levels of different attributes.

Choice experiments build on the random utility theory, where individuals are assumed to choose for the utility-maximising option when confronted with choice alternative. This way, DCE can be used to provide an explanation of human choice behaviour (Louviere et al., 2010). The utility function is depicted by (1).

(1) $U_j = V(\beta, X_j) + \varepsilon_j$

Where utility U derived from choice alternative j depends on the function V (the deterministic part), defined by the attribute levels, ε_j (a stochastic component) is a random error term, X_j is a vector containing attribute levels for alternative j, and β is a vector of estimated coefficients (Hauber et al., 2016). Through surveying people related to a certain organisation (in this case a local authority), the random utility theory applies to the organisation, rather than the individual respondent. Applied to (1), we assume that the utility that a municipality j derives from a certain choice alternative is approximated through the expertise of a representative of this municipality.

3.3.2 Consistency tests

Since DCE relies on RUT, choice models can be vulnerable to threats of choice inconsistencies. Although the occurrence is expected to be more frequent in environmental economics because of unfamiliar goods/services, such analyses are still rare (Mattmann et al., 2019). Scarpa et al. (2007) recommend incorporating behavioural tests to identify inconsistent preferences and to evaluate sensitivity to inclusion or exclusion of inconsistent respondents. Hence, similar to Scarpa et al. (2007), two dimensions of choice inconsistency are assessed: monotonicity and stability.

First, to gauge monotonicity, respondents were subjected to a dominance test, which is applied in 25% of DCEs in health economics examined by Tervonen et al. (2018), but less frequently observed in environmental research. In a dominance test, respondents are exhibited to a choice set consisting of a dominant option: option A is at least as good in every attribute as option B, and better on at least one attribute. Opting for the inferior alternative B could – according to the axioms of RUT – be a sign of inconsistent preferences. Many studies in health economics recognise the added value of removing respondents who don't comply with monotonicity (Tervonen et al., 2018), and it was applied in environmental economics too by Scarpa et al. (2007).

Next, every respondent received a duplicate choice task to test for stability. Before the actual choice experiment, an exemplary choice set is provided to ensure respondents fully understand their task. This exemplary choice set then reappears in the actual choice experiment.

3.3.3 Statistical analysis

Often, DCE data are analysed through conditional logit (CL) or multinomial logit (MNL) models. However, two limitations made CL modelling less favoured for our analysis. (1) CL is unable to account for preference heterogeneity, (2) the *independence of irrelevant alternatives* (IIA) property on which CL would presumably be violated. Moreover, MNL too assumes that preferences across respondents are homogeneous (Srivastava et al., 2020). Thus, to account for unequal preferences between respondents and relaxing the above conditions, the Hierarchical Bayes (HB) method was applied to estimate the individual part-worth utilities for the attributes in the DCE (Louviere et al., 2010). In HB models, MNL is still the underlying choice-probability model, but attempts to model responses from each individual, and not all observations in the sample (Hauber et al., 2016). This way, HB guarantees consistency and efficiency of the results when conditions are more relaxed (Byun & Lee, 2017).
Choices in two levels are iteratively estimated using HB:

1. The lower or likelihood level: through conditional logit, individual choices are modelled (displayed in equation (1))
2. The upper or sample level: distributed multivariate-normal, characterising the heterogeneity among respondents (visualised in equation (2))

$$(2) \qquad \beta_n \sim N(b, W)$$

With β_n the individual-specific preference parameters, b the overall preference means and W the variance-covariance matrix of preferences across respondents. The mean of the posterior is an equivalent estimator to MLE, and the standard deviation of the posterior is equivalent to traditional standard errors for the estimator (Train, 2001). So, the posterior means calculated by the HB algorithm, are the sample's average of the parameters β_n (Hauber et al., 2016). Thus, the Bayesian approach makes estimations of the posterior distribution of the parameters by coupling the likelihood function of our data with the prior distributions of the parameters (Byun & Lee, 2017).

After estimating the main-effects model (15,000 Bayesian iterations), the variable importance is assessed. This will reveal which attributes weigh the heaviest in the decision-making process. The variable importance is independent of the choice model and the fitting method. Intuitively, if an attribute is a decisive factor to the predicted choice response, variation in this attribute will generate high variability in this response. The total effects terms for all attributes will be computed as these prove useful for sensitivity analysis and provide information on the non-additive model parts as well (Saltelli, 2002).

3.3.4 Design of DCE

The design of DCE consists of three main stages: selection of attributes and assigning attribute levels, and designing choice sets (Mangham et al., 2008). This was attained step by step. Initially, the authors composed a longlist of attributes that were identified as relevant to the research question from existing literature. Next, several internal discussions with the co-authors took place. Afterwards, external experts and professionals in urban decision making were consulted to discuss the relevance and the face validity of these attributes. This resulted in a gradual reduction of the number of attributes. Another outcome of these discussions is that attributes and their respective definitions were refined in function of the hypothetical scenario and in function of what speaks to decision-makers. From existing literature, realistic levels were produced to serve as reasonable estimations for green space costs and impacts. Several rounds of feedback resulted in a consensus on the attributes and levels most appropriate to the research questions and respondents would be served realistic situations, in accordance with the hypothetical scenario. Attributes that belonged to the longlist were explicitly said to be held constant over all choice options (Bateman et al., 2002). The scenario was brought to respondents in a video, again to familiarise and engage respondents. The outline of this video is written below.

A high degree of detail was put in the hypothetical scenario to exclude interfering and underlying factors to influence the outcomes of the choice experiment. It was described to respondents in an informative video as follows:

"Welcome to 'Oostwijk'. Oostwijk is a neighbourhood in your municipality. Oostwijk can be characterised as a residential area with predominantly terraced houses. The average private garden surface in Oostwijk is 40 m^2. Demographically, Oostwijk hosts a combination of young families and people aged 65+, with a population density of 700 inh./km^2. 85% of the inhabitants have access to neighbourhood green[5]. In this neighbourhood, the local government is looking to redesign an area with a vacant building and wasteland, both already owned by the municipality. The destined area is 1 ha (100-meter x 100-meter) and is inaccessible today, it will be redesigned as a public park. This redesignation to green space is accepted in the regional decree and spatial implementation plan. Studies with respect to soil remediation or preparatory works have been done and don't influence your choice."

We chose to approach the more general *green infrastructure* concept through a neighbourhood park. This is based on the characteristics of parks on the one hand and the objective of the study

[5] 'Neighbourhood green' is used by the statistics department of the Flemish government and is defined as % of people living within a 400 meter radius of publicly available green space with a minimum size of 0,2 (https://www.statistiekvlaanderen.be/KSMD-86-nabijheid-van-groen). The average in Flanders lies at 96%.

on the other. Since identifying trade-offs between the different co-benefits was one of the objectives, the type of green infrastructure in the choice experiment needed to be capable to deliver different types of ecosystem services; implying biophysical, cultural and economic benefits. On top of that, the experimental set-up needed to be relatable, requiring a degree of familiarity with all respondents, being consistent in interpretation. Hence, more innovative green infrastructure types such as green roofs and green walls were avoided to minimise the impact of any information bias, since some officers/politicians might be familiar with green roofs/walls, while others may be less so. The attributes and corresponding levels are defined as depicted in Table 7.

Table 7 Neighborhood park attributes that were included in the choice experiment, their respective descriptions and levels

Attributes	Description	Levels
Cost	The total cost for the redesign of the wasteland area. These include preparatory works and the effective realisation	€350,000 €500,000 €650,000
Yearly maintenance cost	Green space – as grey space - requires maintenance. The yearly maintenance costs include all maintenance costs: labour costs, outsourced services, materials, …	€10,000 €20,000 €30,000
Deferred costs	As a result of the increased infiltration and water buffering capacity through the additional green space, an increase of the capacity of the local sewage system can be deferred in time. The cost of this deferred investment is €1,5 million, constant over time.	€1,5M (deferred) with 10 years €1,5M (deferred) with 20 years €1,5M (deferred) with 30 years
Recreational value	The number of visits is co-dependent on the facilities of the park. The recreational value is depicted through the number of yearly visits to the park (≠ visitors).	10,000 yearly visits 20,000 yearly visits 30,000 yearly visits
Climatic impact	Green space will capture carbon, having a positive influence on the battle against climate change. In the choice experiment this impact is measured in equivalents of yearly CO_2 emissions per family in Flanders (average of 3,5 tonnes of CO_2 yearly)	Emission of 5 families yearly Emission of 15 families yearly

After this, instructions for the choice experiment itself and an example of such a choice task were provided. Respondents were repeatedly requested to opt for the alternative they expect to be chosen in their municipality, not their personal favourite.

Figure 9 Example of a choice task in the decision-makers' choice experiment

Attribute	Option 1	Option 2	Option 3
Investment cost	€ 500.000	€ 350.000	*Everything remains as is*
Maintenance cost	€ 20.000 yearly	€ 20.000 yearly	
Deferred cost of sewage construction	€ 1,5 millions postponed with 20 years	€ 1,5 millions postponed with 10 years	
Recreational value	25.000 yearly visits	10.000 yearly visits	
Climate impact	Yearly equivalent of CO_2 emissions of 15 families sequestrated	Yearly equivalent of CO_2 emissions of 15 families sequestrated	

Option 1 Option 2 Option 3

The experimental design was executed through JMP Pro 15, resulting in a Bayesian D-optimal design, leading to an efficient DCE design. Our choice design consists of 10 choice sets of three choice alternatives: two unlabelled hypothetical alternatives and a no choice option. This means that users are confronted with 10 different choice tasks, where there are differing 'Option 1' and 'Option 2' alternatives with varying levels of the attributes. The choice task was supposed to realistically reflect an actual decision process. Hence, a status-quo option was included for every choice set. In this status-quo, the spatial interpretation of the hypothetical scenario would not change from the situation today, resulting in zero levels for all the attributes. The two hypothetical choice alternatives are fully described in each choice set, based on their respective levels. Figure 9 provides an example of such a choice task. Each respondent was assigned a random order of the choice sets.

After the experimental design, the choice survey was subjected to a pre-testing phase, where 20 individuals pre-tested the survey and the face validity of the questionnaire. Feedback on the experimental set-up, technical functionalities of the online survey, time requirements, potential bottlenecks, etc was provided to improve the questionnaire. A selection of decision-makers with varying profiles was sampled for this task. These decision-makers were carefully chosen and included individuals from political mandates (a mayor, aldermen, local councillors) and non-political functions (local environmental officers, spatial planners, an expert from the Flemish Association for Public Green (VVOG)). After receiving feedback from the pilots, adaptations to the survey mainly included clarifications of the hypothetical scenario, addition of attribute definitions, small modifications to the attribute levels and graphic support of the survey.

Before the actual choice experiment, respondents were questioned about the decision-making processes within their municipality. This encompassed Likert-scale questions aimed at assessing the level of municipal awareness regarding the impacts of climate change and the extent to which specific GI features are taken into consideration. After the choice experiment, a series of questions gauged personal attitudes towards a selection of environmental and sustainability statements. At the end, respondents were asked to leave limited demographic information (municipality, gender, age, and function). Additionally, we sought information regarding the respondents' political affiliations. If they identified as "political," they were then prompted to select either "(local) majority member" (i.e., in power) or "member of the (local) opposition" (i.e., not in power)

3.3.5 Data collection

The distribution and collection of discrete choice experiments was executed through on-line surveys with Qualtrics software. Since the target group for this study consists of local public decision-makers, most respondents were reached through targeted mailing, using contact details of local governments' employees and councillors in Flanders. Our mailing list was composed of all public officers engaged with management functions (CEOs, financial directors, executives) and those public officers employed in the fields of sustainability, environment, greening, economy, public spaces, and spatial planning. Next, all politically engaged local decision-makers were added to the mailing list: mayors, aldermen and local councillors. Through targeted mailing 7320 mails containing individual links were sent. Recipients were sent one reminder two weeks after the initial notification e-mail. Apart from targeted mailing, respondents were also collected through newsletters and news articles sent out by several regional associations such as the Flemish Association for Cities and Towns (VVSG), Flemish Association Public Green (VVOG) and BOS+, a Flemish environmental association specifically promoting natural and forest conservation and qualitative greening with an extensive municipal engagement.

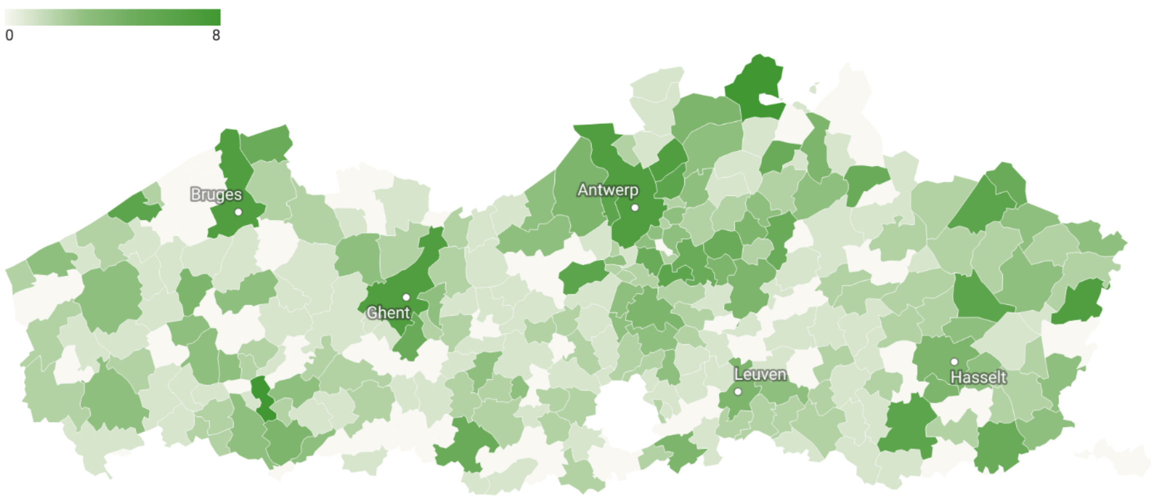
Data collection was conducted from December 2020 to February 2021. A total of 1095 individuals participated, of whom 568 individuals provided a complete survey response. We incentivised respondents to fully complete the survey by offering to donate €1 to a charitable cause of their choice upon completion.

3.4 Results

3.4.1 Descriptive statistics

Out of the 300 Flemish municipalities, 568 respondents from 235 municipalities completed the online survey (78% of municipalities represented). Figure 10 displays the relative frequency observed for these municipalities.

Figure 10 Map of Flanders, Belgium with an oversight of the number of respondents per municipality taking part in the study



These observations correlate to Figure 8, displaying population densities in Flanders. Only in municipalities in the south of Brussels, bordering the Walloon region (so called *municipalities with facilities*), we observe a slight underrepresentation in the sample, possibly as a result of a language barrier. In Appendix 3-A, the spatial VRIND-classification (introduced in 3.2) for Flemish municipalities is applied to our sample, with distinction between the five Flemish provinces. This provides more insight into the representativeness of the sample. On average, 2.4 decision-makers per municipality filled out the survey.

Demographics of the respondents are displayed in Table 8. The share of highly educated people is a result of the target audience of this survey. It is not surprising that the sample of decision-makers has a higher proportion of people that enjoyed higher education compared to the general population. Classified under the heading of 'public officer' are many function titles, often differently structured across municipalities: local executives, staff members, members of the management team, strategic and policy officers, heads of departments, environmental officers, greening officers, sustainability officers, mobility officers, financial officers, experts spatial planning and public works, *etc*.

Table 8 Demographics of the respondents in the sample of Flemish local decision-makers

Categorical variables		**Amount**	**% of sample**
Gender	*Male*	353	62
	Female	207	36
	Prefer not to say	8	1
Educational level	*Higher education – University*	266	47
	Higher education - College	247	43
	Secondary education	53	9
	Primary education	1	<1
	Other	1	<1
Function	*Mayor*	18	3
	Alderman/woman	100	18
	Councillor	134	24
	General manager	24	4
	Financial manager	8	1
	Public officer	284	50
Use of neighbourhood green	*Daily*	60	11
	Weekly	248	44
	2 times per month	86	15
	Monthly	59	10
	Less than monthly	115	20

Numerical variables	**Min-Max**	**Mean**	**SD**
Age	20-77	47	11,5
Number of years active in municipality	0-43	10.2	9.7

3.4.2 Respondents' perceptions on GI decision making

To get a thorough understanding of current local decision-making processes regarding greening and green infrastructure, respondents were asked exploratory Likert-scaled questions. First, we gauged how respondents perceived the awareness of several environmental issues within their municipality. After this, respondents were expected to indicate the frequency of different indicators of *informed decision-making* regarding greening investments. Results of the above can be found in Table 9.

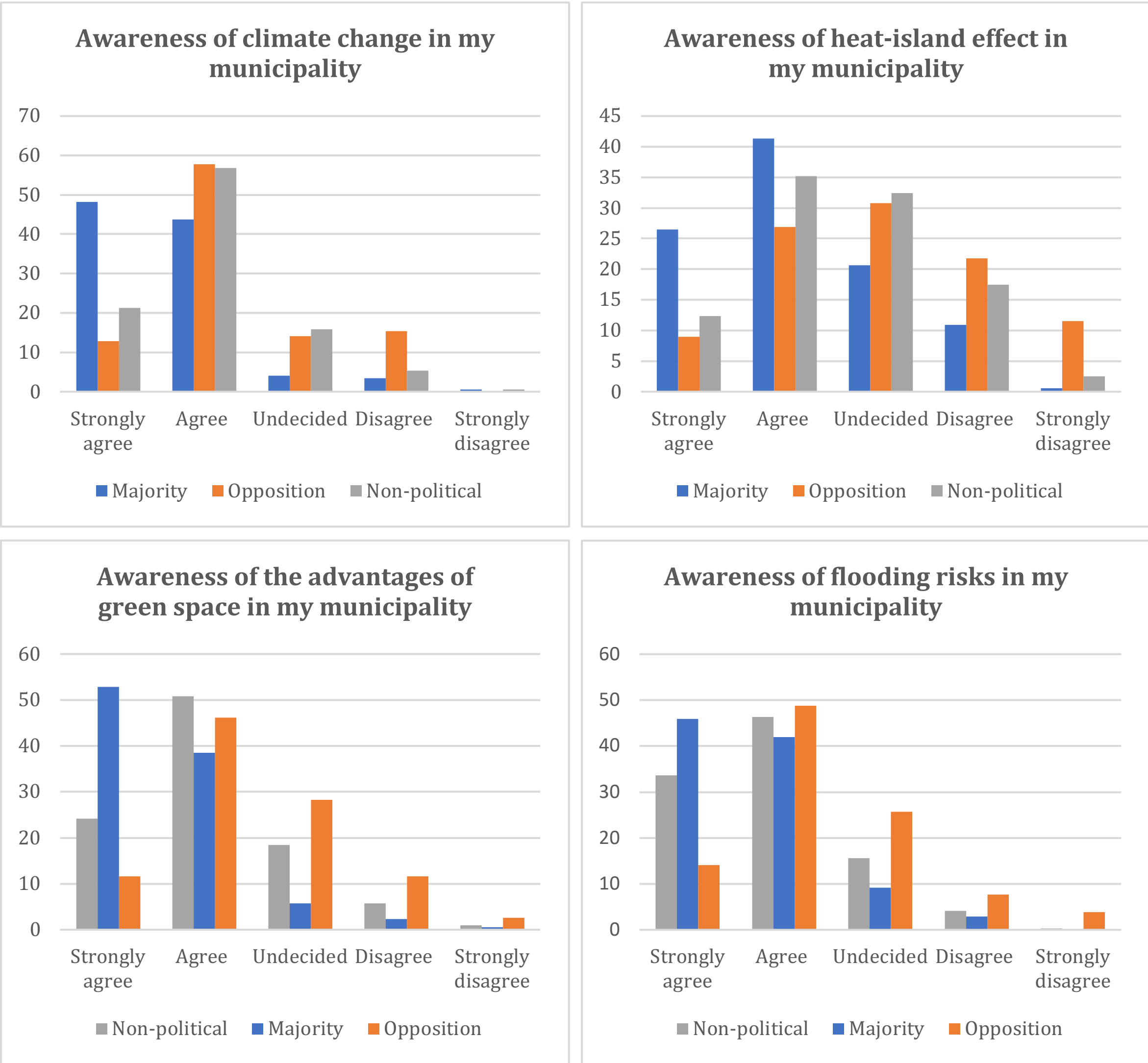
Table 9: Respondents' perceptions on green infrastructure and its consideration in local decision-making processes

In the administration of my municipality, people are aware of …	Strongly agree	Agree	Undecided	Disagree	Strongly disagree
… the impact of climate change on our living environment (%)	162 (29)	300 (53)	68 (12)	35 (6)	3 (<1)
… the heat-island effect (%)	93 (16)	204 (36)	162 (29)	91 (16)	18 (3)
… flooding risks (%)	198 (35)	257 (45)	85 (15)	24 (4)	4 (<1)
… the advantages of green space (%)	178 (31)	263 (46)	90 (16)	31 (5)	6 (1)
In my municipality…	**Always**	**Often**	**Seldom**	**Never**	**I don't know**
… investments in public green are based on numbers of potential impact (%)	46 (8)	192 (34)	211 (37)	53 (9)	66 (12)
… people not only consider quantity, but also quality of public green (%)	169 (30)	261 (46)	118 (21)	8 (1)	12 (2)
… biophysical benefits are considered in the decision-making process (%)	116 (20)	248 (44)	168 (30)	16 (3)	20 (4)
… economic benefits are considered in the decision-making process (%)	87 (15)	191 (34)	190 (33)	52 (9)	48 (8)
… cultural/social benefits are considered in the decision-making process (%)	94 (17)	300 (53)	128 (23)	25 (4)	21 (4)

From the above, we see that most of the statements return desirable majority (Strongly agree/Agree and Always/Often) responses from a societal point-of-view. However, considerable heterogeneity in the responses is observed when setting these out over different respondent characteristics.

When the sample is divided into political subcategories, a more nuanced portrayal of the situation can be derived. In Figure 11 we distinguish between 'member of the majority (i.e., local ruling party)', 'member of the opposition' and 'non-political (general/financial managers and public officers)'.

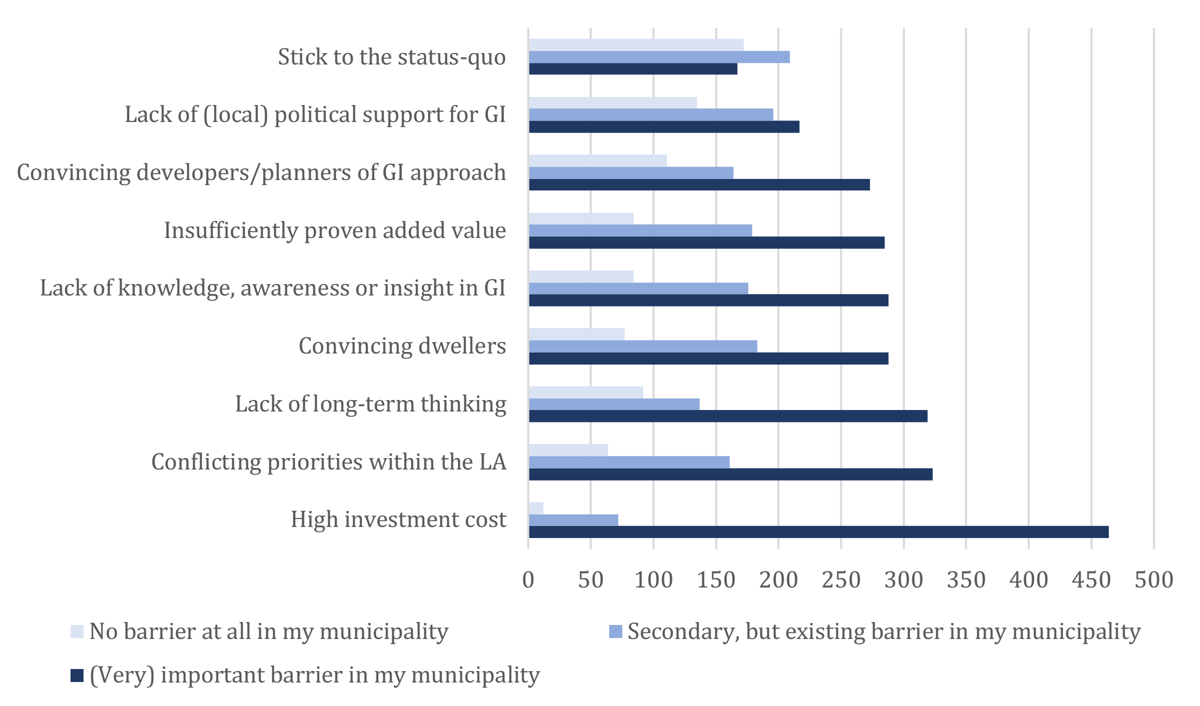
Figure 11 Perceptions on the decision-making process of green infrastructure investments across decision-makers' political engagements (majority/opposition/non-political)



From these graphs we conclude that members of local majority parties (mayors, aldermen and councillors) tend to rate awareness within their administration higher, especially on the 'Strongly Agree' category. On the other side, members of the opposition systematically rate the awareness lower, while public officers choose for the middle way. Similar graphs for the indicators of informed decision-making can be found in Appendix 3-B. When asked if respondents expect that accessible and clear numbers on costs and benefits of green infrastructure would help steer the decision-making process, 492 (87%) responded affirmatively, while 27 (5%) respondents believed it wouldn't. On the other hand, it is seen that economic benefits are less considered in GI decision-making than biophysical and cultural/social benefits.

Decision-makers also ranked different barriers to GI implementation. We proposed a selection of barriers from O'Donnell et al. (2017), respondents ranked these from 'very important barrier in my municipality' to 'no barrier at all in my municipality'.

Figure 12 Identification and scoring of barriers to green infrastructure implementation as expressed by local decision makers in Flemish local authorities



As can be seen from Figure 12, the investment costs are clearly considered the most stringent barrier experienced by local actors. Lack of long-term thinking and conflicting priorities within LAs come second. Setting these barrier identifications out against the VRIND-classification introduced in 3.2, provides additional insights into the barriers at play in different categories of local authorities. For this analysis, the levels were re-coded: (very) important barriers received a score of 1, secondary/no barriers received a score of 0. Pairwise Student's t-tests were then conducted on every barrier, using this VRIND-classification. In Appendix 3-C, the results of this analysis are summarised in a connecting letters report. Because there are only few observations (11 respondents) of municipalities in the periphery of Brussels, these results should be treated carefully.

Noticeably, in cities ('centre cities' and 'metropolis') most barriers are consistently less frequently designated as important or very important. In that effect, cities are significantly less hampered by a lack of knowledge/awareness, are less affected by high investment costs, don't experience a lack of (local) political support and don't feel like the added value of GI is insufficiently proven. However, two barriers are identified significantly more in Flemish cities compared to other VRIND classes: convincing developers/planners and conflicting priorities within the LA.

3.5 Choice modelling results

3.5.1 Main-effects model

Before applying the HB model to our sample, the monotonicity test was evaluated. This resulted in 20 respondents not passing this test (i.e., choosing for the non-dominant choice option). However, similar to Scarpa et al. (2007), the results of the main-effects model with inclusion and exclusion were first compared. The results before exclusion, can be found in Appendix 3-D. Similarly, the consistency test was evaluated. 87 respondents (15%) were found to show an inconsistent choice. This percentage is similar to other DCE studies (e.g., Srivastava et al. (2020)). Moreover, respondents answered the first of their duplicate choice sets as an exemplary choice set to enforce respondent confidence. Hence, we decided that there is not enough evidence to exclude respondents violating this criterion. After this, the first model is a simple main-effects model, that was generated using the HB option with firth-bias adjusted estimates. Attributes were effects-coded because all levels can be estimated (Bech & Gyrd-Hansen, 2005) and in our case adds to the interpretability of the results. Moreover, we have included a no-choice option in the DCE, reflecting the baseline hypothetical scenario. As proposed by Haaijer et al. (2001), including an all-zero alternative provides the risk of distorting the effects on continuously coded attributes, since the zero values will act as real levels to those linear attributes. Hence, by using all effects-coded attributes, the no choice option is captured as a realistic option in the choice task, and all part-worths are estimated relative to the zero-utility of opting out (Haaijer et al., 2001). Table 10 below displays the parameter estimates and significance levels obtained by the MNL-HB.

Table 10 Modelling results of the main-effects only model from the discrete choice experiment

Term	Posterior Mean	Posterior Std Dev
Investment cost [500000-350000]	-3.045***	0.231
Investment cost [650000-500000]	-1.715***	0.239
Maintenance cost [20000-10000]	-2.078***	0.184
Maintenance cost [30000-20000]	-2.678***	0.249
Deferred cost [20 years-10 years]	0.945***	0.128
Deferred cost [30 years-20 years]	-0.547**	0.218
Number of visits [25000-10000]	1.176***	0.150
Number of visits [40000-25000]	1.416***	0.208
Climate mitigation [15-5]	0.638***	0.215
No Choice Indicator	-12.597***	1.106
Goodness of Fit Measure		**Value**
-2 * Avg Log Likelihood		-2370.796

*** 99% confidence level, ** 95% confidence level, * 90% confidence level

As can be seen from Table 10, all terms are significant at the 99% level, expect for Deferred cost [30 years-20 years]. Expectedly the cost components have significant negative consequences for the overall utility. Regarding the benefit attributes, we detect the expected signs for the posterior means too, expect for the '30 years level' of the Deferred cost attribute. Seemingly, utility of Deferred cost augments from the lowest to the middle level, but respondents attach slightly less utility from the highest level compared to the middle level. The relative variable importance of the attributes on the predicted response shows that the investment cost is the most decisive. Next, maintenance costs influence decisions to a lesser degree. Observing the benefits, we see that the number of visits has some importance, albeit less than 1/3 of the total effect importance of the investment cost. Finally, deferred cost and climate impact are almost negligible, the graphical total effects (variable importance) can be found in Appendix 3-E. From the graph we can derive that the benefit categories or ecosystem services account for less than 16% of the total variable importance. Evidently, the No Choice coefficient exhibits a significant negative value, indicating a substantial aversion to selecting the opt-out option.

3.5.2 With interaction terms

After the main-effects model, we proceeded to incorporate subject effects. Several different model formulations were specified in terms of significance and goodness of fit. The model was reduced until leaving out additional variables significantly worsened this goodness of fit. This interaction model involves group-level variables only, since it showed better fit than the combined individual-group level variables model. The group-level variables are municipal characteristics. Using the zip codes provided by the respondents, we associated these municipal characteristics with the choices they expressed. To calculate the per capita financial results, we divided the municipality's budget for the 2020-2025 legislative period by the number of residents in that municipality. The full list of municipal variables that were subjected to the choice model can be found in Appendix 3-F. Eventually, the final model with interaction terms is defined in Table 11.

Table 11: Modelling results of the full interaction model from the discrete choice experiment

Term	Posterior Mean	Posterior Std Dev
Investment cost[500000-350000]	-49.974***	4.020
Investment cost[650000-500000]	-41.861***	8.087
Maintenance cost[20000-10000]	-32.964***	4.358
Maintenance cost[30000-20000]	-37.842***	11.353
Deferred cost[20 years-10 years]	37.614***	5.360
Deferred cost[30 years-20 years]	-7.516	4.811
Number of visits[25000-10000]	46.871***	4.694
Number of visits[40000-25000]	61.289***	5.946
Climate mitigation[15-5]	24.836***	5.269
Investment cost[500000-350000]*Financial res./capita	0.085***	0.016
Investment cost[650000-500000]*Financial res./capita	0.061***	0.019
Maintenance cost[20000-10000]*Financial res./capita	0.072***	0.016
Maintenance cost[30000-20000]*Financial res./capita	0.135***	0.021
Deferred cost[20 jaar-10 jaar]*Financial res./capita	-0.021*	0.012
Deferred cost[30 jaar-20 jaar]*Financial res./capita	0.041***	0.015
Maintenance cost[20000-10000]*Pop. density	-0.068***	0.013
Maintenance cost[30000-20000]* Pop. density	-0.126***	0.024
Investment cost[500000-350000]* Pop. density	-0.086***	0.011
Investment cost[650000-500000]* Pop. density	-0.044***	0.015
No choice indicator	-630.791***	36.363
Goodness of Fit Measure		**Value**
-2 * Avg Log Likelihood		-190.949

*** 99% confidence level, ** 95% confidence level, * 90% confidence level

In the overall model, we observe similar directions for all the attributes compared to the main-effects model. As can be interpreted from the model output, population density significantly impacts both cost components negatively. The higher the population density of a municipality, the more sensitive it is thought to be to the costs of the investment. On the other hand, the financial result (per capita) of a municipality positively impacts the preparedness to invest. Especially regarding higher maintenance costs, municipalities performing better financially are less sensitive to higher levels of maintenance costs. Regarding deferring costs, we notice a significantly positive relation between the financial result per capita of a municipality and the long-term deferral (20 years to 30 years) decision criterion. Again, it is shown that the no-choice indicator bears substantial negative utility.

3.6 Discussion

Local Flemish decision makers were prompted to fill out our survey on green infrastructure decision making. This survey entailed a qualitative part, where barriers were ranked, and municipal awareness of certain GI related benefits was questioned. Next there was a quantitative part, where individual decision-makers were invited to select the choice set of a hypothetical neighbourhood park that they believe would reflect the choices of their local administration. By reaching out to 235 out of 300 Flemish local authorities, we sampled 568 respondents involved in their local GI decision-making processes. This provides an unprecedented insight into actual local GI reasoning.

Generally, Flemish local decision makers state that awareness of the benefits of green infrastructure in their local municipality exists. At the same time, over 50% of the respondents indicate that green space decisions are based on numerical impacts, and different benefit categories (cultural, biophysical, economic) are considered. However, breaking out these Likert-scaled data over different political engagements (majority/non-political/opposition), provides alternative insights. Members of the majority show more tendency to provide socially desirable answers in their perceptions on awareness in the municipality. On the other hand, opposition council members display the opposite, implying critical opinions about the governing political parties. Non-politically affiliated respondents choose the middle way. In that light, we believe that tangible indicators might be able to make the processes behind local GI decision-making more objective and transparent. The extent to which municipalities (dis)regard cultural/biophysical/economic or make use of numerical impacts, for example, seems to be measurable. Capturing and monitoring this information with indicators, would benefit regional governments so that resources can be allocated more efficiently in order to improve informed decision-making.

When respondents were asked to rank different barriers to GI implementation in their municipality, the investment costs were identified as the most important barrier. Other important barriers in Flanders are conflicting priorities and a lack of long-term thinking. Comparing with the O'Donnell et al. (2017) barrier identification in Newcastle, we notice that Flemish authorities' representatives experience considerably less reluctance towards new approaches but are instead much more wary of cost considerations. After further investigating, we found that not all municipalities behave the same. We notice that 'metropolis' and 'centre cities' experience structurally different barriers than smaller-sized municipalities. Our results indicate that larger cities struggle significantly more with convincing developers/planners and conflicting priorities within the local authority. On the other hand, investment costs are less of a barrier compared to the smaller municipality types, indicating that resources can be found more easily. Smaller and countryside municipalities are more often confronted with barriers such as: lack of knowledge/awareness, and insufficiently added value. Overcoming these barriers related to knowledge and value demonstration should be one of the focal points for short-term policy objectives, as this could imply quick wins.

As a result of the dominance test for monotonicity, 20 respondents were excluded from the sample to generate the statistical models. Many studies in health economics recognise the added value of removing respondents who don't comply with monotonicity (Tervonen et al., 2018), and it was applied in environmental economics too by Scarpa et al. (2007). As is demonstrated by our choice experiment, including violators of monotonicity tests might produce significant distortions, leading to questionable conclusions. Moreover, exclusion of monotonicity violators leads to more conservative WTP estimations.

Studying the main-effects model of the choice experiment for different neighbourhood parks, several conclusions can be drawn. First, and expectedly there's a very clear reluctance towards scenarios with higher investment or maintenance cost. If we consider the benefit categories, the largest positive impact on utility is accounted for by the number of visits, the proxy for recreational benefits of green infrastructure. The other benefit attributes are only of marginal importance to the generally predicted response. Secondly, we examine predictable directions for the parameters in our main-effects model. One exception to this is the highest level of the Deferred Cost. Apparently, municipalities derive utility from deferring the cost from 10 to 20 years, but not from postponing this cost even more from 20 to 30 years. Respondents do clearly attribute more utility to deferring this investment with 30 years, when comparing with the base level of 10 years. This indicates that respondents recognise the added value of postponing an investment, but it seems there's a tipping point to the marginal utility derived from postponement. Nevertheless, if approaching this purely economically, being able to defer costs further into the future can represent substantial monetary gains, depending on the discounting rate that is utilised. From a societal point-of-view, being able to postpone certain investments further into the future (because the risk is mitigated by the adaptive spatial design), means that the risk of damage caused by e.g., extreme weather events is minimised for a longer period, and is thus highly desirable. Both these economic and societal arguments indicate that informed decision-making should consider long term impacts to reveal the full potential of co-benefits from green infrastructure. Even more, to reach a positive return-of-investment for a case of green infrastructure these longer-term effects are important determinants, from a scientific point-of-view at least. The main-effects model thus results in three main findings. First, there's an obvious preference for the short-term cost decision factor: the investment cost. Second, when observing attributes that have an extended time horizon by yearly recurring costs/benefits, we find that the (maintenance) cost component has considerably more influence on the utility and consequently decision making than any of the benefit attributes. Third, as described before, the direct and immediate benefit of recreational value does influence the outcome to some extent, while the long-term and indirect benefits of deferred cost and climate impact are seen to barely influence actual decisions. We can thus categorise these findings into two main take-aways: cost-elasticity of local authorities and short-termism within decision-making processes.

As is also revealed by the results of ranking barriers, the investment cost is the largest stumbling block for GI implementation and decision-making. Cost arguments weigh much more on decisions than benefit arguments, at least the benefit arguments that were part of the experiment. Even more interesting is that local authorities seem to value economic benefits of GI less than biophysical or cultural benefits, according to the GI awareness questions. This aligns with the finding of Back and Collins (2022), indicating that decision-makers require social benefits, but that these are insufficiently integrated into existing tools. Also in Chapter 2, we described that cultural ecosystem services are not adequately addressed in GI valuation tools. Nevertheless, to reach a positive return-on-investment argument for a GI project, the full range of benefits should be considered.

In the interaction model, we obtain a more thorough insight into this cost-elasticity. First, it was found that municipalities with higher population densities are expected to be more bothered by higher costs, both maintenance and investment costs. We could tie this finding to the observation that municipalities with higher population densities are significantly more hampered by conflicting priorities within their LA, as was found in the barrier identification. Another potential explanation of the effect of population density on willingness to invest, might be that municipalities with high population densities are not prioritising the greening of an area on their territory that has a lower-than-average local population density. The hypothetical scenario was set-up in an area with a population density of 700 inh./km^2, the Flemish average is 488 inh./km^2 (Statistiek Vlaanderen, 2021a). Alternatively, we could argue that – given the fiercer competition on land - densely built municipalities are more cost-sensitive. In future research this is an important hypothesis to be tested.

Second, the interaction model shows that a worse financial balance has a significant impact on both cost components. In fact, we see that the better the balance, the less of an important decision criterion these cost components become. We observe that the municipal budget is one of the most conclusive factors in choice behaviour. This indicates that public greening expenses are more likely to be made as an optional when there is budget left. Further, the fact that 60% of the respondents identified conflicting priorities as a (very) important barrier endorses this finding. The influence of the financial balance of a municipality goes beyond the previous. Additional insight into the effect of the deferred cost attribute in the main-effects model is provided in the interaction model. We find that municipalities with better financial balances (per capita) for the legislative cycle 2020-2025 significantly value a 30-year deferral over the 20-year deferral. MacKenzie (2016) states that near-term costs and longer-term benefits – as is often the case for GI investments - may require different institutional responses. 40% of the respondents identifies 'lack of long-term thinking' as a (very) important barrier within their local authority with respect to GI implementation. Consequently, we can conclude that municipalities doing worse financially turn out to be less prone to invest in GI and that they are less likely to fully commit to additional investments to receive long-term benefits of GI investments, suggesting GI is seen as a luxury product, or one with higher risk attached. This might indicate that there is a structural issue preventing a transition towards greener, more sustainable living environments and to get those municipalities aboard.

Yet, decision-makers (87%) do believe that empirical numbers on the impacts or ecosystem services can steer processes. This is in contrast with Primmer et al. (2018), who found that local level decision-makers were sceptical about the use of valuation. The fact that the vast majority believes ESK would benefit decision-making, confirms that the expertise that is already out there does not flow back to the beneficiaries efficiently. On the use of ESK we see that in this study the available knowledge is of secondary importance. The ES that is most likely to influence decision-making in our park context is the recreational value: an immediate and direct ecosystem service as it is formulated in the experiment. Previous research found that direct and anthropocentric benefits are more likely to be prioritised (Back & Collins, 2021). On one hand, and in line with Nyborg (2014), this could imply that decision makers need arguments to be presented in easily relatable terms. Throughout the participatory tool development process detailed in Chapter 5, it becomes evident that decision-makers – indeed - prefer the presentation of arguments in an intuitive manner. On the other hand, it could - again -be evidence of short-term thinking and political or strategic motivations. In this regard, the time horizon of benefit streams is highly important. After all, we see that easily interpretable and short-term benefits are strategically interesting for instrumental use. In order to successfully advance to demand-driven ESV approaches such as introduced by Marre and Billé (2019), valuation practices should thus first provide results in terms that are demanded by decision makers.

As stated by van Stigt et al. (2015) policy and planning decisions are often the result of bounded rationality, rather than linear-rational processes, something that is confirmed with our results. Several elements influence this rationality in local decision-making in spatial planning. One important dimension that underlies decision-making is politics, reflected in the analysis of perceptions on GI decision-making across different engagement levels (majority/non-political/opposition). In the experimental design of the DCE, the authors have tried to minimise the impact of the political dimension, while the political process of choices in later stages at the local authority level are fully considered. For example, one crucial element in decision-making in Flanders, is the notion of the spatial implementation plan (Ruimtelijk Uitvoeringsplan). The discussion on spatial interpretation is often highly debated until it is captured in this implementation plan. This is a result of competitive claims on scarce available land. Thus, by assuming that the conversion to green space was already decided on, a large part of the initial political process was eliminated. Our simplification of the political process might declare the divergence from the status-quo option (significant negative utility from the no choice option), since research has previously shown that politicians are often drawn to the status-quo (Samuelson & Zeckhauser, 1988). This status-quo bias is absent in this hypothetical set-up, although it is still identified as a (very) important barrier to GI implementation by 30% of the respondents. The latter indicates that decision-makers believe that the willingness to invest in green infrastructure is there, and if municipalities lack GI ambition, it is then likely to occur in earlies stages of spatial planning (i.e., adoption in spatial implementation plans).

Resulting from the experimental approach in this study, two important limitations should be acknowledged. First and foremost, the fact that individual respondents are used to reflect the behaviour of a complex organisation could have implications on the validity of the results. By implementing a monotonicity test, we have tried to filter out respondents that seemed to not fully understand the choice task. Still, respondents might not feel confident speaking for the organisation as a whole. Secondly, respondents with political affiliations are categorised in two main classes: members of a local majority party and members of a local opposition party. By focussing on this partition, we could identify interesting perceptual differences on GI decision-making between ruling and non-ruling politicians, however we are not able to identify the influence of the left-right political and ideological spectrum. Studies have however found that local politics is less influenced by the bigger ideological debates or the traditional political spectrum and the outcome of local elections revolves more around personality and local networks than around ideology (Dodeigne et al., 2021; Marien et al., 2015). This is the case for Belgium, but similar findings were observed in the Netherlands (Boogers & Voerman, 2020). Even in the US local elections are described as managerial democracies that are fundamentally different from national politics (Oliver et al., 2012). Still, more research into the influence of partisanship of (local) GI decision making and more particularly linking this back to the stage of the development of spatial implementation plans in Flanders, is needed.

In this chapter we established how economic benefits are not appreciated in the same manner as costs, when considering GI. This reasoning could originate from the observation that benefits are typically not enjoyed by those bearing the costs. In Chapter 2, we revealed how valuation tools do not incorporate evidence on the cost side. Yet, decision-makers strongly believe that GI evidence would steer decision-making processes. Hence, in Chapter 5 we propose a novel tool, where cost indications are included. In this way, decision-makers are very straightforwardly exposed to the relation between costs and benefits, with which we show in Chapter 5 that a minimal increase in costs can yield substantial increases in benefits or ecosystem services. With the evidence in Chapter 4 indicating that the community is considerably less cost-sensitive, we aim to relax the current dominance of GI costs at the local decision-making level through explicitly setting these out against the benefits. Through this approach, our objective is to enhance the connection between local policy implementation and the community, fostering greater alignment and acceptance.

Further, in this chapter we also found that cultural or social benefits are rated as highly important by decision-makers, which emphasises the need for such data. At the same time, existing tools barely address cultural ecosystem services, which was shown in Chapter 2. This clearly indicates that there's a gap between what decision-makers need and demand, and what the current tools offer. Therefore, in Chapter 5 we demonstrate how we attempt to narrow this science-policy gap by introducing systematic ways to assess cultural ecosystem services.

3.7 Conclusion

First and foremost, we find that willingness to invest in green infrastructure is generally present in Flemish municipalities. However, several factors influence this willingness to invest, which were revealed by a discrete choice experiment and accompanying qualitative survey.

While the investment cost is found to be the most important barrier to GI implementation, this is significantly less the case in larger municipalities than in smaller and countryside municipalities. On a few other barriers we also find that the size of municipalities influences the significance of the barrier. Whereas large municipalities are significantly more concerned with convincing planners and developers of a GI approach and with conflicting priorities within the local authority, small municipalities struggle more with a lack of knowledge and awareness, and with lack of evidence of added value. In addition, local awareness and informed GI decision making is subject to substantial strategic behaviour: majority members are more positive about their approach to GI, members of the opposition are overly critical and non-politically appointed local officers choose the middle way. The strategic behaviour impedes transparent and objective decision-making procedures.

By deploying Hierarchical Bayes estimation models, we find that the choice experiment also proves that cost attributes (investment cost and maintenance cost) are considerably more important contributors to a GI-related decision in local authorities. In fact, only one (out of three) benefit appears to have directive influence: recreational value. The short-term cost (investment cost) and benefit (recreational value) have far more impact on decision-making than the longer-term cost (maintenance cost) and longer-term benefits (deferred costs and climate impact). These findings are supported with the qualitative part of our survey, where 40% identified 'lack of long-term thinking' as problematic. Cost-sensitivity and short-termism clearly lead the decision-making process. Further, the interaction model demonstrates that municipalities with a better financial balance per capita are willing to invest more and attach significantly more meaning to the long-term benefit argument. The lower willingness to invest on the part of local authorities with less financial resource suggests that investment in GI is seen as a luxury product, or one with higher risk attached.

For ecosystem services valuation and ecosystem services knowledge utilisation to progress, the benefit arguments should be expressed in terms that are demanded by decision makers, often in terms of direct and immediate impact. In this light and given the contribution of costs in decision making, we believe that research on GI's ecosystem services generation, in relation to respective investment and maintenance costs, would positively impact the useability of results in local decision making. Furthermore, overarching bodies' green infrastructure strategies should focus on the barriers that matter in municipalities of different sizes and structures: capacity building and knowledge transfer to smaller and countryside municipalities, (larger) cities require tools and obligations to persuade their developers towards a GI approach and to help their decision makers to prioritise GI. Next, in order to be able to monitor local authorities' performance on green infrastructure implementation, but also on (informed) green infrastructure decision making itself, sets of objective indicators would contribute to avoiding unhelpful strategic and political behaviour.

Lastly, guidance was provided on how future research on GI decision making should attempt to overcome the methodological and empirical limitations that we were confronted with in this study.

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Chapter 4
A discrete choice experiment to assess the people-policy gap in green infrastructure

In Chapter 3 we found how local GI decision-making is impacted by short termism, high cost-sensitivity, and that heterogeneity in choice behaviour can often be explained by the population density and the financial balance of the municipality. Through these insights, a better understanding of the supply side of GI was acquired. From the objective of narrowing the gap between people and policy, this chapter focuses on the demand side of GI. In Chapter 1 it was established how community acceptance and engagement is critical towards long-term uptake of sustainability or climate adaptation policies. For tools to effectively contribute to demonstrating the added value of GI, it becomes crucial to integrate the value orientations of residents and align their expectations or perceptions on GI with those of local decision-makers. This was also one of the findings in Chapter 2, where the participative tool development was found critical towards applicability. Further, this chapter contributes to an enhanced comprehension of how tools can be applied by local decision-makers to bridge residents' concerns with the higher-level policy goals, which contributes to narrowing the people-policy gap. By thoroughly establishing that link, the comprehensive and participatory process of creating our GI/ES valuation tool in Chapter 5, is emphasised.

Chapter based upon: Van Oijstaeijen, W., Van Passel, S., & Cools, J. (2023). Residents' perceptions on ecosystem services from green infrastructure: results from a sequential best-worst scaling and discrete choice experiment approach. Working paper.

4.1 Introduction

As we already described in Chapter 1, Flanders, the northern region of Belgium, is one of the densest built areas in Europe, characterised by a high degree of ribbon and scattered development (Vermeiren et al., 2018). As a result, the region is becoming more and more vulnerable to the intensifying effects of global change. As approximately 15.3% of the land is covered in artificial surfaces (Statistiek Vlaanderen, 2023), issues pertaining to water security and heat islands are becoming more pronounced. The estimated annual value of reductions in infrastructure and mobility costs resulting from the gradual mitigation of urban sprawl is approximately 1.3 billion (Vermeiren et al., 2022). These potential savings represent only a portion of the overall savings, as they do not account for the costs associated with climate adaptation and the foregone ecosystem services. Policy interventions aim to prioritise and emphasise the preservation of open space. The Flemish government started discussions on the *building shift* - at that time called *concrete stop* - in 2016, only to reach an agreement on the content in 2022. The objective of this policy is to reduce the current rate of surface area development from 6 hectares per day to 3 hectares per day by 2025, ultimately leading to a complete halt in net land take by 2040 (Departement Omgeving, 2022). This aligns with the broader European ambition to achieve net land take reduction to zero by 2050 (European Environment Agency, 2023). The primary objective is to promote the consolidation and densification of towns and cities, discouraging any additional ribbon development. Simultaneously, the Flemish government unveiled the Climate Adaptation Plan 2030 (Vlaamse Overheid, 2022), which seeks to integrate climate adaptation measures more extensively into spatial planning. Both policy instruments are closely interconnected and mutually reinforcing in their implementation. While the building shift primarily focuses on preserving open space and curbing land consumption, the Climate Adaptation Plan 2030 places greater emphasis on enhancing the quality of open space through the implementation of green infrastructure and nature-based solutions.

However, much of the responsibilities and challenges on spatial planning and management lie at the local level, with towns and cities. Previous research (Back & Collins, 2022; Dhakal & Chevalier, 2017; Li et al., 2020; Matthews et al., 2015; O'Donnell et al., 2017; Reu Junqueira et al., 2021; Viti et al., 2022; Voskamp et al., 2021) has identified various barriers that hinder the effective implementation of green infrastructure initiatives at the local scale, impeding the translation of overarching strategies into practical actions. Resource constraints and strategic behaviour – among other factors - prevent local administrations from consistently pursuing green infrastructure or nature-based solutions in spatial planning over traditional infrastructure. Meerow (2020) state that GI decisions therefore are affected by opportunism, or not consider the full range of ecosystem functions, but rather one or a few benefits. This is also what we found in Chapter 3 of this dissertation, when we provided unprecedented insight into the suppliers' side of green infrastructure by studying actual decision-makers in Flanders, Belgium (Van Oijstaeijen et al., 2022).

Facilitating access to ecosystem services knowledge through tools has been introduced to support local authorities in reaching the capacity to appreciate a wider range of benefits, improving informed decision making. With such tools, local officers should be able to concretise arguments for their specific GI case, without extensive time, expertise, or investment requirements. Our review of tools in Chapter 2, however, demonstrates how this is currently often ‘too good to be true’, and clear trade-offs are made in tool development (e.g., simplicity – scientific soundness). Typically, tools are well-suited to demonstrate biophysical impacts, but are less qualified to include citizen’s perceptions and needs. Nevertheless, from a spatial planning perspective, coupling public values with climate adaptation strategies has been found elementary for implementation (Ordóñez Barona, 2015). Public preferences and trade-offs for ES delivery have been surveyed, to our knowledge, this is the first study to apply such an approach specifically to urbanised environments, particularly focusing on small-scale green infrastructure interventions. Previously, such research was applied on larger nature reserves, often with the objective to monetise biodiversity components (Andreopoulos et al., 2015; Cerda et al., 2013; Shoyama et al., 2013). Methodologically, choice experiments in the context of small-scale green infrastructure are limited to several studies exploring preferences on (visual) characteristics (Aspinall et al., 2010; De Valck et al., 2017; Ta et al., 2022; van den Berg et al., 2022; van Vliet et al., 2021), rather than on the services the greening provides (i.e., ecosystem services). Best-worst scaling on the other hand have been used for smaller-scale and ecosystem service specific research (e.g., on stormwater management (Dobbie & Farrelly, 2022)), local benefit preference ranking (Ordóñez Barona, 2015), or urban green space characteristics (Madureira et al., 2018; Ta et al., 2022) however not comprehensively assessing ecosystem services. These studies (both DCE and BWS) commonly focus on quantifying the GI characteristics that would optimise the recreational value of open spaces.

Stakeholders’ analysis revealed that communication, participation, and collaboration across different stakeholders is critical to democratise nature and landscape planning (Dick et al., 2018). Identifying (dis)similarities between stakeholders’ views therefore is essential. Furthermore, conducting trade-off analysis on these service preferences, as proposed in this research, provides guidance for prioritisation in local management and facilitates effective communication to promote citizen acceptance and active engagement. This approach enhances the implementation of green infrastructure through public participation (Kronenberg et al., 2021). After all, it is thought that citizens can be effective drivers of greening, making urban systems more climate adaptive (Bayulken et al., 2021).

In this research, we adopt a sequential experimental approach that integrates two methods: a best-worst scaling experiment used as input for attribute selection and reduction, followed by a discrete choice experiment. The survey was conducted in two stages, separate from each other to analyse the results and reconfigure the survey for the choice experiment. This innovative study design offers quantitative and ranked evidence regarding the (urban) ecosystem services derived from local-scale (urban) green infrastructure. Moreover, the two-stage experimental approach enables a comprehensive understanding by providing insights into how respondent characteristics influence their values. Given the limited availability of open space and the intense competition for such space in the region of Flanders, it is crucial to ensure that investments in green infrastructure align with the needs of citizens and contribute to their quality of life, and simultaneously addressing climate adaptation features. While the concept of ES was initially introduced to bridge the gap between science and policy, this study aims to identify pathways to narrow the gap between people and policy by utilising the ES concept. Consequently, these findings will contribute to bridging the gap between environmental policies and strategies and the perspectives of the general public, ultimately aiming to facilitate the implementation of GI. Since a choice experiment involving a comparable green infrastructure scenario has been conducted with local decision-makers in Chapter 3 (Van Oijstaeijen et al., 2022), the analysis of potential divergences in perceptions and preferences among various stakeholder groups presents a unique opportunity to facilitate the bridging process between these stakeholders (Depietri, 2022). Trade-offs, and synergies in green infrastructure management, decision-making and stakeholders' preferences are determined, proposing ways forward. This further allows to identify how valuation tools can be designed to accommodate for residents' perceptions, facilitating communication between the different stakeholders and how toolkits can used by practitioners, while incorporating local variations in preferences.

4.2 Method

First, the hypothetical scenario for both stated-preference methods was established. This scenario was chosen for familiarity and comparability reasons. In their participative research to people's values and beliefs regarding GI in Rotterdam, Derkzen et al. (2017) identified familiarity as a key feature for citizens to value GI. Further, the experimental design is very similar to the DCE study with Flemish decision-makers from Chapter 3 (Van Oijstaeijen et al., 2022), collecting evidence on this hypothetical scenario with a different stakeholder group. By doing so, we can discern differences between stakeholder groups and elucidate approaches to bridging the gap between them. Traditionally, discrete choice experiments are designed through literature review and expert consultation. Given the limited available participatory research on the topic, a two-phase experimental approach was preferred for this choice experiment. Following a comprehensive literature review, a longlist comprising 13 potential attributes (visualised in Table 14) was identified to assess citizens' perceptions of GI/ES. To refine the attribute selection for the subsequent discrete choice experiment, a best-worst scaling experiment was conducted, resulting in the final list of attributes.

4.2.1 Theoretical background

Best-worst scaling

As introduced in 1.5.2, the best-worst scaling method is a SP technique designed to reveal relative preferences for a topic of interest. It was developed by Finn and Louviere (1992). BWS has two main advantages over standard rating scales. First, it forces respondents to discriminate between items, resembling real market choices more accurately. Second, BWS is not susceptible to respondents' subjective interpretation of the scale labels, resulting from cultural differences or verbal ambiguities (Louviere et al., 2013). This uncertainty of interpretation poses questions to the validity and reliability of rating scales (Flynn & Marley, 2014). Therefore, BWS has been recognised as the preferred method to measure consumers' value orientation (Parvin et al., 2016). Further, it allows to estimate the average utility for an attribute k across all its L_k levels. In the BWS object-case respondents are forced to repeatedly choose from a set of objects the "best" and the "worst" object in that list. In doing this, respondents reveal the attribute pair that he/she deems to be furthest apart on the latent utility scale (Flynn et al., 2007). Underpinned by random utility theory, relative preferences for these objects can be revealed (Louviere et al., 2013). BWS relies on the assumption that respondents' choices on the extremes (best/worst) are more reliable than those in the middle, expressing the maximum difference in utility between attributes (Van Schoubroeck et al., 2023).

The BWS choice sets are designed with a balanced incomplete block design (BIBD) such that every choice option appears equally often, and co-appears equally often with other choice options (Louviere et al., 2013). In our study, we evaluated 13 potential decision-criteria for green infrastructure cases. Respondents were asked to indicate which attribute they value the most for a new neighbourhood park, and which attribute they value the least. In this experiment, respondents received 13 such choice tasks. Every choice task consists of four attributes, with every attribute appearing four times (see Table 12). The order of choice tasks, and the order of appearance of the attributes within every choice task were randomised.

Table 12 Balanced incomplete block design with 13 alternative neighbourhood park attributes (1-13) in 13 different choice tasks (A-M).

Choice task	Neighbourhood park attributes			
A	3	5	10	12
B	1	4	11	12
C	3	4	6	8
D	2	3	11	13
E	1	8	10	13
F	1	2	5	6
G	1	3	7	9
H	6	7	10	11
I	6	9	12	13
J	5	8	9	11
K	2	4	9	10
L	2	7	8	12
M	4	5	7	13

Discrete choice experiment

In this chapter, insights on people's value orientation acquired through the BWS are used to select the attributes for further trade-off and WTP-analysis through choice modelling (CM) techniques. CM relies on the assumption that goods or services can be described in function of its attributes and their levels (Bateman et al., 2004). Complementary to the pairwise comparisons in the object-case BWS, DCEs can be used to gain insights in value attribution to specific attribute levels, trade-offs between them (Zhang et al., 2015) and so provide welfare and WTP estimations. The approach of applying BWS to inform attribute selection for DCE has been applied before by Webb et al. (2021), building further on the complementarity and the evidence of BWS-1 and DCE showing consistency in results (Zhang et al., 2015). The hypothetical scenario was consistent across the two experiments.

In contrast to the BWS, levels are assigned to all attributes in a DCE. Respondents are expected to choose for the preferred choice alternative, based on the bundles of attribute levels. Like BWS, DCE relies on random utility theory, assuming utility-maximising choice behaviour. Eq. (1) depicts the utility function. In this function, the utility U that is derived from some choice alternative *j* is dependent on the deterministic function V, and a random error term – or stochastic component - ε_j The function V is defined by the vector X_j that contains the attribute levels for choice alternative *j* and a vector of estimated coefficients B (Hauber et al., 2016).

(1) $U_j = V(B, X_j) + \varepsilon_j$

4.2.2 Design of experiments

Best-worst scaling experiment

A preliminary compilation of potentially influential attributes pertaining to neighbourhood parks was generated through a comprehensive review of existing literature. To maintain consistency throughout the sequential stages of the experimental design, a well-defined hypothetical scenario was established. This scenario, specifically designed for green infrastructure, intentionally adopted a simplistic approach to ensure that the study objective resonated with all participants. After all, (urban) parks and green spaces deliver the broadest array of ecosystem services (Evans et al., 2022), and we know from previous research that this is generally recognised by citizens (Nastran et al., 2022). In the presented hypothetical scenario, respondents are introduced to a plot measuring 100m x 100m within their municipality, equivalent to roughly two football pitches. Currently, this plot is developed and inaccessible to the public. The greening case involves transforming this plot into a 1-hectare neighbourhood park, thereby creating multifunctional green space in the vicinity. Participants are informed that the spatial design of the park will be influenced by the prioritisation of attributes as determined by them. To familiarise respondents with this hypothetical scenario, graphics (visualised in Figure 13) were implemented. Following the presentation of the hypothetical scenario, a question was administered to assess respondent attention and comprehension. The hypothetical scenario for the BWS was presented to the respondents as follows:

« Near your residence, the municipality is planning to repurpose an area of 100 meters by 100 meters into a park zone. To shape this park area, they intend to gather input from residents to determine which features are important for a green zone in your neighborhood. Based on the identified important features, they can then proceed to develop a specific design for the park area. »

Figure 13 Graphical support to hypothetical scenario

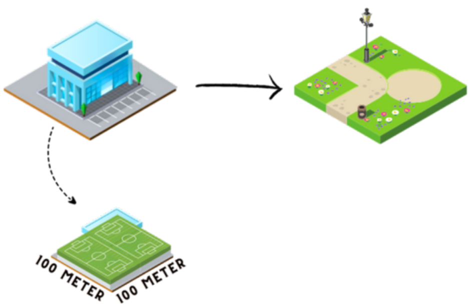


Table 13 Example of a choice task in the best-worst scaling experiment

For a new green area in my neighbourhood, I find the following characteristics to be respectively the least and the most important.		
Least important		Most important
	CO_2 uptake	
	Cooling effect	
	Frequency of maintenance	
	Species richness (fauna – insects, small mammals, birds, amphibians)	

In both steps of the sequential experimental design, respondents were shown an example of a choice task they would perform to assure it was fully understood. Respondents were then asked to indicate the most important (best) and least important (worst) features for a neighbourhood park in their municipality in the BWS. Every respondent completed 13 choice tasks (visualised in Table 13), with the list of attributes for the BWS depicted in Table 14. Similar to Tyner and Boyer (2020), the attributes in the BWS consist of marketable ecosystem services (e.g., property values, park facilities), and non-marketable ecosystem services (e.g. species richness, peace and tranquillity).

Table 14 Neighbourhood park attributes included in the best-worst scaling experiment, where every choice task consists of identifying the 'best' and the 'worst' attribute from a set of four

N°	Neighbourhood park attributes	References
1	Number of visitors	Madureira et al. (2018)
2	Facilities (benches, playground)	De Valck et al. (2017); Madureira et al. (2018); Tyner and Boyer (2020); van den Berg et al. (2022)
3	CO_2 uptake	Derkzen et al. (2017); Evans et al. (2022); Mexia et al. (2018)
4	Ambient noise reduction	Chiesura (2004); Derkzen et al. (2015, 2017); Evans et al. (2022)
5	Cooling capacity	Derkzen et al. (2015, 2017); Evans et al. (2022); Haase et al. (2014)
6	Rainwater infiltration and storage	Derkzen et al. (2015, 2017); Evans et al. (2022)
7	Local air quality	Derkzen et al. (2015); Evans et al. (2022); Mexia et al. (2018)
8	Property values	Tyner and Boyer (2020)
9	Density of forestation	Suárez et al. (2020); Ta et al. (2022); van den Berg et al. (2022)
10	Frequency of maintenance	Madureira et al. (2018); van den Berg et al. (2022)
11	Species richness (flora)	Evans et al. (2022); Madureira et al. (2018); Tyner and Boyer (2020)
12	Species richness (fauna)	Evans et al. (2022); Madureira et al. (2018); Tyner and Boyer (2020)
13	Quietness	De Valck et al. (2017); Madureira et al. (2018); (Ordóñez Barona, 2015)

Discrete choice experiment

After the BWS contributed to the first main stage of the DCE (i.e., selection and reduction of attributes), levels are assigned and the choice cards composed (Mangham et al., 2008). Two attributes were pre-identified as essential: a monetary attribute, defined as a surcharge on the municipal tax, and distance from the residence. After all, these attributes contribute to a degree of consequentiality for the respondent, which reduces the hypothetical bias in the experiment (Flynn & Marley, 2014). These attributes were complemented by those that were identified as most influential through the BWS: species richness, peace, and tranquillity (number of visitors on the other side of the spectrum), rainwater retention and infiltration, and CO_2 impact. Further, descriptions were adjusted to bundle objects from the BWS experiment in one DCE attribute (e.g., species richness fauna, species richness flora, and forestation, all expressed under *Naturalness*). To define the levels of the attributes, the authors held several rounds of discussions. Also, we assured comparability with the choice experiment conducted with local decision makers in Chapter 3, to obtain complementary stakeholder perceptions. The attributes associated with the initial longlist were explicitly stated to remain consistent across all available choices (Bateman et al., 2004). For example: it is explicitly mentioned that the number of parking spaces remains constant.

Figure 13 was again used as graphic support, the hypothetical scenario for the DCE was presented to the respondents as follows:
"An area in your municipality or city is soon to be repurposed. As a result, 1 hectare (100m x 100m) of space will become available – roughly the size of two soccer fields. This area is set to be repurposed into a multifunctional green space. It's essential to note that this space was not accessible to the public, so there will be no loss of parking spaces in the process!

Matters that are beyond the scope of this decision-making process include:

- Any additional cost reflected in housing or rental prices. This additional cost is assumed to be identical for each scenario and is therefore kept constant.
- The duration of the construction work and the inconvenience it will cause are the same for every alternative.
- The cooling effect of different choices is also assumed to remain constant.
  The quantity of amenities (such as banks and playgrounds) is identical for all designs.
- The sound insulation effect of the neighbourhood park is constant for all designs as well."

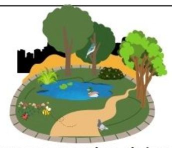
Respondents were ought to complete 10 choice sets. Every choice task consists of two choice options, and an opt-out. The opt-out is defined as an all-zero option, were the site remains as is (i.e., inaccessible, and grey infrastructure). The DCE exists of two surveys with 10 different choice sets, with equal number of respondents for both surveys, and the surveys randomly assigned to respondents. An example of a choice task is provided in Figure 14.

Table 15 Definitions of the attributes in the choice experiment and their descriptions, and their levels

Attributes	Description	Levels
Municipal tax surcharge	The new neighbourhood park, through its investment and maintenance costs leads to an annual surcharge on municipal tax. On average, the additional personal income tax (APB) - which can be seen as a tax to the municipality - is 7% of the federal basic tax in Flanders. The average Flemish taxable income amounts to €21,078 (Statbel, 2022), given the tax scales this leads to €6,400 taxes (FPS Finance, 2023). In such a case, the APB averages €450.	• €10 • €25 • €50 • €75 • €100
Walking distance from residence	Duration of shortest walkable route from home to the entrance of the neighbourhood park.	• 5 min • 10 min • 15 min
Naturalness	Naturalness is determined by species richness. The more diverse species and forms of planting, the more life in the park, the more natural the character of the neighbourhood park.	• Low species richness[6] • Average species richness[6] • High species richness[6]
Number of visitors	Number of visitors who enter the neighbourhood park on average daily for recreation. In a park with more visitors, there may be less tranquillity but more opportunity for social interaction.	• 30 visitors daily • 70 visitors daily • 110 visitors daily
CO_2 uptake	The infilling of the district park into a green zone and consequently CO_2 uptake not only reduces greenhouse gases, but also improves local air quality. In the choice experiment this impact is measured in equivalents of yearly CO_2 emissions per family in Flanders (average of 3,5 tonnes of CO_2 yearly)	• Emission of 5 families yearly[7] • Emission of 15 families yearly
Water retention and infiltration	Interventions in the design of the neighbourhood park will locally improve runoff and infiltration of precipitation, relieving the burden on the sewer system. This will reduce the risk of flooding during periods of heavy rainfall.	• flood probability reduced until 2033 • flood probability reduced to 2043 • flood probability reduced to 2053

[6] These levels were supported by illustrations, which can be found in Appendix 4-A.
[7] To ensure consistency with Van Oijstaeijen et al. (2022), this particular attribute was designed with only two levels in the choice experiment.

Figure 14 Example of choice set in the discrete choice experiment, alternating the levels of the attributes, respondents receive 10 different choice tasks

		Option 1	Option 2	Option 3
Yearly surcharge on municipal tax		25 euros/year	75 euros/year	 Everything remains as is
Walking distance from residence		10 minutes	15 minutes	
Naturalness		 Average species richness	 Low species richness	
Number of visitors		30 visitors on average per day	70 visitors on average per day	
Water retention and infiltration		Flooding probability reduced until 2033	Flooding probability reduced until 2033	
CO_2 uptake		Equivalent to emissions of 5 families yearly	Equivalent to emissions of 15 families yearly	

4.2.3 Data collection

Best-worst scaling experimental survey

The BWS survey was designed as an exploratory study to reduce the attributes using actual value orientations from the target group of the DCE. Therefore, the BWS survey was kept deliberately short. The BWS experimental survey commenced with respondents providing their consent for participation in line with the research objectives and data collection protocols. Subsequently, basic demographic inquiries were administered to fulfil predetermined quotas related to geographical distribution (province), age group, and gender. Following this, participants were introduced to the hypothetical scenario (as detailed in 4.2.2). In case respondents expressed a need for further information, they were presented with an unrelated and simplified example of a BWS choice set. After completing the series of BWS choice tasks, respondents were presented with a set of Likert-scaled questions (visualised in Table 16) designed to assess sustainable behaviour. Utilising a set of five Likert scale items, a composite score was derived by summing the responses, which were subsequently normalised to a scale ranging from 0 to 1. It is recommended to consider this composite score as being at the interval measurement scale (Boone Jr & Boone, 2012; Harpe, 2015). This composite score is further called the respondent's "Sustainability profile". Finally, respondents were asked to provide information regarding their educational level, zip code, and marital status. After a pretesting stage on 20% of the target number of respondents (200), the survey was slightly adapted for clarity and visual enhancement reasons. Further, the pretesting contributed to define a lower limit to the time required (180 seconds) to consciously complete the BWS survey. Data was collected using online panellists, with surveys designed in Qualtrics software. The online BWS survey was launched on March 14th, 2023. A total of 254 respondents initially participated in the survey, but 80 (31%) were excluded from the analysis for various reasons. The main reasons for exclusion were non-completion of the survey due to quotas on age groups, gender, and province. Additionally, survey completion time and choice consistency were assessed to identify respondents who were deemed "unreliable". Two criteria were used to delete responses: (1) respondents who completed the survey too quickly, defined as less than 180 seconds based on pretesting, and (2) respondents who selected at least two attributes as both "best" and "worst" in the survey. Finally, respondents who did not accept the consent form were also removed from the analysis. The final sample size for the BWS analysis consisted of 174 responses.

Table 16 Likert-scaled questions gauging the respondents' stated sustainable behaviour, basis for a composite sustainability profile

Statement	Always	Often	Sometimes	Seldom	Never
I am environmentally conscious					
I am concerned about sustainability					
For short trips, I limit the use of the car.					
I limit my waste production					
I consciously consume products with sustainability labels (Bio, FairTrade, Eco, ASC, ...).					
I eat vegetarian/vegan					
I travel by plane					

DCE experimental survey

After the analysis of the BWS results, the design of DCE was developed. This involved defining attributes and levels and preparing a comprehensive survey on preferences regarding public and private green infrastructure. Like the BWS survey's experimental design, respondents were initially presented with the consent and quota-related questions. Subsequently, respondents' awareness of climate change-related topics was assessed using four multiple-choice questions (found in Appendix 4-B), and sustainable behaviour (like in Table 16) was again queried to obtain a respondent's "Sustainability profile". Prior research has indicated associations between education, familiarity with environmental issues, and personal values related to green infrastructure, and revealed GI preferences (Miller & Montalto, 2019; Turner et al., 2016). Therefore, this information is collected to control for in the results. After familiarising respondents with the hypothetical scenario as discussed in of this chapter, they received the actual choice sets, which were free of attribute constraints. The survey then gauged whether respondents disregarded certain attributes. Further, we asked respondents about their satisfaction with the neighbourhood they currently live in (visualised in Table 20), the proximity of their plot to the nearest accessible green space, and frequency and reason of visiting green space. This information was collected to understand potential response heterogeneity and are subjected to further analysis (see further, in 4.2.4). Lastly, we inquired about their current housing situation, and about motivations to implement GI measures on private property.

Prior to the official survey launch, a pre-test was conducted with a subset of the target respondents, comprising 20% of the intended sample size (1000 individuals). The pre-test aimed to identify linguistic errors and survey flow issues. During the pre-testing phase, the average completion time ranged from 12 to 18 minutes, with a minimum completion time set at 8 minutes. The DCE survey was subsequently launched for online panel participants on April 7th, 2023. A total of 2060 individuals initiated the survey; however, due to the time requirement, there was a higher dropout rate. Out of the initial count, 813 individuals did not complete the survey, declined to accept the consent form, or were excluded based on predetermined quotas for age, gender, and province at the beginning of the survey. Like the BWS experiment, respondents exhibiting "unreliable" behaviour were identified and removed from the sample based on specific criteria. These criteria included respondents who completed the survey too quickly, with a lower limit set at 480 seconds. Respondents demonstrating straight-lining behaviour (i.e., consistently selecting either choice “Option 1”, either “Option 2”) were also excluded. However, straight-lining behaviour for the opt-out option was not always penalised, as it could be protest voting with an underlying reason. Therefore, such cases received an additional question to gauge for the reason of this choice behaviour. If the respondent selected “because I want to finish the survey as quick as possible”, the response was discarded. Other potential reasons for opting out included: “I don’t want a park’, ‘Someone else should pay for climate adaptation’, ‘I can’t afford this amount of money’, etc. Ultimately, a total of 833 validly completed surveys were included in the final data analysis.

4.2.4 Statistical analysis

Best-worst scaling

For the analysis of BWS Case 1 data, two approaches are regularly applied: a counting analysis and modelling analysis. The counting approach exists of analysing the frequency of attribute i being selected by respondent n as the best (B_{in}) or worst (W_{in}) - or respectively the most and least important - for a new neighbourhood park, among the full list of questions respondent n received. In that way, we obtain individual-level scores. Further, aggregating these individual-level scores leads to an oversight of best (B), worst (W) and best-worst (BW) scores. In this case, we are primarily interested in the total-level scores. Thus, the frequency with which attribute i is chosen as the most important park attribute across all questions and respondents N, denoted as B_i (Aizaki & Fogarty, 2023). For every attribute i the BW score is calculated according to Eq. (2).

(2) $BW_i\ score = \sum B_i - \sum W_i$

Second, the modelling analysis was performed through a conditional *maxdiff* logit (CL) model to estimate the respondents' ranked preferences for neighbourhood park attributes. Since respondents implicitly maximise the difference between certain attributes on a latent utility scale in every choice task, let λ_j be the location of value j on this latent utility scale. The true unobserved importance level for individual i is than given by $I_{ij} = \lambda_j + \varepsilon_{ij}$, with ε_{ij} a random error term. For respondents respectively choosing attribute *j* and attribute *k* as the best and worst attribute from the BWS choice set with *J* items, it is assumed that the probability is equal to the probability of the distance between I_{ij} and I_{ik} being greater than all other possible distances between attributes in this choice set (Lusk & Briggeman, 2009) – hence *maxdiff*. Following the previous, the conditional logit model is defined in Eq. (3) (Lusk & Briggeman, 2009; Tyner & Boyer, 2020). Interpretation of these results is improved through calculating the share of preference (SoP) for a park attribute j, according to eq. (4) (Van Schoubroeck et al., 2023). The sum of SP_j for all attributes j adds up to 1, defined on a ratio scale.

$$(3) \qquad Prob(j\ is\ most\ preferred, k\ is\ least\ preferred) = \frac{e^{\lambda_j - \lambda_k}}{\sum_{l=1}^{J} \sum_{m=1}^{J} e^{\lambda_l - \lambda_m - J}}$$

$$(4) \qquad SoP_j = \frac{e^{\lambda_j}}{\sum_{k=1}^{J} e^{\lambda_k}}$$

Both the BIBD design and the BWS analyses beforementioned were conducted using the support.bws package in RStudio (Aizaki & Fogarty, 2023).

Discrete choice experiment

To account for variations in preferences among respondents, the HB technique was used to estimate the individual part-worth utilities of the attributes in the DCE (Louviere et al., 2010). Unlike the CL and regular MNL models, HB is particularly suitable when there is an expectation of heterogeneity in preferences across respondents. While the underlying choice-probability model is still MNL, through HB it is adapted to model responses on an individual-level, not on the observations in the sample (Hauber et al., 2016). Except for the monetary attribute, all attributes were effects-coded to facilitate the development of a WTP profile. Opting for effects-coding over dummy-coding results in variable estimations that are uncorrelated with the grand mean (Flynn et al., 2007). Using Hierarchical Bayes, choices are estimated iteratively on the lower or likelihood level, and the upper or sample level (Byun & Lee, 2017), as was described in 3.3.3. The calculated posterior means represent the average of the parameters β_n in the sample (Hauber et al., 2016). The model estimates were obtained using the choice platform in JMP Pro 16 software, utilising 5,000 iterations.

Ordered logistic regression

Ordered logistic regressions were employed to research the heterogeneity in neighbourhood satisfaction responses. Given the ordinal scaling of the dependent variables (using a 5-point Likert scale), a proportional-odds ordered logit model was applied. Prior to this, the independent variables were checked through variance inflation factor analysis to ensure that the non-multicollinearity assumption of the ordinal logistic regression was not violated. These were run using the ologit command in Stata 17.

4.3 Results

4.3.1 Best worst scaling

Descriptive statistics

Table 17 depicts respondents' characteristics in the BWS survey. Gender, location (province), age group and educational qualification is displayed.

Table 17 Demographics of the respondents in the best-worst scaling scample of Flemish residents

Respondent characteristics		Number	% in sample
Gender	Male	91	52.3
	Female	83	47.7
	Non-binary	-	-
	Prefer not to say	-	-
Province	Antwerp	53	30.4
	West-Flanders	31	17.8
	East-Flanders	37	21.3
	Flemish Brabant	32	18.4
	Limburg	21	12.1
Age group	25-34	23	13.2
	35-49	45	25.9
	50-64	60	34.5
	65-79	46	26.4
Highest educational qualification	No formal education	4	2.3
	Primary education	7	4.0
	Secondary education	81	46.6
	Higher education	82	47.1

Modelling results

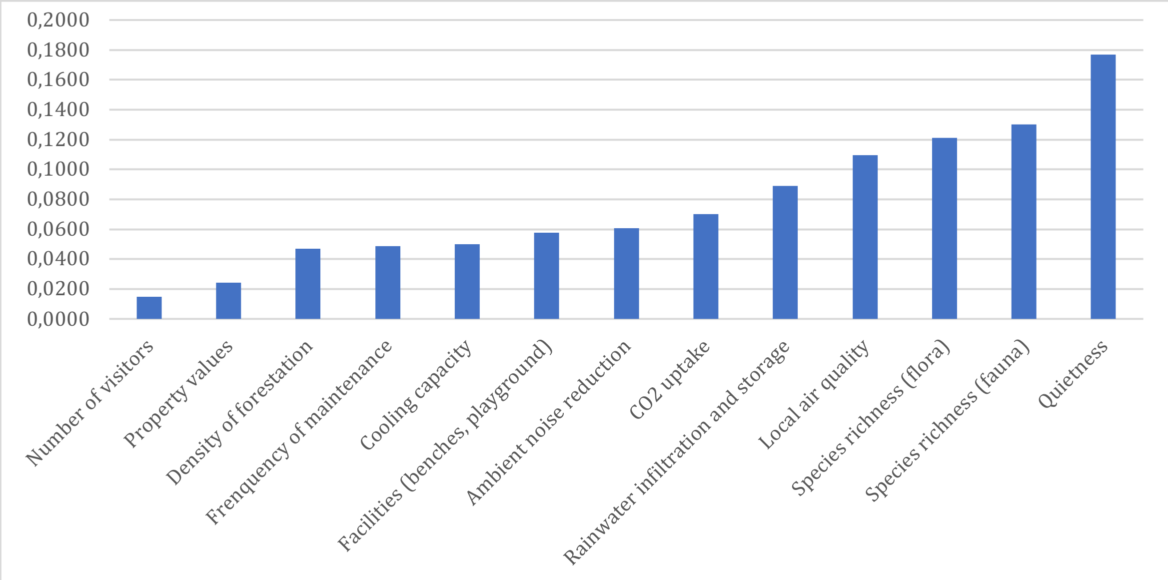
The best and worst scores in Table 18 denote the frequency that an attribute was chosen as most important feature for a neighbourhood park and least important feature for a neighbourhood park. Analysing the BW scores. we find that the number of visitors, property values, and (to a lesser extent) frequency of maintenance receive the lowest score. On the other end, quietness, species richness (both in fauna and flora), and local air quality outperform the other items. The results of the conditional logit model are analogous. Since the first item – number of visitors – is used as benchmark, it has a coefficient of zero. We notice that all attributes have a significantly positive mean value, indicating that they are all preferred over the benchmark item. The column share of preferences serves as data input for Figure 15, depicting the order of attributes from least important to most important.

Table 18 Best-worst scaling results of a counting analysis and conditional logit model

Counting analysis				Conditional logit model				
	Best	**Worst**	**BW**	**Mean**	**P-value**		**Standard errors**	**Share of preference**
Number of visitors	30	461	-431	0	-		-	0.0146
Facilities (benches. playground)	171	201	-30	1.369	< 2e-16	***	0.0888	0.0575
CO_2 uptake	142	114	28	1.568	< 2e-16	***	0.0897	0.0703
Ambient noise reduction	145	152	-7	1.419	< 2e-16	***	0.0882	0.0605
Cooling capacity	100	180	-80	1.230	< 2e-16	***	0.0886	0.0501
Rainwater infiltration and storage	212	101	111	1.806	< 2e-16	***	0.0905	0.0891
Local air quality	234	66	168	2.013	< 2e-16	***	0.0920	0.1096
Property values	78	379	-301	0.504	1.54E-18	***	0.0892	0.0243
Density of forestation	120	219	-99	1.167	< 2e-16	***	0.0881	0.0470
Frequency of maintenance	113	217	-104	1.203	< 2e-16	***	0.0896	0.0487
Species richness (flora)	259	56	203	2.114	< 2e-16	***	0.0921	0.1213
Species richness (fauna)	294	71	223	2,184	< 2e-16	***	0.0928	0.1300
Quietness	364	45	319	2,492	< 2e-16	***	0.0948	0.1769

*** 99% confidence level, ** 95% confidence level, * 90% confidence level

Figure 15 Share of preferences for neighbourhood park attributes, from least important (left) to most important (right), based on conditional logit model.



These findings informed the articulation of attributes for the DCE. Both quietness and the number of visitors emerged as informative factors for decision making and were found to be strongly correlated. To facilitate quantification in the DCE, we selected the number of visitors as a measurable metric, hypothesising a strong negative correlation with respondents' utility. Additionally, due to the significance of species richness (fauna and flora) as the second and third most important feature of a neighbourhood park, it was incorporated as an encompassing attribute named 'species richness' in the DCE. Furthermore, given the correlation between local air quality and CO_2 uptake, we translated this relationship into attributes by specifying the annual uptake of carbon emissions from a certain number of families, explicitly highlighting its contribution to local air quality. Finally, the park's role in improving rainwater infiltration and storage capacity was included as an attribute in the DCE.

4.3.2 Discrete choice experiment

Descriptive statistics

A total of 833 respondents from 239 Flemish municipalities filled out the online survey. This sample was stratified on age and geographical area (province) in Flanders, Belgium. From Figure 16 the relative frequency per municipality can be observed. Noticeably, this correlates with Flemish population density graphs (can be found in 3.2, Figure 8). Other characteristics of the sample can be found in Table 19. The sustainability profile represents a composite of Likert scale data that measures the adherence to sustainable principles in individuals' daily lives (visualised in Table 16).

Figure 16 Map of Flanders, Belgium with the number of respondents in the residents' discrete choice experiment sample per municipality

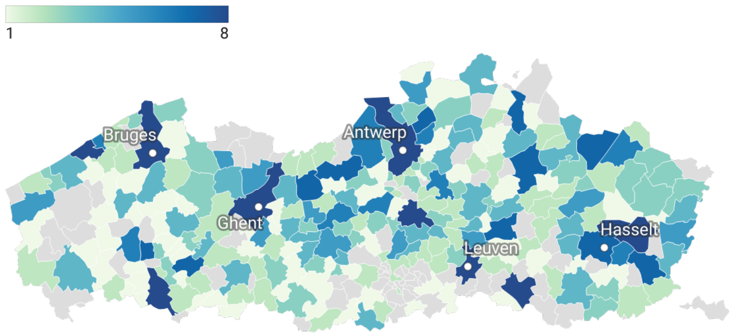


Table 19 Demographics of the respondents in the discrete choice experiment sample of Flemish residents

Respondent characteristics		Number	% in sample
Gender	Male	387	46
	Female	444	53
	Non-binary	1	<1
	Prefer not to say	1	<1
Province	Antwerp	236	28
	West-Flanders	158	19
	East-Flanders	184	22
	Flemish Brabant	128	15
	Limburg	127	15
Age group	25-34	114	13.7
	35-49	194	23.3
	50-64	304	36.5
	65-79	208	25.0
	80+	13	1.6
Highest educational qualification	No formal education/primary education	38	4.5
	Secondary education	337	40.5
	Higher education – non-university	292	35
	Higher education – University	166	20
Frequency of visiting closest green space	Daily	175	21
	2-3 times per week	181	21.7
	Weekly	182	21.8
	2-3 per month	79	9.4
	Monthly	61	7.3
	Less than monthly	155	18.6

Numerical variables	Min-Max	Mean	SD
Sustainability profile	0.11-1	0.61	0.15
Population density	62-3364 inh/km^2	900 inh/km^2	720.2 inh/km^2

Respondents' perceptions on neighbourhood level greening

To deepen the understanding of choices made in the DCE, the survey gauged people's perceptions on their neighbourhood and the available green infrastructure in their neighbourhood in Likert-scaled questions (results are visualised in Table 20). Generally, respondents are satisfied with their neighbourhood. Although over 65% of respondents believe there is plenty of neighbourhood greenery now, 55% believes that more greenery would make the neighbourhood more visually attractive. Interestingly, over 40% state that they would participate in maintaining green infrastructure, if the municipality were to install more.

Table 20 Respondents' perceptions on their neighbourhood and its green infrastructure

	Strongly agree	Agree	Undecided	Disagree	Strongly disagree
I am satisfied with my neighbourhood (%)	235 (28)	422 (51)	118 (14)	43 (5)	15 (2)
I find my neighbourhood visually attractive (%)	196 (24)	343 (41)	192 (23)	81 (10)	21 (3)
There is plenty of greenery in my neighbourhood (%)	241 (29)	325 (39)	136 (16)	107 (13)	24 (3)
More greenery would make my neighbourhood more attractive (%)	180 (22)	278 (33)	294 (35)	58 (7)	23 (3)
If my municipality were to install more greenery in my neighbourhood, I would be willing to participate in the maintenance (%)	119 (14)	245 (29)	280 (34)	127 (15)	62 (7)
In future plans, it will become more important to foresee plenty of green space in the public realm (%)	363 (44)	353 (42)	98 (12)	12 (1)	7 (<1)

To understand heterogeneity in the responses, further analysis on respondents' characteristics was executed. The influence of respondents' age, population density of their municipality, sustainability profile, and the distance to the nearest park on the perceptions of neighbourhood GI is studied. The impact of gender was also scrutinised, but no significant influence was found. Ordinal logit regression results are visualised in Table 21. Results illustrate how population density is a great predictor for people's appreciation of the neighbourhood. People living in denser populated areas are less satisfied with their neighbourhoods, find their neighbourhoods significantly less attractive, are less satisfied with the amount of greenery and are convinced that more greenery would make the neighbourhood more appealing. On the other hand, the closer the nearest green space to the residence, the more satisfied people are with their neighbourhood, the more they find their neighbourhood visually attractive and the more they believe there is plenty of green in the neighbourhood. Age has a comparable effect; the older respondents, the more satisfied they are with their neighbourhood, the more they believe there is plenty of greenery in their neighbourhood, and the less they believe that more greenery would make their neighbourhood more appealing. This reasoning can also be reversed in that younger people demand more green. Further, and expectedly, we find a negative association between the minutes to the closest park space and the frequency of visiting. The sustainability index has predictive power on respondents' perceptions as well. People stating to be more sustainable are found to want more green infrastructure in their neighbourhood and are typically more willing to participate in the maintenance of this GI, as well as they are more convinced of the higher importance of GI in future spatial plans. However, in general, it can be observed in Table 20 that people almost unanimously acknowledge the need for more GI in future spatial designs.

Table 21 Results from ordered logistic regressions on residents' perceptions of neighbourhood greening

	Satisfied	**Visually attractive**	**Plenty of greenery**	**More green attractive**	**Maintenance**	**Future**
Age	0.0109**	0.0069	0.0323***	-0.021***	-0.0118***	0.0023
	(0.0046)	(0.0044)	(0.0045)	(0.0044)	(0.0044)	(0.0046)
Population	-0.0034***	-0.0004***	-0.0003***	0.0003***	<0.0001	-0.0001
density	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Sustainability	-0.3779	-0.0471	-0.9261**	3.6681***	4.2645***	5.0046***
profile	(0.4519)	(0.4332)	(0.4379)	(0.4634)	(0.4542)	(0.4953)
Distance	-0.092***	-0.1038***	-0.1482***	0.0804***	0.0212*	-0.019
	(0.0126)	(0.0124)	(0.0129)	(0.0124)	(0.0117)	(0.0124)
cut1	-4.7445	-4.5961	-4.0671	-1.9324	-0.5469	-2.0858
	(0.4597)	(0.4284)	(0.4189)	(0.4082)	(0.3669)	(0.5213)
cut2	-3.3124	-2.8487	-2.0539	-0.5393	0.8228	-1.0519
	(0.3999)	(0.3773)	(0.3695)	(0.3723)	(0.3575)	(0.4273)
cut3	-1.9699	-1.3771	-0.9521	1.7017	2.4262	1.0048
	(0.3811)	(0.3634)	(0.3615)	(0.3729)	(0.3661)	(0.3817)
cut4	0.4468	0.5557	1.0112	3.3688	4.0755	3.3
	(0.3747)	(0.3622)	(0.3629)	(0.3859)	(0.3835)	(0.3985)

Note: Values in the table are the ordered logistic regression coefficients, with standard errors in parentheses. *,**,*** denoting the 0.01, 0.05, and 0,10 significance levels respectively

In the DCE survey, participants were additionally requested to indicate their motivations for visiting neighbourhood green spaces. Out of the total 833 respondents, a significant majority of 76% expressed a belief that such visits are advantageous for obtaining fresh air, while a similar proportion of 73% asserted its positive impact on health. Furthermore, 72% of the respondents expressed an inclination to visit these spaces in search of peace and tranquillity, while 56% stated a desire to *escape*. Notably, the aspect of social cohesion associated with neighbourhood greening garnered the least interest among respondents, with only 20% citing it as a reason for visiting.

Modelling results

Main-effects model

Table 22 MNL-HB estimations of the main-effects model

Term	Posterior Mean	Posterior Std Dev
Walking distance [10 min-5 min]	0.426***	0.054
Walking distance [15 min-10 min]	-0.429***	0.050
Naturalness [Moderate species richness-Low species richness]	0.391***	0.052
Naturalness [High species richness-Moderate species richness]	-0.572***	0.065
Number of visitors [70 daily-30 daily]	-0.077	0.049
Number of visitors [110 daily-70 daily]	-0.388***	0.052
CO_2 uptake [15 families'-5 families']	0.204***	0.055
Water infiltration [20 years-10 years]	0.202***	0.065
Water infiltration [30 years-20 years]	0.295***	0.065
Municipal tax	-0.004***	0.001
No Choice Indicator	-4.736***	0.253

*** 99% confidence level, ** 95% confidence level, * 90% confidence level

The results of the hierarchical Bayesian model yield several main findings, depicted in Table 22. Firstly, it was found that while species richness was identified as the most important factor in the BWS, the DCE produced more ambiguous results in this regard. Specifically, there was a significant positive effect on respondents' utility when moving from the low to the moderate level of species richness. However, there was also a significant negative effect when transitioning from the moderate level to the high level of species richness. This suggests that respondents derive the most utility from the midpoint value in terms of species richness. Similarly, respondents exhibited a preference for the midpoint value of walking distance from their residence to the new park. In both cases, there was no significant difference in utility between the lowest and highest levels of these attributes in the survey.

With respect to the ecosystem services provided by the neighbourhood park, positive effects were observed for increased CO_2 uptake and the associated improvements in air quality. Furthermore, respondents expressed a significantly higher willingness to pay when the water infiltration capacity of the area improved, leading to a reduction in flooding incidents. Importantly, the duration of this benefit was found to influence respondents' utility, with longer-term benefits being associated with greater utility. Lastly, the number of visitors to the park was found to have a negative impact on the derived utility, confirming the importance of quietness, as previously demonstrated in the BWS. As expected, a higher surcharge on the municipal tax resulted in less inclination among respondents to choose this option, indicating a sensitivity to cost considerations.

Full model

Controlling for variables derived from the DCE survey provides a comprehensive understanding of the utility function. The analysis reveals that three uncorrelated variables significantly influence respondents' choice behaviour. Of these variables, two are intrinsic to the individuals themselves, namely age and the sustainability profile, while the third variable pertains to their place of residence, specifically population density, which was selected to account for variations in urbanisation. Gender of the respondent was found to not significantly influence choice behaviour. The results of the full model are presented in Table 23.

Table 23 MNL-HB estimations of the full interaction model derived by including subject effects (Age, sustainability profile, population density)

Term	Posterior Mean	Posterior Std Dev
Walking distance[10 min-5 min]	10.281***	1.337
Walking distance[15 min-10 min]	-11.181***	1.639
Naturalness[Average species richness-Low species richness]	12.608***	1.533
Naturalness[High species richness-Average species richness]	-14.139***	2.129
Number of visitors[70 daily-30 daily]	-2.310**	1.128
Number of visitors[110 daily-70 daily]	-4.316***	1.389
CO2 Uptake[15-5]	-0.971	0.961
Water infiltration[20 years-10 years]	-0.998	0.964
Water infiltration[30 years-20 years]	-3.888***	1.404
Municipal tax	-0.123***	0.028
Municipal tax*Age	-0.006***	0.001
Number of visitors[70 daily-30 daily]*Age	-0.030	0.028
Number of visitors[110 daily-70 daily]*Age	-0.078***	0.028
CO_2 Uptake[15-5]*Sustainability profile	3.896**	1.673
Water infiltration[20 years-10 years]*Sustainability profile	4.296*	2.289
Water infiltration[30 years-20 years]*Sustainability profile	10.873***	2.349
Number of visitors[70 daily-30 daily]*Population density	-0.005	0.003
Number of visitors[110 daily-70 daily]*Population density	-0.015***	0.004
CO_2 Uptake[15-5]*Population density	0.014***	0.003
Water infiltration[20 years-10 years]*Population density	0.012***	0.003
Water infiltration[30 years-20 years]*Population density	0.011***	0.003
No Choice Indicator	-181.975***	16.859

*** 99% confidence level, ** 95% confidence level, * 90% confidence level

The outcomes demonstrate the impact of age, sustainability profile, and population density on choice behaviour within the DCE context. Upon interpretation, it is evident that older respondents are less willing to pay for a new neighbourhood park, indicating a stronger preference for privacy and quietness (as denoted by the negative sign associated with higher visitor levels). The sustainability profile is a composite variable, which is explained in Sections 2.3.1 and 2.3.2. The full model reveals those individuals with higher scores on the sustainability profile proxy place greater importance on factors such as CO_2 impact and water infiltration capacity when making decisions. Furthermore, as depicted in Table 23, there is a positive relationship between higher population densities and WTP for environmental attributes, including CO_2 uptake and water retention. Conversely, respondents from denser populated municipalities exhibit a wish for lower visitor numbers, indicated by the negative sign on its coefficient.

4.4 Discussion

This research adopted a sequential experimental approach to examine individuals' perceptions and value attribution concerning ecosystem services within green infrastructure. A best-worst scaling experiment was conducted to gather input for attribute reduction in a subsequent discrete choice experiment. The online panellist surveys yielded valid responses from 1007 participants, with 174 individuals participating in the exploratory BWS experiment and 833 respondents completing the comprehensive DCE survey. It is important to note that participants did not take part in both experiments, ensuring distinct and independent data points. With this study, we aim to surpass the current state-of-the-art of stated preference studies that assess people's preferences for green infrastructure solely for recreational purposes. Instead, our objective is to gain a deeper understanding of prioritisation and value attribution towards ecosystem services in general provided by green infrastructure. As policy discussions increasingly focus on implementing climate adaptive measures, it is crucial to align these efforts with the views and perceptions of residents. This alignment will facilitate the synergistic planning and design of green infrastructure, ensuring that it effectively meets both policy goals and the needs of the community. By comparing the perspectives of these two stakeholder groups, we seek to address the people-policy gap in the context of green infrastructure. The objective of this chapter is therefore complementary to that of Chapter 3. In Chapter 3 an insight was provided in GI or ES supply, in this chapter we look at the demand of GI. We identify (dis)similarities in the supply and demand of GI, thereby narrowing the gap between the expectations of residents and the actions taken by decision makers.

Methodologically, employing a sequential BWS-DCE experimental design was found to yield several advantages. First, we experienced the BWS to be an efficient and more participative approach to traditional methods for attribute reduction (e.g., focus groups, literature review). By gauging people’s value orientation through BWS, we obtained attributes that are more salient to respondents, since the target groups of both surveys are the same. This point is even more relevant when there is limited existing research that can be used as a basis for defining DCE attributes. Through combining both methods, we further obtain a richer and more robust insight into residents' preferences. Since – as we demonstrated in this discussion – results of one method can be compared and validated through findings of the other.

The BWS gave evidence of people's most valued attributes for a hypothetical new neighbourhood park in the vicinity. These attributes can be strongly associated with ecosystem services that a park would generate. The results clearly indicate how respondents value health first, similar to Ordóñez Barona (2015). Both the mental health (*peace* and *quietness*) and the physical health (*air quality*) attributes scored very highly. Next, respondents regard biodiversity or *species richness* highly. Even more, if taking fauna and flora under the same heading, species richness is unequivocally the most important feature according to the sample. Number of visitors, which would be very important if respondents were to appreciate a new park for its addition to the social cohesion, was found the least important feature. Besides this, the impact on property values appears unimportant to respondents. These results are consistent with an ecosystem benefit ranking study conducted in the US Great Lakes area. Tyner and Boyer (2020) found that respondents mostly valued anthropocentric arguments, nevertheless they ranked ecosystem conservation over property values and recreational use. Analogously in this BWS, biodiversity or species richness was valued over these rather economic arguments. These results fed the attribute reduction for the DCE. Eventually, CO_2 uptake, water buffering and infiltration, species richness, and the number of visitors were added to the monetary argument and the walking distance from the residence to the new green infrastructure. Number of visitors was included as a proxy for the quietness of the area.

From the BWS, we unambiguously conclude that people value species richness or biodiversity and consequently naturalness of a neighbourhood park highly. In the DCE main-effects only model "naturalness" (defined as covering the two most important objects in the BWS), the importance of biodiversity is confirmed. This is in line with other research, finding positive associations with residents' appreciation of (urban) green space and species diversity (Badura et al., 2021). However, the DCE also demonstrates that respondents' appreciation of naturalness is not unambiguous. Respondents expressed a preference for moderate levels of naturalness in park spaces, valuing the higher level significantly lower. Along the same lines, Badura et al. (2021) found that respondents valued species diversity in nature-based solutions at a reducing rate. This suggests that while individuals positively value naturalness, there is a desire for a balance between natural features and managed elements. Similar results were found in other research gauging people's preferences on visual properties of green infrastructure: e.g., Suppakittpaisarn et al. (2019) revealed how *messiness* negatively affects desirability of GI. Given that the presentation of the "naturalness" attribute was supplemented with accompanying graphics for clarification, the lower preference for "high species richness" over "moderate species richness" could also stem from aesthetic or visual preferences rather than considerations related to biodiversity. Frantzeskaki (2019) established the importance of aesthetically appealing NbS or GI for residents to appreciate them as one of the seven lessons for planning NbS in cities.

A similar observation was made for the distance to the park, respondents appreciate proximity, but appear to prefer the neighbourhood park to not be too close. The negative association with proximity to some point may be due to potential nuisances associated with open spaces in cities. However, this observation is specific to the hypothetical scenario of a neighbourhood park and may not reflect general perceptions of green infrastructure. Because the results from the ordered logistic regressions indicate that respondents living farther from the accessible green space are less satisfied with the neighbourhood, find their neighbourhood less attractive, feel like they don't have enough green in the neighbourhood and believe that more green would make the neighbourhood more attractive. Research has previously identified how green elements are incredibly relevant for people's mental health (Nutsford et al., 2013; Plambech & Van Den Bosch, 2015; Taylor et al., 1998). Our BWS experiment also underlined how much people value green space for mental wellbeing, seeking for peace and tranquillity. Further, respondents' motivations for visiting neighbourhood green are strongly aligned with these aspects of mental and physical health. Further research is therefore needed to explore people's attitudes towards different types of green infrastructure in various contexts to explore the assumed effect of nuisances or ecosystem disservices on people's value attribution that was observed in the DCE. The ordered logit analysis further uncovers some of the heterogeneity in the sample. While people are generally satisfied with their living environment and the amount of greenery present, age, population density, sustainability profile and distance to the nearest accessible green space impacts the dimensions of neighbourhood greening satisfaction.

Generally, we find that the younger respondents are, the less satisfied they are with the neighbourhood and its attractiveness. Younger respondents demand more greenery in their neighbourhood, which is supported with evidence from the DCE interaction model where we find that they are also less cost sensitive. These findings can be linked back to the path dependence and institutional lock-in issue introduced in 1.3 of this dissertation. As Davies and Lafortezza (2019) state that the required institutional changes are challenging and inter-generational, our evidence of younger generations' perceptions on GI provide promising indications to realise such changes. In the DCE, we further find that respondents with a higher sustainability profile score, derive more utility from higher levels of the environmental attributes CO_2 uptake and air quality, and water infiltration. Further, the more sustainable respondents claim to be, the more likely they are willing to participate in the maintenance of new green infrastructure, and the more convinced they are about the role of GI in the future. This implies that intrinsic motivation (Stern, 2000) is critical towards acceptance of climate adaptive and green infrastructure. Education and GI policy participation are therefore valid pathways towards acceptance and effective GI implementation.

Due to the lack of official data on the urbanisation rate of individual Flemish municipalities, population density was employed as a proxy measure. The findings unambiguously demonstrate that population density exerts a significant influence on respondents' choices. Respondents residing in denser populated municipalities exhibit lower levels of satisfaction with their neighbourhoods and perceive them as less attractive. Additionally, they express a stronger desire for additional green infrastructure, believing that it would enhance the visual appeal of the area. It is important to recognise that their request for more green infrastructure extends beyond mere visual aspects. Noticeably, population density plays a part in the DCE, where we notice that respondents from denser populated municipalities put higher weights on regulating ecosystem services such as CO_2 uptake and air quality, and water retention and infiltration. Possibly this originates from the observation that urbanised environments are already more vulnerable to extreme weather events (Krarup, 2022), and thus residents are more aware of the need for enhancing climate adaptivity. This finding highlights the significance of considering population density as an approximation for urbanisation differences in the analysis. These elements contribute to concluding that valuation tools should be adapted to urbanised contexts in their practices to reveal not only monetary, but also qualitative values for GI, thus considering the higher demand for ES in cities. In Chapter 5 we therefore introduce a tool that accommodates to include multiple value dimensions in building the case for (urban) GI.

The comprehensive model further reveals that respondents residing in densely populated areas place greater importance on lower levels of visitors. This observation suggests that urban residents are more inclined to seek peace and tranquillity in green spaces rather than social interaction. This finding may also be influenced by past experiences, as urban areas often face a scarcity of green spaces, resulting in crowded parks. Consequently, respondents from these areas may exhibit a higher sensitivity towards the attribute of visitor levels. Furthermore, we find that these residents also perceive a lack of greenery in their neighbourhood. This observation suggests that individuals residing in densely populated areas feel that the existing green infrastructure in their surroundings is insufficient. These findings align with previous research indicating that individuals in more urbanised regions tend to favour numerous smaller urban parks over a smaller number of larger parks (Ta et al., 2022).

Comparing the DCE results with previous research utilising the same GI case for a DCE with Flemish decision makers, we can identify (dis)similarities between both. In the Chapter 4 we asked which GI option would be implemented in their municipality (Van Oijstaeijen et al., 2022). First, a remarkable similarity between both stakeholder groups results from the attribute selection stage of the DCE. The attribute selection for decision-makers, informed by consultations with planning experts and local practitioners, yielded comparable attributes to those identified in the BWS study. This not only underlines the face validity of the attributes, but it also highlights a shared understanding and valuation of key characteristics in green infrastructure. The alignment of attribute preferences between decision-makers and the broader public, as represented by the BWS respondents, indicates the potential for collaboration and consensus-building in the development. However, there is a notable difference in the consideration of costs between taxpayers and decision makers, with taxpayers assigning considerably less importance to the costs compared to decision makers, as evidenced by the relatively low variable importance of the municipal surcharge for residents. Decision makers indicate that cost arguments heavily influence decision-making processes within the municipality. Yet, the levels were designed so that – on average – the cost attributes in both experiments are proportional to the income of both stakeholders (i.e., average income taxpayer and average municipal income). Underlying these findings, we can think of two different explanations. First, municipalities experience more conflicting demands on finances. Second, the beneficiaries of the benefits of GI are not the same as the *investors*. Since many of the benefits or ecosystem services do not straightforwardly translate into budgetary savings, such monetary arguments are valued less by decision-makers. In this regard, using stated preference techniques (such as BWS or DCE) helps to expose and address this value pluralism between stakeholders. This supplements the *factual* GI case based on tangible costs and benefits, strengthening the participative and inclusive nature of GI. Therefore, the use of valuation tools should always be complemented with actual stakeholder consultation. Further, there is a divergence in preferences regarding the number of visitors between residents and decision makers, with decision makers placing higher value on increased visitation to GI sites, while residents, as the intended target audience, express a preference for fewer visitors and prioritise the tranquillity that accompanies lower visitor numbers. Notably, the number of visitors ranked as the least important attribute in the BWS analysis, and social cohesion was identified as the least valued argument for visiting local green spaces. Fourth, in the decision makers' DCE we saw that long-term arguments were often disregarded. The opposite seems to hold true for the public: long term arguments are acknowledged forcefully. The BWS showed that respondents are not interested in short term economic benefits (e.g., higher property values), the water infiltration attribute was valued highly in the DCE, CO_2 uptake has a significant impact on their decisions too. Additionally, respondents almost unanimously agreed on the importance of GI in the future, demonstrated in Table 20. These findings show that perceptions are strongly context specific and oppose some views by decision makers, which underlines the call for local scale assessments of residents' expectations of urban green space (Ordóñez Barona, 2015). In this context, local authorities might find BWS experiments appealing, considering their straightforward methodology and potential for easy replication. It is therefore an appropriate method to complement applying a GI valuation tool, as is introduced in Chapter 5.

In the regional Flemish Adaptation Plan 2030 densification and core compression are important strategies (Vlaamse Overheid, 2022). In theory it is aimed that these strategies simultaneously address the need for accessible local green spaces and other forms of GI. This multifunctional nature of GI should be integrated and emphasised in policy, as fragmented narratives have been identified as potential barriers to its implementation (Bush, 2020). To assist local authorities in navigating this process, clear guidelines or principles should be established. This is particularly important considering that we find that respondents from densely populated areas express a significantly stronger desire for more greening. This finding conflicts with the observations in Chapter 3, where it was established that cities face additional challenges in terms of persuading developers and managing conflicting priorities. While these citizens demand more GI, structural issues within these denser local authorities prohibit the realisation in practice, illustrating a gap between people's expectations and policy implementation.

Expectedly, such gaps can be addressed through overarching policy measures. Metrics like the 3-30-300 rule can serve as enforceable instruments for local authorities to promote green infrastructure and enhance the quality of urban environments specifically. The 3-30-300 rule advocates for specific targets to ensure the provision of nature and green spaces to residents. It proposes that every individual should have a view of at least three trees from their residence, the neighbourhood should have a minimum of 30% canopy cover, and accessible green spaces should be available within a 300-meter radius (Konijnendijk, 2021). Such indicators can contribute to overcoming prioritisation issues within local authorities and provide instrumental support for spatial planning services in implementing GI. Using these jointly with GI valuation toolkits revealing ecosystem service generation addresses both GI quantity and quality, striving for liveable, resilient, and future-proof municipalities.

4.5 Conclusion

In conclusion, this research employed a sequential experimental approach to investigate individuals' perceptions and value attribution towards ecosystem services in green infrastructure. The study utilised a best-worst scaling experiment to identify the most valued attributes for a hypothetical neighbourhood park. The results indicated an emphasis on health-related aspects and biodiversity, while property values and social arguments were disregarded. The subsequent discrete choice experiment incorporated attribute reduction based on the BWS results, including factors such as CO_2 uptake, water buffering and infiltration, species richness, number of visitors, a municipal surcharge, and walking distance to the new green infrastructure. A total of 1007 individuals participated in the research. With this research, we extend existing stated preference GI studies beyond mere recreational value, towards ecosystem services and consequent landscape resilience.

The DCE findings revealed mixed attitudes towards naturalness, with a preference for moderate levels of naturalness over higher levels, indicating a preference for natural, but not wild park spaces. Proximity to the park was valued, but respondents also preferred a certain distance from their residence, potentially due to concerns about potential nuisances associated with urban open spaces. These observations are specific to the hypothetical scenario of a neighbourhood park and further research is needed to explore attitudes towards different types of green infrastructure in various contexts. Especially studying ecosystem service preferences for street-level greening - given that it is versatile and widely implementable – can contribute to effective GI implementation strategies.

The study also provided insights into residents' satisfaction with their living environment and the amount of greenery present. Heterogeneity in responses was partially explained by factors such as age, population density, sustainability profile, and distance to the nearest green space. Older age and proximity to the nearest green space were positively associated with satisfaction and perceived attractiveness of the neighbourhood, while population density had a negative impact. Respondents exhibiting more sustainable practices showed a higher willingness to pay for environmental attributes and are more willing to participate in the maintenance of new green infrastructure.

Comparing the DCE results between decision makers and the broader public, several (dis)similarities emerge. Both groups share similar attribute preferences, highlighting a shared understanding and valuation of key characteristics in green infrastructure. However, there is a discrepancy in the importance of cost considerations, with taxpayers assigning less importance compared to decision makers. Furthermore, residents and decision makers hold divergent views on the number of visitors, with decision makers favouring higher visitation while residents prefer fewer visitors for a quieter experience. The BWS study also revealed that the public values long-term benefits, such as water infiltration and CO_2 uptake, and expresses a strong consensus on the importance of GI in the future, while short-termism prevails in local decision-making. Overall, tailored approaches to urban green space planning – supported by tangible and enforceable indicators (e.g., 3-30-300 rule) - are necessary, considering residents' perspectives to bridge the gap between people and policy (Depietri, 2022). By incorporating these insights, municipalities can create sustainable and inclusive urban environments that meet the needs and aspirations of residents, while simultaneously becoming climate resilient and biodiversity supporting.

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Chapter 5
A novel tool to reveal GI costs and benefits: the Nature Smart Cities business model

In Chapter 2, we explored the potential of toolkits to support GI implementation, aiming to bridge the divide between scientific research and local policy by leveraging GI and ES valuation tools. Building upon the participative stakeholder analyses conducted in Chapters 3 and 4, we gained further insights into how both decision-makers and residents perceive and prioritise specific GI attributes, highlighting the factors that influence their preferences. In this chapter, we harness these accumulated insights to introduce a novel tool for valuing ES derived from GI. What sets this tool apart from the current state-of-the-art is its collaborative development with local authorities. It not only incorporates the perspectives of decision-makers but also integrates the GI value orientations of residents. As a result, this tool not only narrows the gap between science and decision-making but also bridges the divide between the public and local decision-making processes, or broader: policy implementation.

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5.1 Introduction

The incorporation of natural areas in urban and densely populated areas is increasingly recognised for its multiple environmental and social benefits (Carter et al., 2015; I. C. Mell, 2017), for example mitigating the impacts of surface flooding, reducing urban heat island effects, and increasing social cohesion among residents. GI has the potential to deliver (re-)integration of (semi-)natural elements to create healthier, more climate-resilient, and enjoyable areas for urban residents (Pauleit et al., 2017), as well as raising awareness of the natural approach with both public and practitioners. Increasingly, (retro)fitting natural elements in populated environments provides a credible approach for urban planners to anticipate and mitigate inimical consequences (Bayulken et al., 2021). Interest in GI among with policy makers has increased in the last decade (Babí Almenar et al., 2021), with GI acknowledged through strategies at different levels of decision making (e.g., EU Strategy on Green infrastructure (supranational level), National strategy for Pollinators (Belgium – national level), Flanders' building shift (regional level). Nevertheless, implementation of GI and ecosystem services in local authorities' practice is still believed to be challenging and slow (Back & Collins, 2021; Bowen & Lynch, 2017; Matthews et al., 2015; Roe & Mell, 2013). Research has uncovered a significant gap within (local) authorities between the strategic vision and the operational implementation dimension, not fully committing to policies' high-level goals, objectives, and ambitions (Back & Collins, 2021; Bush, 2020; Raynor et al., 2017).

The origins of this hampered implementation are discussed intensively in GI and NbS literature. Viti et al. (2022) describe the perception of developers, that high(er) costs of operationalisation and maintenance are a key barrier for widespread NbS application. Generally, the most cited barriers are indeed resource related: a lack of funding, and maintenance requirements (Li et al., 2020), but also the uncertainty or difficulty in measuring costs and benefits (Reu Junqueira et al., 2021). Further barriers or challenges include a lack of knowledge or expertise, unfavorable perceptions about GI, reluctance to change established practices, and institutional path dependence and siloes (Dhakal & Chevalier, 2017; Matthews et al., 2015; O'Donnell et al., 2017; Voskamp et al., 2021). GI/NbS knowledge and evidence gathering, and efficient dissemination, could contribute to overcoming many of these barriers. One of the main gaps however remains if and how this knowledge is used in practice, at the local spatial planning level. Overcoming the GI implementation gap depends on the size of municipalities as well; smaller municipalities often have less capacity and perceive knowledge deficiencies, while larger municipalities are more likely to struggle with convincing developers (Back & Collins, 2021; Van Oijstaeijen et al., 2022). Thus, local capacity drives the perception of knowledge barriers. Adem Esmail et al. (2022) found that scientific literature is barely influencing the uptake of greening practices in spatial planning. Moreover, current local plans lack applications of the ecosystem services concept (Cortinovis & Geneletti, 2018). This finding is endorsed by previous literature identifying knowledge gaps between science and policy as a determining factor in the hampering NbS uptake (Bayulken et al., 2021). Narrowing the gap between scientific insights and local authorities' practice would benefit (especially for smaller municipalities) a transition towards more informed decision-making processes regarding greening practices.

From an academic perspective, interest in (urban) ecosystem service generation as a concept to be integrated in urban planning is receiving more attention (Haaland & van den Bosch, 2015). The growing body of evidence on the multi-functionality of (semi-)natural elements in built environments (especially in Europe) founds this statement (Chatzimentor et al., 2020). Research by Dick et al. (2018) with 27 ES/GI case studies revealed that the main benefit of ES research lies in knowledge accumulation, closely followed by directly applicable methods and tools to bridge between science and the development and implementation of decision making, management and planning. Integrating ES research in decision-support tools is a means to facilitate informed decision-making practices at the local scale, and the potential of this integration lies in the high potential of replication and upscaling (Longato et al., 2021). Comprehensive valuation mechanisms have been recommended (Di Marino et al., 2019; Ershad Sarabi et al., 2019) to assist LAs to increase support for GI implementation by evidencing the multiple GI benefits (Bowen & Lynch, 2017; O'Donnell et al., 2017) without additional local capacity requirements. A systematic review by Song et al. (2018) highlighted the need for comprehensive cost and benefit accounting methods, contributing to the inclusion of economic assessments into decision making. Currently, the largest added value that lies in GI/NbS – its multifunctionality – is generally disregarded, since GI projects are often implemented for single-purposes. The mainstreaming of comprehensive valuations for greening practices potentially reinforces the argument for the green option. In a more comprehensive approach, the wide range of co-benefits can be considered, strengthening the investment case for GI approaches. Expectedly, value revelation will contribute to facilitate funding issues. Further, the NetworkNature project has provided a unique, user-oriented platform that bundles knowledge and expertise on ongoing research and existing knowledge gaps in NbS and GI research (networknature.eu).

This research responds to the call for practical applications and policy-science evidence for ES integration (Rozas-Vásquez et al., 2019). Hansen et al. (2019) identified a lack of application-oriented frameworks or decision-support tools at a local authority's disposal to mainstream the concepts of GI/ES/NbS in their planning practices. In recent years, interest in such tools is clearly increasing from an academic point of view, with more decision-support tools emerging serving a wide range of purposes (Van Oijstaeijen et al., 2020; Voskamp et al., 2021). They range in complexity from intuitive textual guidelines to complex hydrological or ecological modelling tools. However, it was found that many of these free-to-use tools are currently not used by local municipalities, because they seem too complicated, because they are just not known about, or because they don't provide comprehensive results across a range of ES (Back & Collins, 2021). Back and Collins (2021) conducted research with local authorities to find three key principles for uptake of these tools: useability, comprehensiveness, and credibility. Since the starting point for this research is the integration and mainstreaming of scientific knowledge and evidence in local decision making, a strong emphasis is put on these three key principles.

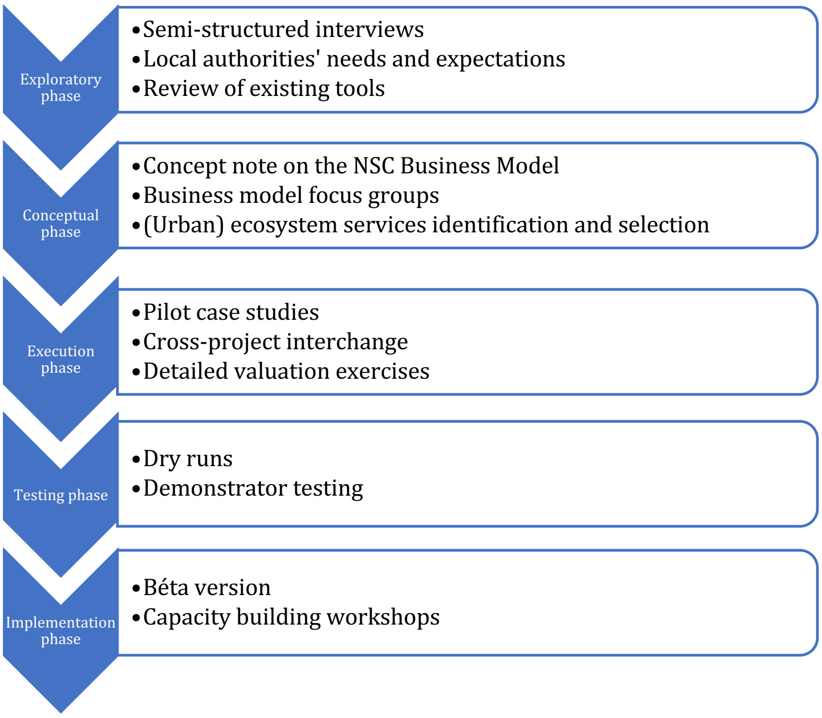
In the Nature Smart Cities (NSC) project, a transdisciplinary approach to knowledge integration and applicable monetary valuation practices was adopted. Across the consortium of eight city partners and three academic partners, the science-policy interface was fundamental to the outcome of the project. By tying actual GI pilot investments to academically supported valuation and financing applications, collaboration across disciplines was stimulated in all steps of the spatial planning process. Fostering this collaboration and building on the evidence collected from real-life examples led to a detailed insight into the bottlenecks of GI implementation at the local level, as well as current shortcomings in academic approaches to ES knowledge integration and application. This project therefore focuses on the nexus between gaps in ecosystem services knowledge use and application in spatial planning and decision making, and the integration of business models to facilitate this. With this introduction of the Nature Smart Cities Business Model (NSC-BM), we contribute to raising capacity and aim to provide local authorities with the means to incorporate informed GI decision making practices by offering a comprehensive estimation of costs and benefits through ecosystem service valuation. Business models in the context of municipal authorities can be seen as the further elaboration of municipal strategic plans into actionable project ideas. The role of a business model for GI would be to guide the transition from strategic vision into actions. The Nature Smart Cities business model therefore helps to perform systematically an indicative comparative scenario analysis, especially relevant in early project planning and the design phases. This contributes to bringing a plan into practice on the project scale, while monitoring and further developing progress towards municipal strategic objectives. In what follows, the NSC-BM is first presented methodologically and secondly demonstrated through a case study. Further, the term “green infrastructure” is used as an encompassing application of ES and NbS.

5.2 Overview of the Nature Smart Cities Business Model

5.2.1 Development of the NSC-BM

A key element in every step of the development, displayed in Figure 17, is close cooperation between academia and practice. This emphasis in itself explains the successful completion of the project, delivering seven GI pilot investments and the NSC-BM which is introduced in this research paper.

Figure 17 Overview of cascading phases in the development of the Nature Smart Cities business model



In the exploratory phase, the focus lay in exploring the state-of-the-art in academic literature and in identifying gaps and barriers in current practices. Within the NSC consortium, city partners' needs and expectations were established through consultation. Alongside this, semi-structured interviews led to a ranking of priorities in municipal GI implementation (Back & Collins, 2021). Through the literature review of current decision-support tools and their practices in Chapter 2, a thorough understanding of shortcomings on the academic side was acquired. Both parts are elementary in the subsequent phase of conceptually defining the NSC-BM strategy. A concept note was prepared and was the subject of three (online) focus groups with the NSC consortium during partner meetings in October 2019, April 2020, and October 2020. While aligning the interests of city partners, the academic partners identified and selected ES to be included in the assessment with an emphasis on urban applicability (Bolund

& Hunhammar, 1999). This way, the result is tailored for local officers to facilitate building a case for small-scale green interventions, providing arguments both in terms of ecosystem services and also tied to cost indications. After careful analysis of quantification methods for the selected ES, the academic partners conducted fieldwork on specific pilot cases to capture the extent of ES delivery. By comparing the results of these specific measurements with standardised and easily replicable valuation methods, the protocols for ES quantification and monetization were concretised. This phase was subject to cross-project interchange, building further on the existing knowledge base; in November 2020 an exchange event with the interreg2seas Cool Towns (www.cooltowns.eu) project took place, while the values database was also informed through collaboration with the IGNITION-project. An external contractor was recruited to program and automate the business model flow in MS Excel Visual Basic for Application (VBA).

Starting in July 2021, the first working version was subjected to several dry runs on actual GI cases by independent researcher Phil Back. After initial adjustments and bug fixes, the official demonstrator testing was initiated, running from September 2021 until November 2021. In this exercise eight demonstrator tests were carried out to prove the effective working of the NSC-BM and to identify areas where modification might be needed. Test sites were recruited through an open call, resulting in sites in the UK, the Netherlands and Belgium covering a range of GI projects. The demonstrator testing led to an extensive report of 309 comments, errata, feedback, recommendations, and suggestions (Back, 2021). All these were classified by the researcher in one of four groups: 'must do', 'should do', 'could do', and 'won't do', indicating their importance. Further, insight was gained into the relevance of the tool by subjecting the participants to a test against key criteria of usability, comprehensiveness, and credibility/clarity (Back, 2021). After careful revision, a beta version of the tool was launched internally. In February 2022, the project partners held a pilot testing retreat, in which all city partners were handed the toolkit and instructed to input their GI projects under the supervision of academic partners. Bug fixes and stability issues were addressed afterwards, preceding the public presentation of the tool through the capacity building programme. During two series of three workshops (March-April, June 2022), local authority officers in the UK, the Netherlands and Belgium were introduced to the tool. The first (online) series consisted of a general conceptual introduction of ecosystem services valuation, its relevance and how the tool narrows the existing ES knowledge and integration gap. Complementary to this theoretical approach, the second capacity building workshop series provided local authorities with the opportunity to be at the controls of the NSC-BM themselves. Serving as an important validating part of the project, participants were urged to share feedback and comments to better meet local officers' demands. A total of 266 individuals across 133 local authorities took part in the capacity building programme. Eventually, after processing the feedback from the capacity building programme, the Nature Smart Cities Business Model was officially launched at the Nature Smart Cities closing conference on September 28th, 2022.

5.2.2 Pillars of the NSC-BM

Co-creation and co-design

Earlier research has identified that the specific requirements of LAs are generally insufficiently addressed in existing GI tools (Van Oijstaeijen et al., 2020), contributing to the finding that very few LAs know of and make use of these decision-support tools. Therefore, the focus of attention in the entire process of developing the NSC-BM was the involvement of LAs, specifically targeting the tool's employability at the local scale.

Accessible multi-criteria decision analysis

The tool offers the base of a multi-criteria decision analysis (MCDA), combined with economic cost and benefit assessment. According to Langemeyer et al. (2016), a MCDA is a multi-step process that provides structure and formalises decision-making processes transparently and consistently. In that respect, the NSC-BM aims to do this by integrating and standardising an approach to adopt ES assessments in early-stage greening projects in urbanised environments. As a continuously evolving field in academia, the inclusion of the concept of (urban) ecosystem services allows for the tool to accommodate future scientific advancements. Furthermore, the EU encourages embedding the ES concept in decision-making, mainstreaming it through its own policies (Bouwma et al., 2018).

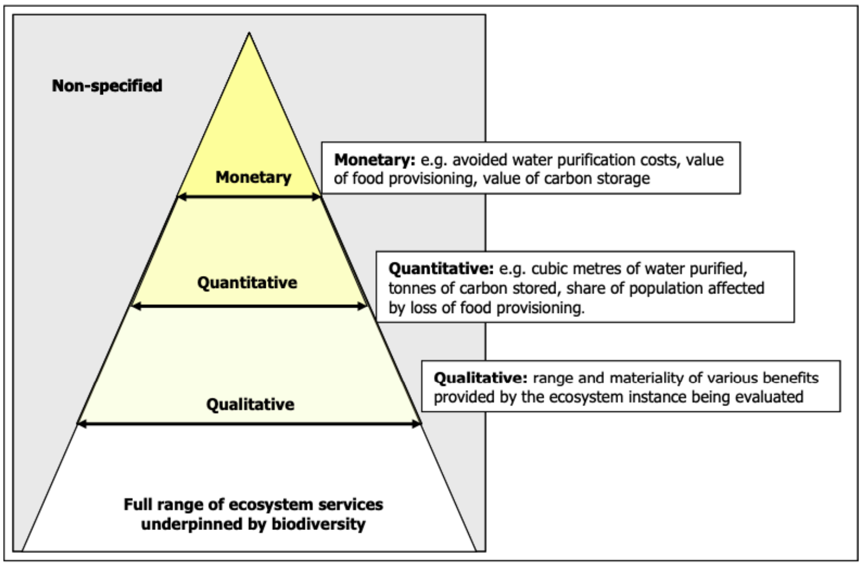
Green-grey-hybrid scenario analysis

Lack of expertise, know-how and capacity impedes evaluating the benefits of different approaches in early project stages. Tailored for small-scale and well-defined (urbanised) project areas, the NSC-BM serves to estimate how green, grey, and hybrid solutions impact ES generation on a scenario basis. Implementing the tool therefore helps to explore trade-offs that result from different spatial interpretations and to adapt or improve the project plans, which might facilitate securing appropriate (political) impetus or funding.

Multi-level value attribution

The benefit valuation method of the NSC-BM follows the reasoning offered by Kettunen (2009). The valuation pyramid (Figure 18) illustrates how the full range of ES can be described largely in qualitative terms, a smaller subset of those can be quantitatively assessed, while only a fraction can be monetised.

Figure 18 The valuation pyramid by Kettunen et al. (2009), visualising why ecosystem services assessments should support multidimensional evidence

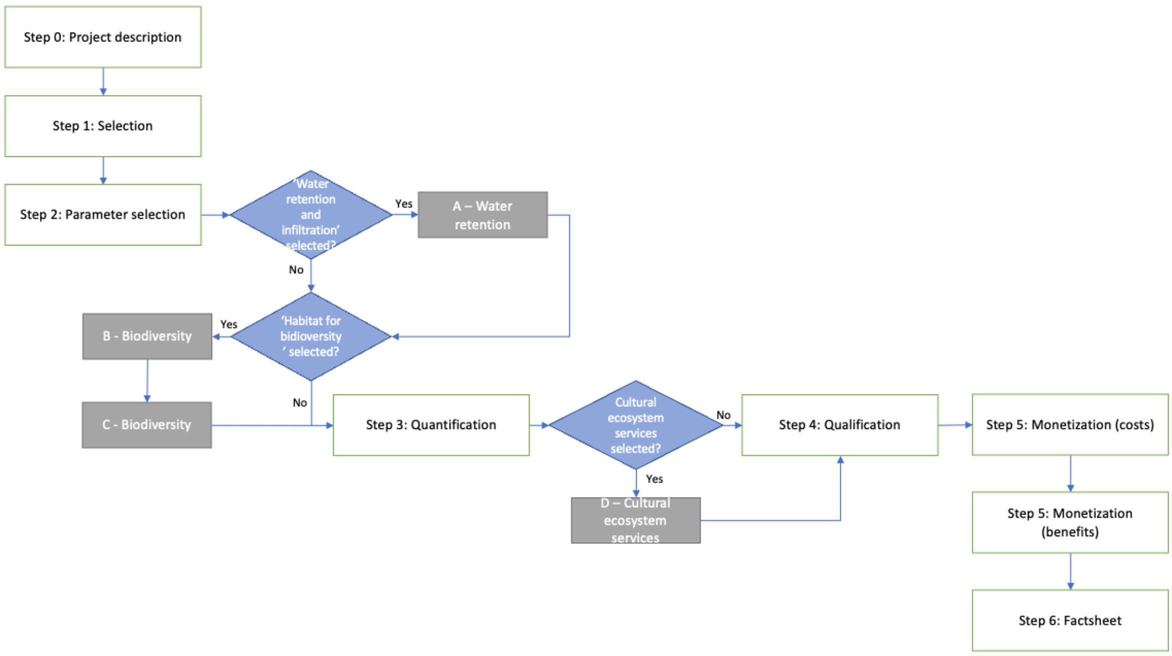


This flow of evidence is continued in the tool. While some ES can be monetised, the tool acknowledges the value plurality that is attached to urban GI by different stakeholders by combining qualitative, quantitative, and monetary evidence (Langemeyer et al., 2016; Spangenberg et al., 2015). However, the importance of acknowledging these different value dimensions in public decision-making is emphasised throughout the tool, and the evidence flow that can be obtained follows the reasoning of the valuation pyramid.

5.3 Nature Smart Cities Business Model flow

The tool is intended to be used by public sector officers and practitioners exploring the multi-benefits of greening measures across various land-use scenarios, specifically in early project stages to increase awareness of the full range of ES values (Cortinovis & Geneletti, 2018). The tool is pre-programmed as an automated Excel tool, estimating ES impacts and infrastructure-related costs based on a land use typology. In the first steps, users are expected to input the information about their greening projects and the project area. As described before, the NSC-BM offers the basis for a multi-criteria decision analysis, with ecosystem services evidence as decision criteria. The outcome of the NSC-BM is a graphically supported and easily interpretable factsheet, where alternatives are set against each other for their decision criteria using pairwise comparison (Langemeyer et al., 2016). The flow of the NSC-BM is visualised in Figure 19. with the sequential Excel worksheets depicted. Users always start with Step 0: Project description (top left corner) – following the arrows, conditional on ecosystem service selection (Step 1) - to end on the bottom right corner with Step 6: Factsheet. The boxes in white depict the main steps or worksheets in the tool, while the boxes in grey represent worksheets that appear conditionally of the statements in the diamonds. The selection of the criteria (i.e., the ecosystem services to be included in the assessment) is the starting point for every application. Depending on the stakeholders involved, the user determines which ecosystem services are most relevant for this specific case and for the decision-making process. Further, the user's green infrastructure case is estimated using ball-park figures and simplifying assumptions. A thorough overview and guidance manual informing users on every step is available, the link can be found in Appendix 5-A.

Figure 19 Overview of the step-by-step flow in the NSC-BM Excel tool



5.4 Case study

To demonstrate the BM's functioning, and how it produces and visualises evidence for a local authorities' greening projects' planning and design stages, we illustrate this through a case-study using a real-life GI case. A decision-makers' view was taken to describe and evaluate different spatial interpretations of the study site. The evaluation is based on the criteria that were identified as highly relevant for the pilot case by the municipality. By illustrating how the NSC-BM can be used to enhance spatial designs in terms of ecosystem service generation in GI projects at early stage, we arrive at an indication of the usability and added value for local authorities.

One of the pilot cases in the NSC project that served to co-develop and co-design the business model is situated in the small municipality of Kapelle, the Netherlands (approx. 13,000 inhabitants in 2022). In Wemeldinge Noordzijde, a neighbourhood in the municipality of

Kapelle, a regeneration project was planned, to respond to increased frequencies of extreme weather events and the structural vulnerability of the neighbourhood to floodings. The project took the form of a climate adaptive design. After several consultation and participation rounds with local residents and the design team, the municipality arrived at an ambitious greening scenario aimed at building resilience and creating a pleasant living environment for local inhabitants. The project area covers 60,000 m^2 in a residential neighbourhood, visualised in Figure 20. The map shows how the municipality aims to improve local GI provision by making streets (semi-)permeable and by enhancing the design of existing green space. In this case study, methods to quantify and monetise are briefly touched upon. However, for a detailed overview of the data and methods used for ecosystem service quantification and monetization, we refer to the technical manual of the Nature Smart Cities Business Model (link can be found in Appendix 5-B).

Figure 20: Map of the pilot case project in Wemeldinge Noordzijde, Kapelle.

5.5 Data gathering

The sequence of steps presented in this case study chapter is analogous to the business model flow from Figure 19. In this flow, steps 0 to 2 are used as data gathering steps, results are then presented from step 3 onwards. To illustrate every step, the output from the NSC-BM is displayed.

5.5.1 Step 0: Scenario description

In the first step of the NSC-BM, the user is expected to describe the spatial interpretation the baseline scenario, as well as describe how the landscape might change in the future. The number of alternative scenarios that can be submitted is unlimited, although for reasons of clarity, it is recommended to enter between 4 and 6, to not overcomplicate the assessment. Landscape categories and types are preprogramed and can be selected through drop-down menus.

For the case-study site, three scenarios were defined. The first scenario is the baseline scenario, describing the spatial elements and their representation at the beginning of the project. The second scenario is the Revitalization scenario, this is the original project plan and what was eventually realised by the municipality. This plan corresponds with the municipal strategic plans to realise a 10% increase in the quantity of GI. It involves the construction of permeable streets and parking spaces, and the construction of wadis to remediate flood risks. Additionally, large (sick) trees were replaced by new trees. Since the NSC-BM could not be used in the earliest project design stages due to project timings, we have defined a third scenario (revitalization PLUS), in which the impact of spatial designs can be straightforwardly upgraded with limited budget impacts, using the intelligence that is generated by the NSC-BM. In this scenario, a small portion of the amenity grassland was replaced by alternative green elements: small trees, flower fields, shrubby plants, and tall grass. Table 24 provides an overview of all landscape elements.

Table 24: Description of the baseline, revitalization, and revitalization PLUS scenarios in terms of land use surfaces, output from NSC-BM

	Category	Type	Amount
Baseline scenario	Low green	Amenity grassland	11,850 m^2
	Grey infrastructure	Impermeable surface	18,150 m^2
	Grey infrastructure	Normal roof	30,000 m^2
	Trees and shrubs	Single tree (6m-12m)	46
	Trees and shrubs	Single tree (>12m)	20
Revitalization scenario	Low green	Amenity grassland	10,515 m^2
	Grey infrastructure	Impermeable surface	11,270 m^2
	(Semi-) permeable surface	Semi-permeable grow-through pavers	6,940 m^2
	Grey infrastructure	Normal roof	30,000 m^2
	Sustainable drainage systems	Trench-troughs or wadis	1,275 m^2
	Trees and shrubs	Single tree (6m-12m)	90
Revitalization PLUS scenario	Low green	Amenity grassland	9,500 m^2
	Grey infrastructure	Impermeable surface	11,270 m^2
	(Semi-)permeable surface	Semi-permeable grow-through pavers	6,940 m^2
	Grey infrastructure	Normal roof	30,000 m^2
	Sustainable drainage systems	Trench-troughs or wadis	1,275 m^2
	Trees and shrubs	Single tree (6m-12m)	90
	Trees and shrubs	Single tree (<6m)	20
	Low green	Flower field	500 m^2
	Trees and shrubs	Shrubby plants	300 m^2
	Low green	Tall grass	215 m^2

5.5.2 Step 1: Ecosystem service selection

According to the specific context of the municipality, or the stakeholder the users wishes to communicate with, ecosystem services for the assessment are selected. In the case study, Kapelle's climate and sustainability officer chose four ecosystem services as arguments to put in front of decision makers. The main objective of the project is building in climate resilience, specifically **alleviating flooding** risks since the area is vulnerable to rainwater floods, but **microclimate regulation** is also an important selling point in the administration. Since Kapelle is situated in Zeeland province, where one fourth of the Netherlands' fruit production takes place, the region emphasises the importance of pollinators and new projects must therefore consider their **impact on biodiversity**. Lastly, the project area consists of a residential neighbourhood, hence the choice to include the residents' **aesthetic appreciation** of the living environment as a decision criterion.

5.5.3 Step 2: Parameter selection

The underlying formulas for the valuation and monetization of ecosystem services requires additional information. Values that are provided in this section support the underlying calculations in later worksheets. For some ecosystem services, no additional information is required, for others there is. Table 25 presents an overview of the information that is required for Kapelle's chosen ecosystem services.

Table 25: Overview of parameters required for calculations based on ES selection, output from NSC-BM.

Ecosystem service	Necessary data for calculations	Value
Habitat for biodiversity	No additional parameters required in this step	
Aesthetic appreciation	Number of residents living in or around (max 100m radius) the project area	911
Microclimate regulation	Number of houses in close proximity (max 100m radius) of project area	414
	Average price of electricity (€/kWh)	€0.40
	Average yearly electricity consumption per family in your region (in kWh)?	3200 kWh
Water retention and infiltration	Average precipitation per year (in m^3 per m^2 per year)	0.675 m^3
	Do you intend to collect water from outside the project area (e.g., surrounding roofs)?	No

5.5.4 Worksheet A - water retention

The retention coefficient (RC) denotes the percentage of runoff that will be retained by GI. By combining the average yearly rainfall, the surface area of different GI types, and the retention coefficients, the BM calculates the quantity of yearly retained runoff. This method of quantification is similar to Nature Value Explorer's (Hendrix et al., 2015) and Flemish research bundling and operationalising research on retention coefficients (Verbeeck et al., 2014) (visualised in Table 26). The quantification is automised to be employable by non-experts.

Table 26: Overview of water retention and infiltration capacity for the different surface types of the spatial scenarios, output from NSC-BM

Surface type	Baseline scenario	Revitalization scenario	Revitalization PLUS scenario	
	Area (m^2)	Area (m^2)	Area (m^2)	RC (%)
Lawn & amenity grassland	11,850	10,515	9,500	72
Trees	3,382	3,330	3,610	51
Impermeable	48,150	41,270	41,270	2
Water elements	0	1,275	1,275	100
Semi-permeable	0	6,940	6,940	70
Tall grass & flower fields	0	0	715	100
Middle green	0	0	300	78

RC: retention coefficient

5.5.5 Worksheets B - Biodiversity

The tool's biodiversity assessment is threefold: extent of habitat types, a land use diversity calculation, and a habitat potential for specific species estimation. The first component to quantify is the extent of habitat types. These types are lawn, tall grass, middle green, trees, semi-permeable land, vegetable gardens and water elements, and are drawn directly from the project description users made in the first step. Each measured location can only have one habitat type (even though overlap such as lawns with trees can occur) to achieve a total habitat area that is equal to the project area, apart from impermeable grey surfaces.

The second component, land use diversity, is quantified by using a diversity index. This is a quantitative measure that indicates the types of land use present in a spatial scenario and simultaneously considers richness and evenness (Tucker et al., 2017). These indices are often, though not exclusively, used in ecological research as biodiversity indices. The effective number of species (ENS) is an example of such an index. ENS is an extension to the Shannon-Weaver index (eq. 1), accounting for evenness or entropy. The ENS transforms the Shannon-Weaver index in the more intuitive measure of units of effective species (Jost, 2006). ENS denotes the number of species in an equivalent community (i.e., with the same Shannon index) where all species or land use types are equally abundant. In case of a perfectly even community, the ENS equals the number of species (S) in the project area (Zelený et al., 2021). As estimating population sizes would be too elaborate for a biodiversity estimation, the indices were used to assess land use diversity. The effective number of habitat types is calculated through equation 2. The maximal number of habitat types is equal to the number of different habitats of which the area is not 0 m^2.

Shannon-Weaver index (H'):

(1) $H' = -\sum_{i=1}^{S} p_i . \ln p_i = -\sum_{i=1}^{S} \frac{n_i}{N} . \ln \frac{n_i}{N}$

Effective number of habitat types (D):

(2) $D = \exp(\mathrm{H}')$

with

i the species number, in this case the cover type (such as lawn or trees)

S the number of species in the researched area, in this case the number of habitat types

n_i the degree of coverage by species i, in this case the total area of habitat layer i

N = total degree of coverage, in this case the total area (or the sum of all habitat layer areas)

For this case study, the structural variation is calculated by using the information in worksheet B – Biodiversity, depicted in Table 27.

Table 27: Overview of surfaces contributing to the structural variation of the different spatial scenarios, output from NSC-BM

	Baseline scenario	Revitalization scenario	Revitalization PLUS scenario
	Area (m^2)	Area (m^2)	Area (m^2)
Lawn & Amenity grassland	11,850	10,515	9,500
Overgrown	0	0	0
Tall grass	0	0	215
Flower field	0	0	500
Middle green	0	0	300
Trees	3,382	3,330	3,610
Water elements	0	1,275	1,275
Semi-permeable	0	6,940	6,940
Allotment garden	0	0	0

5.5.6 Worksheet C - Biodiversity

The last component of the biodiversity assessment in the NSC-BM focuses on target species. By expert judgment a list of 34 target species was selected from different taxonomic groups: birds, butterflies, bees, and amphibians (visualised in Appendix 5-C). The selection is based on different variables, such as species' characteristics, habitat requirements, occurrence in western Europe (2-seas area in particular), observations, etc. Experts at the UGhent's Forest & Nature Lab (ForNaLab) contributed to the selection and the formulation of habitat requirements.

Table 28: Oversight of assessment of potential habitat for biodiversity for every spatial scenario, output from NSC-BM

Landscape elements	**Baseline scenario Presence: YES/NO**	**Revitalization scenario Presence: YES/NO**	**Revitalization PLUS scenario Presence: YES/NO**
Lawn	YES	YES	YES
Tall grass	NO	NO	YES
Flower field/meadow	NO	NO	YES
Flower border	NO	NO	NO
Planter	NO	NO	NO
Herbaceous/shrubby plants	NO	NO	YES
Hedge	NO	NO	NO
Tree	YES	YES	YES
Forest	NO	NO	NO
Allotment garden	NO	NO	NO
Berry garden	NO	NO	NO
Green roof	NO	NO	NO
Compost heap	NO	NO	NO
Dead wood	NO	NO	NO
Beehive/beehotel	NO	NO	YES
Birdshouse	NO	NO	YES
Bird feed	NO	NO	NO
Overgrown	NO	NO	NO
Leaves	NO	NO	NO
Green façade	NO	NO	NO
Blue elements	NO	YES	YES
Bare land (acre/fallow land)	NO	NO	NO
Blue elements (if present):			
Conditions			
Standing water	NO	NO	NO
Population of fish present	NO	NO	NO
Elements			
Eutrophic	NO	NO	NO
Oligotrophic	NO	NO	NO
Shaded water feature	NO	NO	NO
Water element with direct light	NO	NO	NO
Water without vegetation	NO	NO	NO
Water with vertical vegetation	NO	NO	NO
Water with horizontal vegetation?	NO	NO	NO

In the tool, the potential of target species' presence for different scenarios is estimated. This is done by examining the target species' minimum habitat requirements based on their respective life cycles (food supply, nesting opportunity and places for overwintering or shelter) (Weisser & Hauck, 2017). By selecting "yes" or "no" in a list of various possible landscape elements a scenario is assessed on the potential of being a suitable habitat for specific target species. In Table 28 the assessment was carried out for our case study in Kapelle.

5.5.7 Worksheet D – Cultural ecosystem services

Users selecting cultural ecosystem services (CES) are prompted with statements to introduce a grounded assessment method. To reduce the subjectivity of the CES assessment, every CES score is built from responses to multiple standardised statements. Each of these needs to be weighted according to its importance, on a scale of 1 to 5, and then scored for each scenario on a scale of 0 to 3. This allows a combined assessment of relative importance and effectiveness of delivery for the stakeholder. The questions are derived from academic literature and expert consultation and is designed collaboratively with colleagues from Imperial College, London (see Appendix 5-D). The only cultural ecosystem service that the municipality of Kapelle prioritised in its assessment is aesthetic appreciation. The calculation for aesthetic appreciation relies on the importance weighting and scoring and is executed by the user. For the pilot case, this led to the inputs depicted in Table 29.

Table 29: Overview of the assessment of cultural ecosystem service Aesthetic Appreciation, output from NSC-BM

Statement	Importance weighing	Baseline scenario	Revitalization scenario	Revitalization PLUS scenario
Does this scenario provide an aesthetically attractive place to live or work in?	3	0	2	2
Does this scenario provide an aesthetically attractive place to live or work in?	1	0	0	0
Does this scenario make outdoor activities more enjoyable?	1	0	0	0
Does this scenario include an attractive mix of different landscape elements?	2	1	1	1
Does this scenario promote people’s engagement with the natural world?	2	0	1	2
Does this scenario create, or add to, a sense of place and visual identity?	4	0	3	3
Do people enjoy spending time in and around this scenario area?	1	0	0	0
Does this scenario contribute towards civic pride in the locality?	1	0	0	0

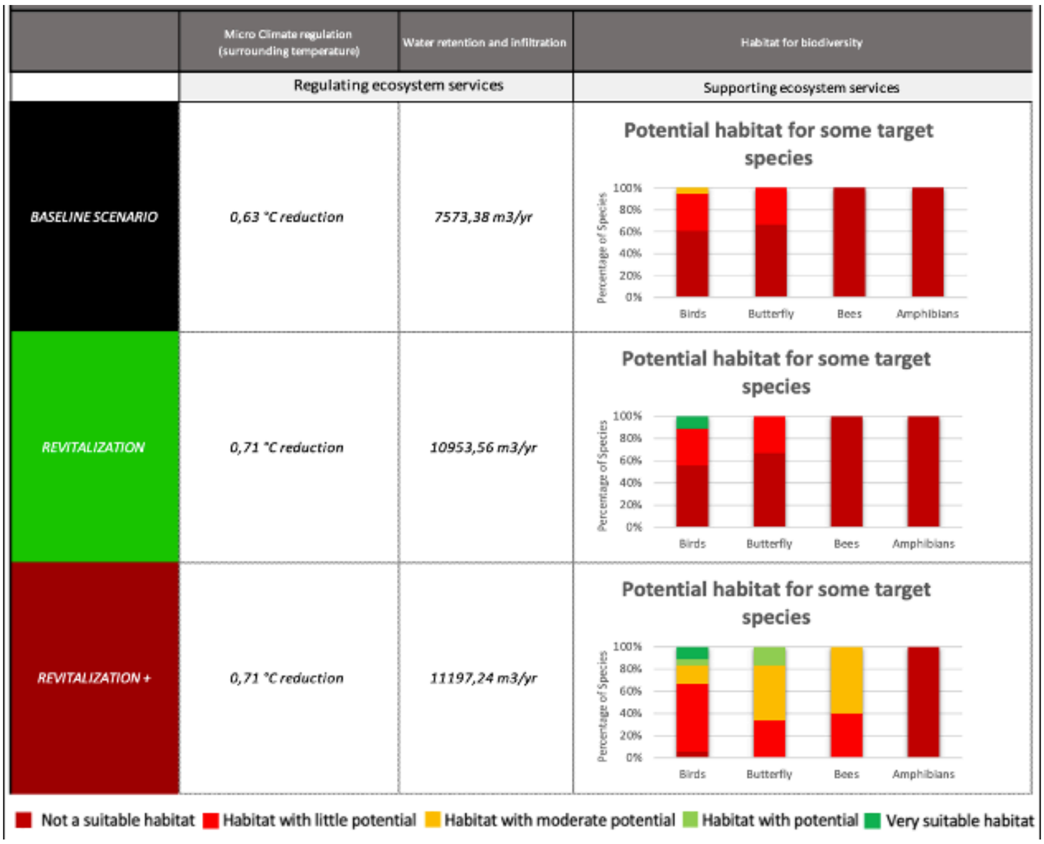
5.6 Results

The results of the pilot case study are summarised on three different levels, referring to Figure 18, the valuation pyramid. From demonstrator testing, we found that local officers felt uncomfortable with the subjectivity of the qualitative assessment part of the business model flow. Hence, it was decided to provide users first with quantified evidence of ecosystem services impacts (if the ES was quantifiable), and with the assessment for cultural ecosystem services. After this, further testing indicated that much of the uncertainty that originated the concerns of subjectivity was resolved.

For the Wemeldinge Noordzijde case, three out of four selected ecosystem services were quantified: (outdoor) Microclimate regulation, water retention and infiltration, and habitat for biodiversity. The results are shown in Figure 21.

5.6.1 Step 3: Quantification

Figure 21 Oversight of the quantitative results for different spatial scenarios, output from NSC-BM



Noticeably, microclimate regulation only slightly improves because of the green infrastructure that was already present in the baseline scenario. The method to quantify is a simplified application of Ziter et al. (2019). Instead of circles to estimate air temperature differences, the average effect on the project's local air temperature was estimated as a weighted average (assuming equal distribution over project area) of GI types and their cooling capacity and their relative surfaces. These values are benchmarked to an all-grey spatial scenario; hence the baseline scenario has a local air temperature reducing effect as well.

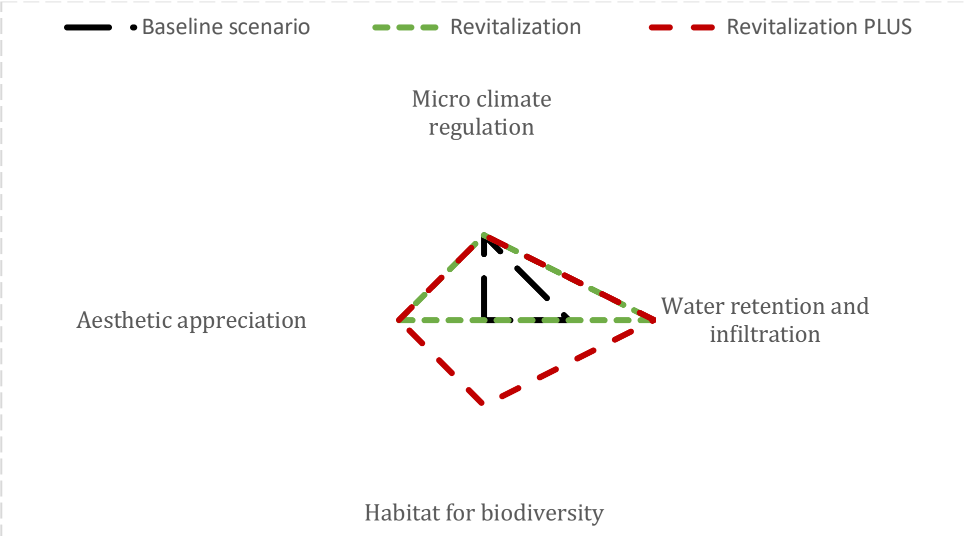
The water retention and infiltration capacity of the area improved considerably. The replacement of impermeable pavements by all semi-permeable pavements that enhances the retention capacity by over 40% compared to the baseline scenario.

The result for biodiversity depicts the suitability (in %) of the habitat for every target species. These percentages of the target species are harmonised within the taxonomic group as an overview of the impact of certain measures (De Beelde & Mertens, 2021). In the case study example, it is found that there is progress on the habitat suitability for a few of the bird species, advancing from 'a habitat with moderate potential' to a 'very suitable habitat'. Besides this, no other species are expected to benefit from the current plans for revitalization. The small adjustments from revitalization to revitalization PLUS however, reveal considerable improvements in the habitat for biodiversity. Birds, butterflies, and bees are all expected to have more habitat potential in this scenario. The Shannon-Weaver index and ENS index regarding structural variation support this result. The ENS increases from 1.70 in the baseline scenario to 3.21 in revitalization and 3.94 in the revitalization PLUS. Interpreting this, we notice the ENS is expected to double by the 10% increase in local green space surface area, and a further 22% increase solely by more GI variation. This underlines the notion that green space quality is often more important than quantity but demonstrates this transparently and makes it tangible for users.

5.6.2 Step 4: Qualification

Users are expected to score the performance of every scenario on the different ES on a scale from 0 (no contribution to ES level/outcome) to 3 (excellent contribution to desired ES level/outcome). This exercise is facilitated by displaying quantitative results first for the quantitatively assessable ES, for the CES the scoring is automatically loaded from worksheet D – Cultural ecosystem services. The qualified results are visualised in a spider diagram (visualised in Figure 22).The number of axis are self-adjusted and based on the number of ecosystem services chosen.

Figure 22 Qualitative scenario comparison produced through the NSC-BM, based on impact scores on a 0 (no contribution to ES generation) to 3 (excellent contribution to ES generation) scale



5.6.3 Step 5: Monetization (costs)

Where possible, the data library is composed of minimum and maximum values for construction and maintenance costs, drawn from (grey) literature research. The cost data library provides indications of costs per unit of different infrastructure types. Hence, scenario costs are calculated by multiplying these unit costs with the number of units present in each scenario. Users are strongly recommended to utilise local values at their LA's disposition to overwrite data library information in the custom values columns) as this improves the accuracy of the outcomes. Moreover, several costs depend heavily on the materials used, the environment of intervention, and local circumstances. Therefore, these monetary cost estimations (visualised in Table 30) should be interpreted as indicative, and allowing comparisons with other scenarios, rather than accurate point estimates. Before starting the calculations, users are given the option to change currencies, discount rates, and to opt for a minimum, average, or maximum cost calculation. In the case study, the municipality of Kapelle opted for the average cost calculation and a (default) discount rate of 3.5%.

In total, the construction cost for the revitalization is estimated at €587,888, for the plus scenario €592,108. Since it already exists, the baseline has no construction costs. Comparing the anticipated maintenance cost, we find that the baseline scenario has a yearly estimated maintenance cost of €109,773.37, the revitalization lands at €110,772.85, and for the plus scenario €112,816 is found. However, a large portion (€99,000) of these maintenance costs originate from maintenance to normal roofs (equal in every scenario), which are privately owned and thus should not weigh on the municipal decision.

Table 30: Estimated costs for every scenario as estimated by the NSC-BM

		Construction cost (range)	Custom value	Maintenance cost/year (range)	Quantity newly built	Total construction cost	Total maintenance cost (annually)
Baseline scenario	Amenity grassland	[11,20]	/	[0.39; 0.39]	0	/	€ 4,621.50
	Impermeable surface	[100, 112]	/	[0.23; 0.27]	0	/	€ 4,590.64
	Normal roof	[30, 80]	/	[3; 3.6]	0	/	€ 99,000
	Single tree (6m-12m)	[54.88; 70]	/	[10; 37.31]	0	/	€ 1,088.13
	Single tree (>12m)	/	/	[10; 37.31]	0	/	€ 473.10
TOTAL							€ 109,773.37
Revitalization scenario	Amenity grassland	[11,20]	16	[0.39; 0.39]	4468 m²	€ 71,488	€ 4,100.85
	Impermeable surface	[100, 112]	20	[0.23; 0.27]	11270 m²	€ 225,400	€ 2,850.50
	Semi-permeable grow-through pavers	[21, 30]	37.5	[0.21; 0.43]	6940 m²	€ 260,250	€ 2,220.80
	Normal roof	[30, 80]		[3; 3.6]	0	0	€ 99,000
	Trench-troughs or wadis	[6.10; 6.10]	10	[0.37; 0.37]	1275 m²	€ 12,750	€ 471.75
	Single tree (6m-12m)	[54.88; 70]	200	[10; 37.31]	90 trees	€ 18,000	€ 2,128.95
TOTAL						€ 587,888	€ 110,777.35
Revitalization PLUS scenario	Amenity grassland	[11,20]	16	[0.39; 0.39]	3453 m²	€ 55,248	€ 3,705
	Impermeable surface	[100, 112]	20	[0.23; 0.27]	11270 m²	€ 225,400	€ 2,850.50
	Semi-permeable grow-through pavers	[21, 30]	37.5	[0.21; 0.43]	6940 m²	€ 260,250	€ 2,220.80
	Normal roof	[30, 80]		[3; 3.6]	0	0	€ 99,000
	Trench-troughs or wadis	[6.10; 6.10]	10	[0.37; 0.37]	1275 m²	€ 12,750	€ 471.75
	Single tree (6m-12m)	[54.88; 70]	200	[10; 37.31]	90 trees	€ 18,000	€ 2,128.95
	Single tree (<6m)	[54.88; 70]	200	[10; 37.31]	20 trees	€ 160	€ 463.10
	Tall grass	[10; 30]		[0.33; 0.33]	215 m²	€ 4,300	€ 70.95
	Flower field	[10; 30]		[0.31; 0.31]	500 m²	€ 10,000	€ 155
	Shrubby plants	[10; 30]		[5.80; 5.80]	300 m²	€ 6000	€ 1740
TOTAL						€ 592,108	€ 112,816

5.6.4 Step 5: Monetisation (benefits)

Three out of the four selected ecosystem services are monetisable (referring to Table 31). For microclimate regulation, this monetised benefit is the sum of avoided cooling costs and the effects of improved thermal comfort (Alves et al., 2019; CRC for Water Sensitive Cities 2016). Based on the cooling effect that was calculated in Step 3: quantification (Figure 21) and the values inserted in Step 2: parameter selection (Table 25), yearly and total economic values are derived. For water retention and infiltration, the method to monetise was replicated from Nature Value Explorer (Hendrix et al., 2015). The monetisation originates from the avoided cost of sewage treatment and the portion of taxpayers' contribution to water drainage that can be attributed to rainwater drainage. For aesthetic appreciation, monetisation is based on Wang et al. (2014), who conducted a review bundling ecosystem service valuation studies. A more detailed overview of the methods used can be accessed through the NSC technical manual, pages 12-55. All benefit streams are discounted at a discount rate of 3.5%.

Table 31: Estimated monetised benefits for every scenario as estimated by the NSC-BM

		Annual benefit	Total benefit (20 years)	Total benefit (40 years)
Baseline scenario	Microclimate regulation	€ 15,297.09	€ 222,727.73	€ 331,952.37
	Water retention and infiltration	€ 4,959.16	€ 72,206.02	€ 107,615.53
	Habitat for Biodiversity	/	/	/
	Aesthetic appreciation	€ 759.17	€ 11,053.55	€ 16,474.14
TOTAL		€ 21,015.42	€ 305,987.3	€ 456,042.04
Revitalization	Microclimate regulation	€ 17,239.58	€ 251,010.63	€ 374,105.02
	Water retention and infiltration	€ 7,172.56	€ 104,433.37	€ 155,647.00
	Habitat for Biodiversity	/	/	/
	Aesthetic appreciation	€ 5,314.17	€ 77,374.99	€ 115,319.31
TOTAL		€ 29,726.31	€ 432,818.99	€ 645,071.33
Revitalization PLUS	Microclimate regulation	€ 17,239.58	€ 251,010.63	€ 374,105.02
	Water retention and infiltration	€ 7,332.12	€ 106,756.62	€ 159,109.56
	Habitat for Biodiversity	/	/	/
	Aesthetic appreciation	€ 6,073.33	€ 88,428.55	€ 131,793.48
TOTAL		€ 30,645.03	€ 446,195.40	€ 665,008.06

5.7 Discussion

In this paper we present a novel tool to examine the ecosystem services or co-benefits that are generated through green infrastructure or nature-based solutions, specifically applicable in urbanised contexts and at early project stages. Through intense co-creation and co-design between academic and city partners in the Interreg 2seas Nature Smart Cities project, this tool fills a gap in current municipal spatial planning and design practices, by integrating ecosystem services thinking. Both internal and external testing and validation phases have confirmed the potential of the tool. Through applying the framework in a real-life case study, we demonstrate what the Nature Smart Cities Business Model can and cannot do.

The application of the case study clearly establishes the main objective of the BM. The BM was developed to provide the means for local authorities to straightforwardly compare several different spatial scenarios in terms of the impacts on ecosystem services and values that they produce. By offering a framework that is adaptable to the specific decision-making context, users can prioritise those ecosystem services that are valued most strongly by the stakeholders they wish to communicate with. In that sense, the BM offers the added value to adapt the key message in terms of the selection of co-benefits to the target audience, making it a strategically valuable instrument for local use.

In the case study, since the project area is vulnerable for torrential floodings, 'water retention and infiltration' is highly prioritised. Through using the tool, the municipality is not only able to quickly generate an indication of the retention capacity of the project area but is also explicitly provided with ideas for landscape elements that would improve the water retention capacity locally. As the assessment indicates, the revitalization project leads to an estimated improvement in water retention and infiltration capacity of over 44% within the project boundaries. This leads to avoided sewage treatment costs, mounting up to over €7,000 of expenses avoided yearly.

As regards microclimate regulation, it is noticeable that there is a very limited effect between the initial baseline state and the revitalization of the neighbourhood. Comparing the scenarios, a modest mean temperature decrease of 0.07°C is expected between the baseline and either of the revitalisation scenarios.

On top of trade-offs that occur across ecosystem service values, the structure of the NSC-BM allows exploring trade-offs in the estimated cost-benefit structure of a project's lifetime. In the case study, we find that maintenance costs are expected to be slightly higher in the revitalization project. On the other hand, there is considerable added value created through the revitalization. The estimated monetary benefits of *aesthetic appreciation* and *water retention and infiltration* indicate that the annual added benefits (from €21,015 to €29,726) amply outweigh the additional yearly maintenance costs (from €109,773 to €110,777). Given that these maintenance costs are dominated by yearly maintenance to private house owners' normal roofs (€99,000), we can even conclude that the (small selection) of benefits outweigh the costs. All these results are summarised in a factsheet. We stress that the absolute values of these calculations are less informative than their comparisons relative to other spatial scenarios.

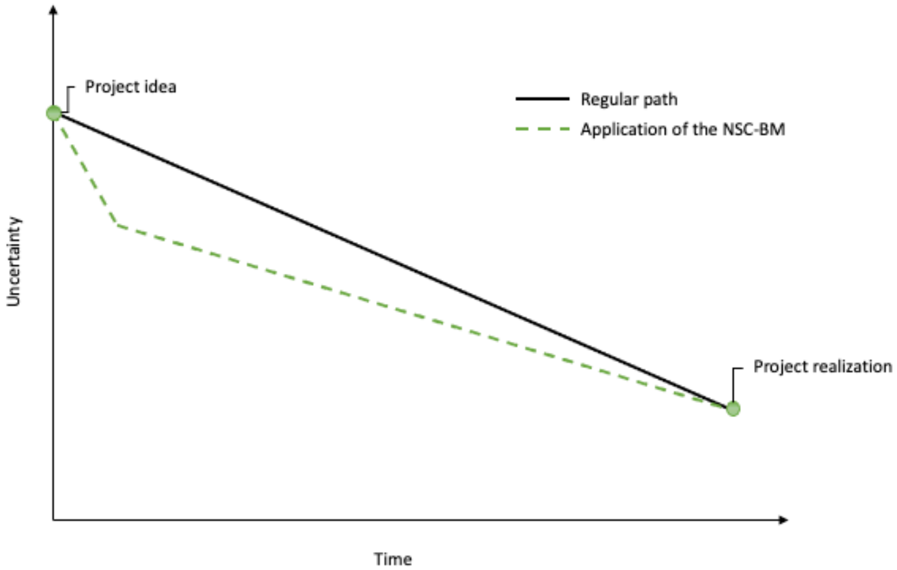
One of the main innovations of the NSC-BM is the fact that it facilitates the use of MCDA in very early project stages by developing an automated framework, which allows users to generate quick estimations on the outcome of different land-use scenarios. With the revitalization PLUS scenario in the case study, we illustrate the relevance of early-stage application of the tool. If the NSC-BM had been applied in the initial stages of our pilot case, the shortcomings on biodiversity would have been identified, prompting remedial action to improve the project design. With the results of the revitalization PLUS scenario, we find that for an increase in project costs with less than 1%, not only could biodiversity have been improved considerably, but other co-benefits could also have been enhanced. This illustrates that the advancement of the NSC-BM does not lie in methodological or modelling improvements to the state-of-the-art, bur instead consolidates information and data from various sources transparently, facilitating the application of scientifically reviewed data in day-to-day spatial planning and decision making. We illustrate how this could lead to significant improvements in GI design, with little effort.

Since the tool builds further on existing ES valuation tools and practices, it does not try to reinvent the wheel. The fact that the tool is designed for application at finer-scale levels is innovative in itself (Hansen et al., 2019). Moreover, emphasis of the project was put on involving key stakeholders in urban planning and design projects. By creating and designing a tool not only **for** target users, but especially **with** target users (Voskamp et al., 2021), the Nature Smart Cities business model fulfils users' needs and expectations more accurately than previous attempts. Furthermore, co-creation and co-development encourages engagement from local decision-makers, which helps translating visions into actions (Guerry et al., 2015). With the NSC-BM, the developers have created a pragmatically designed framework that overcomes existing GI knowledge implementation gaps. Therefore, the tool clearly contributes to bridging the fields of science and policy.

The focus on early project stages results from literature review with existing tools (Van Oijstaeijen et al., 2020), which was thoroughly described in Chapter 2 of this dissertation. If a tool has the specific aim for usability by local officers, this implies reductionist approaches. Hence, these tools should be deployed in early project stages to lower initial uncertainties, where the results might provide information for later-stage in-depth ecosystem services assessments. Figure 23 illustrates how small-scale spatial GI planning projects' uncertainty evolves over time. The objective of the NSC-BM is to translate some of the initial complexities of ES generation to the operational level, thereby reducing uncertainty considerably when progressing from a project idea. Ultimately, this aims to enhance the probability of approval of

GI investments by providing stronger arguments in discussions on spatial planning characterised by conflicting interests.

Figure 23 Positioning of the NSC-BM in project development to illustrate how the NSC-BM contributes to reducing uncertainty in early project stages



The NSC-BM further adds to current practice by establishing a framework for low-level impact assessment of future developments on cultural ecosystem services, and on biodiversity. The introduction of a series of literature-based directive questions to estimate how GI projects influence the generation of cultural ES is an important addition to existing tools. Users can adapt the assessment (to a limited extent) to their decision-making context, by indicating which aspects are most highly valued by the stakeholders in question. Explicitly revealing these cultural benefits may contribute to their current undervaluation – with the exception of recreation (Cortinovis & Geneletti, 2018) - in local spatial planning spheres. Regarding habitat for biodiversity, an easily interpretable method of impact estimation on the habitat potential of a selection of target species within four taxonomic groups (bees, butterflies, birds and amphibians) is provided. This method is accompanied by a calculation of the Shannon-Weaver index and ENS index, based on the acknowledgement that structural diversity contributes to biodiversity. The NSC-BM is the first tool that offers an estimation for habitat for biodiversity within a broader framework of project-scale GI or ES co-benefits assessment. Thus it introduces the dimension of restorative and regenerative actions that enable non-human species to thrive (Bayulken et al., 2021), providing local officers with tangible and interpretable evidence of the importance of green space quality, beyond mere quantity. Adding this element to the tool was essential to acknowledge the weight that local residents attach to species diversity, as we established in Chapter 4. The demonstrator testing showed that this part moved local officers to tweak their designs, adding landscape elements that would improve the biodiversity potential of a project site. The tool therefore contributes to aligning preferences between both stakeholder groups, providing evidence of how tools can be a valuable instrument to narrow the gap between the people and policy.

Popularising access to ES information without excessive time or resource demands assists local officers in building stronger cases for GI investments in early project stages. The practical utilization of the ES concept is thought of as broadening the scope of the planning process (Longato et al., 2021). This was confirmed in the stage of demonstrator testing, where officers stated that applying the tool to their case inspired them to go back to the drawing board and improve the delivery of ES that weren't fully considered yet (Back, 2021). Moreover, by providing this information in an easily interpretable and visual way, the tool acknowledges the need for benefits to be assessed in terms that practitioners and decision-makers understand (Bayulken et al., 2021). Users can opt to include those criteria (or ecosystem services) that are deemed relevant within the context of the assessment. As well as being a design and planning support tool, it might therefore also serve as a means of (strategic) communication. The usability and credibility of the tool was further supported by a step-by-step guidance document (available in English, French, and Dutch) and a technical manual with all the methods and data sources referenced. The link to both documents can be found in Appendices 5-A and 5-B.

A common barrier to GI/NbS implementation at municipal level is silo-based thinking (Wihlborg et al., 2019); integrated assessments can address such barriers. The NSC-BM's ecological, social, and economic valuation methods cross traditional departmental boundaries, which might foster cooperation and integration at local authority level. Apart from the benefit-side, the NSC-BM goes beyond the current state-of-the-art by providing estimations on the cost-side. This addition is mainly based on the finding in Chapter 2 that decision-support tools do not feature for costs, and by the importance that decision-makers put on the cost side in the DCE in Chapter 3. This comprehensiveness was an explicit aspiration from local authorities.

Currently, the NSC-BM and its data library are limited to be employed by LAs in Western-European countries, more specifically the Interreg 2seas-region. Especially for the biodiversity assessment, extensions to the current framework would be needed for other regions. Currently, a tool has been developed that can be widely used, but making the tool more spatially explicit, accommodating local geographical and climatic variables for example (Juhola, 2018), should be envisioned with next versions of the NSC-BM. This would require developing the tool into an online and web-based tool. As this benefits the user interface and is computationally more stable, it provides a clear pathway for future research. Regarding ES valuation, methods to refine current estimation methods without increasing complexity for the user should be considered, always in collaboration with local authorities. Another limitation of the current version is its dependence on 'quick and dirty' benefit transfer methods. Addressing the issue of spatial explicitness in the future will therefore be useful to improve the benefit transfer functions. Acknowledging GI social needs and social justice, combined with ecological justice (Pineda-Pinto et al., 2022) is another opportunity for geographically specific tools.

Monetisation (of ecosystem services) is a subject of debate, especially when considering transferability and universality. While the ES values that are market-based estimates (e.g., food production, carbon sequestration) are easily transferable, other value calculation methods used in the tool (e.g., avoided costs, and results from stated preference methods) are heavily influenced by the socio-cultural and economic context of the area in question. Application outside of the target area is therefore discouraged in the current version of the tool. Monetisation in terms of costs is equally sensitive to local differences. Even within the target region, regional and contextual variability might be significant. The developers advise to overwrite the data library with local information where possible, to increase accuracy of the results. Further, it is important to underline that the NSC-BM is intended for early-project stages. It is not the aspiration of the tool to provide exact values, but rather indications of the order of magnitude, and a scenario comparison to assist local officers in choosing a way forward and in building a GI case.

A further limitation of this research is the narrow interpretation of a *business model* within this framework of a comprehensive value assessment, which can be interpreted of the value proposition part of a business model. This leaves a few optimisation gaps for future research. Two specific dimensions complementary to the current framework, which have not been addressed in other tools either, are worth mentioning in that respect: (innovative) financing of GI and value capturing perspectives. In connecting a project's value proposition to financing and value capturing, the Naturvation Business Model Catalogue for urban NbS is a useful guide that complements the use of the NSC-BM, pointing local authorities in the right direction to leverage on the project's ES (Toxopeus, 2019). Facilitating access to different financing options for local authorities would contribute further to translation from strategic vision into concrete actions but are out of scope for this current tool. On the NetworkNature platform, stakeholders further find a comprehensive knowledge base that fill the knowledge gaps that the current tool still leaves. However, by continuing to monitor the user experience in the future, the developers aim to respond to changing decision-making contexts.

5.8 Conclusion

In this paper, the authors introduce a novel tool resulting from the Interreg 2seas Nature Smart Cities project. The NSC project aimed to facilitate green infrastructure implementation at the local scale to improve the climate resilience of local municipalities. The automated Excel tool that was developed provides local officers with objective arguments for green infrastructure investments without requiring expert consultation. By popularising the access to ecosystem services information in initial project stages users benefit in improving the case for green infrastructure projects, removing a part of the uncertainty that previous research identified as one of the bottlenecks in effective GI investments.

The main contribution of the NSC-BM over existing tools lies in its applicability by local officers. Since the NSC-BM is the product of intensive co-creation and co-design between academia and practitioners, the tool is tailored to the specific needs and requirements that are expressed by members of the target audience. Given the trade-off between complexity and usability that is implied in the application of tools at the local scale, the unique collaboration within the Nature Smart Cities project has provided very significant added value. Moreover, strong emphasis was put on testing the usability in practice. The demonstrator testing and capacity building phases of the project have greatly contributed to successfully addressing this. The NSC-BM offers users the basis for a multi-criteria decision analysis, supported by ecosystem services valuation. These ecosystem services are valued qualitatively, quantitatively, and (where possible) monetarily, to offer a comprehensive oversight of the impacts of spatial GI interventions. Further, the tool offers straightforward methods to assess and interpret the influence of GI interventions on cultural ecosystem services and includes a module to estimate the impact on the habitat for biodiversity. In these features, the NSC-BM goes beyond the current state-of-the-art. Lastly, the developers have included a cost estimation as well, which is unprecedented.

Through a case study in a residential area in Kapelle, The Netherlands, we demonstrate the use of the NSC-BM. The revitalization scenario as it was executed led to an estimated increase of 40% in water retention and infiltrating capacity locally. The assessment indicates a small increase in the cooling capacity of the area as the result of the increased share of green infrastructure, averaging at 0.71°C compared to an all-grey situation. Further, noticeable advances are made regarding the day-to-day aesthetic appreciation of residents. In the revitalization PLUS scenario, we establish how the NSC-BM contributes to early-stage planning and design practices. By making minor adjustments to the revitalization scenario (less than 1% budget increase), the area would score significantly better on the habitat for biodiversity capacity of the area, while simultaneously making small improvements for other ecosystem services. This assessment tangibly indicates how green infrastructure quality is often more valuable than quantity and does not necessarily imply higher costs.

By applying the NSC-BM to a GI case local authorities get a very intuitive oversight of the estimated ecosystem services generation of future projects. This tool goes beyond being a mere planning tool by offering ideas to adapt and optimise designs as well. The tool was validated through a series of demonstrator tests in eight municipalities and through two series of capacity building workshops, reaching a total of 266 individuals across 133 local authorities across the 2 seas region. By the end of September 2023, the tool has been downloaded 212 times, predominantly by local municipalities (72%) in Belgium, the Netherlands, and the UK.

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Chapter 6
Conclusions

6.1 Summary of contributions

Green infrastructure inherently possesses the capacity to address an array of critical concerns simultaneously. Those concerns include the need for climate adaptation, mental and physical well-being, reversing biodiversity decline, enhancing landscape resilience, and countering the repercussions of urbanisation. Conceptually, GI is predominantly focused on urbanised settings, requiring the active engagement of decision-making at the local level. Taking into consideration that the progress of GI implementation falls short of the expectations that are raised through the diverse range of *co-benefits* anticipated with its adoption, in this thesis, we have directed our attention towards the local-level actors involved in the process.

Hence, two key stakeholder groups are identified as the primary actors engaged in implementing local-scale green infrastructure within urban contexts. Firstly, local decision-makers encompassing politicians, practitioners, and spatial planners in local authorities, who frequently operate in accordance with or are constrained by overarching policies. For Flemish municipalities, such overarching policies and strategies can originate from the European level (e.g., EU Strategy for Green Infrastructure), from the Belgian national level (e.g., Strategy for Pollinators), and from the regional level (e.g., Climate Adaptation Plan 2030). Translating these policies and strategies requires knowledge and expertise at the local level. However, we observe that research on GI and ecosystem services does not effectively feed into decision-making (Cowell & Lennon, 2014; Saarikoski et al., 2018). Secondly, residents, who directly experience the implications of interventions within the public domain, play a crucial role. Not only is social acceptance an important prerequisite for GI implementation (Dhakal & Chevalier, 2017), engaging residents to adopt climate adaptive approaches on private land is highly desirable in the Flemish context too. However, research examining the knowledge gap between how residents and decision-makers value ES is currently very scarce. Understanding perceptions and value orientation is crucial for these stakeholder groups to better align. Therefore, the primary objectives of this thesis are to bridge two gaps: the gap between scientific research and (local) policy, and the gap between policy-making and public (engagement and acceptance).

Literature review and a mix of stated-preference methods are used to analyse (i) why, and which knowledge is (dis)regarded in local GI decision making processes and how tools could overcome this knowledge transfer issue, and (ii) how value attribution of GI or ES is heterogeneous between stakeholders, providing opportunities for stakeholder involvement and participation to be improved. Therefore, the main contributions of this thesis are the following:

1. Review of existing tools: unlike previous studies that often assume that evidence flows to decision-makers naturally, we have reviewed the role of valuation tools in integrating ES or GI knowledge into decision-making. A selection of existing tools for ES or GI valuation was reviewed to understand local applicability. In this objective, a collaborative and participatory approach from a local urban planning view on GI was adopted in this review.
2. Quantitative and large-scale qualitative research involving local decision-makers: it is the first time to our knowledge that stated preference data on GI perceptions and values within local authorities is gathered this extensively. The uniqueness of the data grants an unprecedented insight into knowledge utilisation and decision-making processes regarding GI at the local scale. Secondly, quantitative studies with decision-makers – in this case a DCE – on GI, ES knowledge and trade-offs, are very limited. Evidence was gathered directly from local decision-makers, providing complementary quantitative data to the existing body of qualitative research on the subject.
3. Different stakeholder views on GI and its ES generation: by looking at two different actors – representing GI supply and demand - in local policy contexts, we identify common factors and differences. This thesis specifically contributes to providing insights in GI preferences, using different stakeholders' views, the alignment of which would facilitate incorporation in practice. Unlike in previous studies, GI is approached with residents from the argument of different ES generation, including supporting, provisioning, regulating, and cultural services. Previously, stated preference studies to value GI with residents primarily gauged preferences towards (visual) characteristics of landscape elements. Through the wider ES approach, trade-offs are revealed.
4. Facilitating evidence gathering at the local authority level: a novel tool is introduced helping local officers to build a case for a GI investment. The tool goes beyond the actual state-of-the-art of valuation tools through the tailored approach that results from the intensive co-development and co-design of the tool, by academics and practitioners. Therefore, the tool is more applicable in practice, responding to the needs of small and medium-sized cities. This applicability is further enhanced by capitalising on the results of the studies in this thesis.

6.2 Chapter conclusions

6.2.1 Concluding remarks for Chapter 2: review of existing green infrastructure valuation tools

Research question 1: What are the challenges and opportunities associated with existing valuation tools for urban green infrastructure in the context of urban planning and decision-making, and how can straightforward valuation tools be designed to better support the development of green infrastructure in urban areas?

Chapter 2 undertakes a comprehensive literature review to evaluate ten existing GI or ES valuation toolkits. The assessment is conducted based on twelve predefined evaluation criteria. These criteria are developed through a review of the literature and guided discussions with practitioners specialising in GI within local authorities. Through this process, valuable information is gathered and analysed to ascertain the elements of these toolkits that are pertinent and applicable for utilisation within the context of local authorities. The research design used in this study facilitated the evaluation of both the effectiveness of toolkits in meeting the needs and expectations of local authorities, as well as the identification of factors at the local authorities' level that hinder their utilisation. The results demonstrate an imbalance in the treatment of biophysical, and economic value assessment within the evaluated tools. Biophysical value assessment generally receives more attention compared to economic value assessment. This contradicts the expressed need for monetary arguments by local authorities and the findings of the literature review, which highlight the importance of economic justifications for GI investments to compete with grey alternatives. The economic assessments frequently suffer from a lack of evidence pertaining to the entire lifespan of GI, consequently falling short in approximating its total (economic) value. Further, tools do not consider estimated costs of GI interventions, which would facilitate making a compelling investment or business case for local practitioners. At local authorities' side, it is found that scientific approaches, or informed decision-making for GI is currently not mainstreamed. Moreover, it is observed that resource restrictions within local authorities necessitate rapid valuation processes at the project-scale level, without imposing additional expertise requirements. In response to the need for simple, user-friendly approaches, tools are predominantly applicable and employable during the early stages of project development. In later project stages, when more accuracy might be desired, in-depth, and spatially explicit assessments are recommended. Considering the need of local authorities for practical solutions that span across various scales, it is recommended to use toolkits that can be applied from the plot-level to the neighbourhood-level. Finally, and arguably most significantly, toolkits are currently underutilised. In order for these toolkits to become applicable and relevant to local practitioners, there is a crucial need for participative development and co-design processes that bridge the gap between science and policy. Such collaborative approaches facilitate the integration of scientific knowledge and expertise with the practical needs and perspectives of local authorities. This ensures the development of toolkits that are both scientifically robust and tailored to the specific requirements and constraints of local practitioners.

6.2.2 Concluding remarks for Chapter 3: A discrete choice experiment to analyse the science-policy gap in green infrastructure

Research question 2: What are the key factors in local decision-making processes that influence the implementation of green infrastructure in Flemish municipalities? How is ecosystem services or green infrastructure knowledge used in practice in local decision-making?

Chapter 3 of this study expands upon the findings and insights of Chapter 2. Utilising a discrete choice experiment, the primary objective of this chapter was to investigate how the information generated by such a valuation tool would be perceived and incorporated in local decision-making processes. In a DCE, respondents' preferences are revealed through analysing choice behaviour through repeated stated choices based on several GI attributes and corresponding levels of these attributes. This way, this chapter aims to quantitatively evaluate the trade-offs occurring at the local level when making decisions on GI. The interpretation of this quantitative analysis is enhanced with the results from a qualitative survey. By doing so, it aimed to provide a comprehensive understanding of the reasons behind the persistent science-policy gap in the implementation of the ES concept and GI. This was achieved by using a unique dataset consisting of responses from local decision-makers. The final sample consists of 568 decision-makers, from 235 (out of 300) Flemish municipalities. The findings of the study uncover that barriers to implementation vary depending on the type of municipality. Larger municipalities encounter challenges related to convincing developers and managing conflicting priorities within the local authority. On the other hand, smaller municipalities face obstacles such as limited knowledge and awareness regarding green infrastructure, as well as a lack of evidence of the added value of GI. Within local authorities, there's a noticeable divergence in perspectives regarding the adoption of informed GI decision-making practices amongst the respondents. Members affiliated with the ruling local parties tend to exhibit a notably more positive outlook, expressing optimism about the current adoption of such practices. In contrast, individuals associated with the opposition parties tend to be considerably more critical of these methods. Non-politically appointed decision-makers are more inclined to choose the middle way. The DCE results reveal that GI decision-making within local authorities is primarily influenced by cost considerations, with limited acknowledgement of ecosystem services beyond the recreational value. However, it is worth noting that 87% of decision-makers believe that ecosystem service valuation could influence the decision-making process. ES knowledge utilisation is found to be hampered, especially by short-termism and the dominance of cost considerations in decisions. Short-termism is identified by 40% of respondents as a main barrier, also showing in the DCE through not appreciating long-term benefits adequately. The importance of costs is illustrated by the variable importance in the DCE, over 80% of the total variable importance is attributed to the cost categories. This means that almost all decisions are primarily informed by investment and maintenance cost, without considering benefits or ES. The DCE interaction models reveal the importance of a municipality's financial result and the population density of the municipality on the expected willingness to invest in GI.

6.2.3 Concluding remarks for Chapter 4: A discrete choice experiment to analyse the people-policy gap in green infrastructure

Research question 3: How do residents value and prioritise ecosystem services from green infrastructure? How do these stakeholder perceptions and priorities regarding ecosystem services in green infrastructure shape the people-policy gap?

In chapter 4, we address the need for incorporating different stakeholder's views and perspectives for successful management practices. This chapter aligns with chapter 3 through revealing GI preferences from the general public, which offers a complementary view to decision makers' preferences. Aligning these stakeholders' values is critical for effective implementation of climate adaptative infrastructure. Resident's perceptions were obtained through a two-stage sequential BWS-DCE experimental design, collecting evidence from 1007 respondents. Further, qualitative questions gauged for respondents' satisfaction of the neighbourhood they live in. In the BWS and DCE, respondents are introduced to a hypothetical scenario of a new neighbourhood park. In a BWS experiment, respondents are repeatedly shown a number of attributes of GI from which they appoint the best (or most important) attribute and the worst (or least important) attribute. The results of the BWS therefore indicate which attributes of GI residents find most important for the hypothetical neighbourhood park case. This provides insight in people's value orientation, which shaped the design of the DCE. As a result, the DCE composed of six attributes: municipal surcharge, walking distance from the residence, water retention and infiltration capacity, CO_2 uptake (and air quality regulation), the number of visitors, and the naturalness of the park. The DCE findings exhibit that residents appreciate both naturalness and proximity of a neighbourhood park to some extent but appear to prefer their park not too wild and not too close. Heterogeneity in DCE responses could be partially explained by age, population density of the respondent's municipality, and a proxy variable for sustainable attitudes. We reveal that younger residents are less cost-sensitive, and that residents from denser municipalities and those exhibiting more sustainable behaviour attach more value to environmental arguments (CO_2 uptake and water infiltration). Comparing the DCE results with those of the decision-makers in Chapter 3, we can conclude several (dis)similarities. The same attributes are valued by both stakeholder groups, but divergent views exist. While decision-makers are drawn towards parks with as many visitors as possible, residents prefer parks with less visitors, especially if they live in densely populated areas. Further we find that – unlike local decision-makers – residents highly appreciate long-term arguments. Simultaneously, residents are far less cost sensitive in their choice behaviour, valuing the environmental performance in terms of ES higher. These findings are complemented with the qualitative evidence displaying that 65% of the respondents indicate that there is plenty of GI in their neighbourhood, although 55% of the sample believes more GI would further enhance the amenity value. We find that the younger respondents are and the more populated their living environment, the less satisfied they are with the amount of greenery in their neighbourhood. Further, residents living farther from accessible green space are significantly less satisfied with the level of neighbourhood greening. The latter establishes the need to consider social equality in GI planning and management.

6.2.4 Concluding remarks for Chapter 5: the Nature Smart Cities business model

Research question 4: How does the Nature Smart Cities business model for valuing GI benefits and costs contribute to the effective planning and decision-making processes of local authorities in small to medium-sized cities?

Chapter 5 consolidates insights acquired from all preceding chapters. In this chapter the Nature Smart Cities business model (NSC-BM) is presented. With the NSC-BM, a straightforward, and step-by-step method is offered for local authority officers to collect evidence on the ES generated by GI, as well as on the cost side. This step-by-step method lays the foundation for a multi-criteria decision analysis, with ES as the criteria. In the first step, users define their GI project in terms of surface areas of landscape elements. The following steps then use the cascading value model structure (qualitative – quantitative – monetary) to estimate the impact of GI, on both cost and benefit side. For these estimations, generic figures are used. Therefore, the NSC-BM is advisable for use in very early project stages, for clearly defined project areas. Through the intensive collaboration and co-design between academics and practitioners, the toolkit is tailor-made for its target users: practitioners in small to medium-sized cities. To validate our argument and demonstrate the applicability of the NSC-BM a case study in Kapelle, a town in The Netherlands, is used. Estimations of locally prioritised ES are generated for different spatial scenarios. It is shown how the municipality could significantly enhance biodiversity while concurrently generating positive impacts on other ecosystem services, with a marginal increase of less than 1% in estimated project costs. The case study also shows the added value of applying the NSC-BM in early project stages. In that sense, the NSC-BM goes beyond a mere planning instrument by offering users not only guidance but also inspiration to customise their approaches. The NSC-BM was validated through a series of demonstrator tests, and through capacity building workshops reaching over 130 municipalities in the 2-seas region (Belgium, France, the Netherlands, the United Kingdom).

6.3 Overall conclusions

In this thesis, a multidisciplinary approach is adopted to investigate ES, its embodiment in planning practices through the concept of GI, and the implementation of GI in the (urbanised) local landscape. ES valuation therefore serves as the backbone and is approached from different angles. In that sense, Chapter 2 showed how GI valuation tools benefit from adopting the ES framework to value GI projects. Chapter 2 further examines which characteristics of tools are prioritised for use by local authorities and Chapter 3 continues by exploring how ES knowledge can be implemented. Chapters 3 and 4 evaluated how ES evidence that would result from applying GI valuation tools would be used and perceived by two different stakeholder groups. We further analyse which characteristics of these stakeholders influence the value attribution or preference structure. Chapter 5 effectively utilises the ES concept in the formulation of a novel tool for GI valuation for local authorities. Overall, it is attempted to facilitate ES knowledge generation and utilisation at the local decision-making level to serve as effective arguments towards more proactive GI investments. By gradually examining the viewpoints of scholars, practitioners, and residents, several lessons and conclusions are drawn.

The tool that is presented in Chapter 5 bundles the elements that shape the perspectives of these three main stakeholders considered in this thesis: science, policy, and people. The policy dimension, as delineated in Chapter 1 of this dissertation, pertains specifically to policy implementation within the context of operational decision-making at the municipal level. In Chapter 2 we largely explored how scientific valuation tools can contribute to operational GI decision-making, mainly addressing the science-policy gap. We specifically explore how knowledge transfer can be fostered to adopt scientific methods to maximise the potential of GI's multifunctionality. Chapter 3 allowed us to derive insights on how such decisions are currently made, which arguments are (dis)regarded and how the political game influences the outcomes. In economic terms, it provides an insight into the suppliers or provision side of GI. Through revealing residents' priorities and perceptions on GI and ES in Chapter 4, we addressed the demand side of GI. This contributes to collecting evidence of elements shaping the people-policy gap in GI implementation. In particular, it delves into public engagement, stakeholder priorities, and communication as facets of this gap. A brief summary of the findings from Chapters 2-4 that relate to both gaps is given, to establish how Chapter 5 capitalises on all these findings to narrow both gaps;

a. The science-policy gap

We find that there is limited scientific thinking when GI decisions are made and that a perception of 'green is good enough' prevails in municipal spatial planning. Even further, a DCE with local decision-makers confirms that GI is thought of as a luxury good, an afterthought rather than a starting point. In Chapter 3 it was found how smaller municipalities struggle with knowledge gaps (i.e., lack of demonstrated added value, lack of awareness or knowledge about GI practices and their purpose), while larger municipalities have difficulties in convincing planners and developers. A general finding is the dominance of cost arguments in decision-making processes, municipalities are very cost sensitive in selecting a GI project. Next, we see how the local political game influences decision-making through short-term thinking and the importance of conflicting interests. Yet, 87% of the decision-makers in the sample believe that clear numbers on costs and benefits would help to steer the decision-making process.

In theory, scientific GI valuation tools have been designed to overcome this, and to support informed decision-making practices based on ecosystem services thinking. These scientific valuation tools that have been developed are currently not known or used by local authorities. From the science perspective, we should acknowledge that ecosystem services knowledge is not flowing back to decision-makers. One of the reasons influencing this may be because the results of scientific research are not presented in terms that are demanded by decision-makers. With regard to GI valuation tools, we see that tools value benefits but consistently leave out cost calculations. Further, tools do not accommodate to calculate ecosystem services over a longer time span, often restricting to a yearly benefit expression. Moreover, in the benefit or ecosystem services valuations, Chapter 2 revealed a lack of consideration of the integration of social benefits or cultural ecosystem services. Therefore, we concluded that the development of these scientific valuation tools insufficiently addresses the needs of the target audience.

b. The people-policy gap

As set out in Chapter 1, effective policy implementation requires residents' buy-in. We start from the observation from literature that communication, public participation, and perceptions/expectations of GI are critical to build support. In Chapter 4 we establish how – through participatively (BWS) shaping evidence – the DCE proves that residents are significantly less cost sensitive than their municipalities. We further elaborated on how residents seem to generally be more considerate of the longer-term impacts, contrasting with the short-termism found with decision-makers. Residents further almost unanimously acknowledged GI's importance in the future. In the experimental designs in Chapters 3 and 4, value expression by respectively decision-makers (through focus groups) and the public (through BWS) led to very similar attributes for the DCE. However, noticeable differences in appreciation of these attributes were found through the DCE. Residents valued the GI case for peace and tranquility, consistently choosing for fewer visitor numbers. Decision-makers on the other hand believed that for the case in their municipality more visitors are better. This finding illustrates the importance of aligning stakeholder preferences towards creating community support and acceptance. Apart from tranquility, we find that residents highly value biodiversity, which is often not considered in GI valuation tools. We further establish that – as there was in the GI barrier identification with decision-makers – there is considerable heterogeneity in perceptions towards neighbourhood greening. Another gap in expectations between people and policy (implementation) was identified through analysing that heterogeneity. Residents in densely populated municipalities are significantly less satisfied with the amount of greenery in their neighbourhood, indicating a higher demand for GI. Yet, in Chapter 3 we found that denser municipalities are less willing-to-pay for the GI case.

In Chapter 5 it was demonstrated how a novel valuation tool was developed that contributes to narrowing both of these gaps, based on the insights from the previous chapters as follows:

1. The monetisation of ecosystem services demonstrates the monetary value over varying time horizons: annually, 20-year, and 40-year periods. With this approach we illustrate that while these benefits may appear relatively modest in the short term, they accumulate significantly over the infrastructure's lifespan. By adopting this perspective, we acknowledge the importance from a normative scientific and economic standpoint and from the residents' standpoint, to accord greater significance to long-term benefits within the municipal decision-making process, addressing the prevailing short-termism.

2. Besides monetary valuing benefits or ecosystem services, the NSC-BM features cost estimations as well. Both investment and maintenance (yearly, 20-year, and 40-year periods) costs are incorporated for both grey and green elements. This was revealed as a hiatus in current tools and given the cost sensitivity of local authorities can provide meaningful insights into how costs relate to benefits. In Chapter 5 we demonstrated that applying the NSC-BM can yield significantly more benefits, with minimal impact on a project's cost. In this way, the tool can clearly enhance GI quality.

3. Scientific GI valuation tools have traditionally been developed primarily as planning and design supporting tools. The NSC-BM, on the other hand, distinguishes itself by serving not only as a planning and design tool but also as a valuable communication tool. Regarding planning and design of GI, we established that the tool is intended to be used in early project stages to reduce initial uncertainties. Further, in Chapter 5 it was showed that the NSC-BM presents arguments in easily interpretable and graphic terms, aligning with decision-makers' preferences through a factsheet. The communication aspect of effective GI valuation tools encompasses two dimensions. Firstly, within the administration itself, local officers can utilise these tools to convince and prioritise (cities) or provide evidence of added value (smaller municipalities). Secondly, there is a need for communication between the administration and residents to inform and illustrate how their tax contributions enhance their quality of life. Users are afforded the flexibility to choose which ecosystem services to evaluate, enabling them to strategically emphasise specific ecosystem services based on the stakeholder they intend to engage with. In the Flemish sample in Chapter 4 we showed that health impacts, biodiversity, and climate adaptation are valued highly, for example.

Summarising, the main methodological additions of the NSC-BM to the state-of-the-art in GI valuation tools are: hybrid (green-grey infrastructure) spatial scenarios, the module to explicit biodiversity impact, and multi-level value demonstration:

- First, the tool offers users the possibility to assess hybrid green-grey designs in scenario analysis, not solely on the ES generated, but also providing cost estimations. These cost estimations are novel and not only include construction costs, but also maintenance costs.
- Next, users can see how species' habitat potential is influenced by modifications to the spatial design and assess the structure diversity of their scenario straightforwardly. Moreover, residents in Chapter 4 attached very high value to biodiversity, which emphasizes the relevance of this assessment as a communication facilitator with residents.
- Lastly, this is the first GI valuation tool that explicitly works on the value dimensions: qualitative, quantitative, monetary added value. This allows us to go beyond previous tools and provide a built-in feature that provides a more objective method for local officers to assess cultural ecosystem services. The latter are often disregarded but given the high number of beneficiaries in urbanised environments, account for significant value contributions (Cheng et al., 2021).

Chapter 4 underscores the context-specific nature of value orientation. This temporal and spatial subjectivity of value is inherent to ecosystem services valuation and stated-preference valuation specifically, as was discussed in Chapter 1, Section 1.5. A promising method to efficiently incorporate a stakeholder's value orientation into GI planning processes is showcased in Chapter 4. Further, we found that residents living farther from accessible green are less satisfied with the level of neighbourhood greening. This finding further underlines the need for integrated assessments. Through a BWS experiment, local authorities can discern which features residents prioritise in a certain project. BWS offers efficiency, and accessibility both in terms of application and analysis, with comprehensible choice tasks for respondents. This approach allows for widespread public participation, and is less time-consuming than focus groups or interactive workshops. Further, it is highly compatible with the use of tools (e.g., the NSC-BM), where the value orientation can serve as an input to determine which ecosystem services to assess and optimise through applying the NSC-BM. Thus, methodologically, stated-preference techniques are highly complementary to *objective* valuation tools to accommodate for the subjectivity of values. By transparently communicating and mainstreaming such approaches, preferences can be better aligned, and citizen engagement and acceptance may be enhanced.

Within the Flemish policy context introduced in Chapter 1, quantity (e.g., building shift) and quality (e.g., Climate Adaptation Plan 2030, Blue Deal) of GI are key objectives from a supralocal policy perspective. To monitor and measure the quality of GI, the use of valuation tools has been put forward in this dissertation. Such assessments can be performed *ex ante* or *ex post* for GI projects. Standardising such approaches can resolve the knowledge-related barriers to GI implementation for smaller municipalities. For larger municipalities, tangible, measurable and enforceable indicators (such as discussed in Chapters 3 and 4) would contribute to prioritising GI. Indicators could support the monitoring of GI quantity. Consolidating these findings, top-down encouragement and enforcement that combines standardised practices of applying GI valuation through toolkits and monitor quantity through indicators provides a promising avenue for effective GI implementation.

The concept of valuing ecosystem services is central to EU environmental policies.(e.g., through the Integrated Natural Capital Accounting (INCA) project). This dissertation contributes to discussions on how to effectively integrate ecosystem services into local decision-making processes of small-scale projects. By providing a tool that quantifies the monetary and non-monetary values of GI in an accessible and intuitive way, it aligns with EU efforts to promote nature-based solutions and the inclusion of nature's benefits in policy planning. With this thesis we further attempt to emphasise the importance of the local level, providing support and capacity for local authorities.

During the research that led to this dissertation, it became increasingly evident that collaboration and engagement served not only as a means to expose local levers for overcoming science-policy and people-policy gaps but also as a consequential outcome in itself. In Chapter 2, the interaction with practitioners played a pivotal role in delineating the scope of applicability for an ES/GI valuation tool. Chapter 3, with its expansive (and unprecedented) sample of local decision-makers, not only yielded valuable insights into GI decision-making processes at the local level but engaged 568 decision-makers from 235 municipalities by doing so. Similarly, Chapter 4 engaged with over a thousand individuals articulating their GI preferences. In the development and validation of the NSC-BM detailed in Chapter 5, demonstrator tests, workshops, presentations, and webinars again reached hundreds of municipalities and over a thousand municipal officers. This extensive engagement with diverse stakeholders, stimulating them to reflect upon the role of GI and its connection to climate adaptation, can be viewed as a form of building support for the actual implementation of GI. Consequently, the influence of this research, as well as stated-preference valuation methods in general, extends beyond its primary findings. It ripples out into the broader dimension of outreach and education/awareness raising, enriching the collective understanding of GI and its potential impacts on communities and the environment.

6.4 Limitations

It is crucial to engage in a reflective assessment of the limitations in this thesis. These limitations cover both methodological considerations and the scoping choices made.

The main limitation of chapters 3 and 4 is the oversimplification of ‘green infrastructure’ to a mere neighbourhood park. This was a deliberate choice to present respondents in the DCE with an easily understandable and familiar example of GI. While this choice might have had a positive impact on the validity of the results in that respect, it also complicates the interpretation of these results in the much broader space of GI.

A limitation throughout that mainly attributes to chapter 5 is that the tool presented does not adequately address a key element of GI: connectivity (Seiwert & Rößler, 2020). In the trade-off between accuracy and complexity-of-use, practitioners repeatedly signalled the need for hands-on and easy-to-use methods in familiar software. Therefore, it was opted to not work with GIS or QGIS but with Microsoft Excel, ruling out the possibility of a spatially explicit tool. The aspect of dispersed patches of GI, their interconnectedness, ES synergies that arise, and the resulting influence on ES generation cannot be computed. This results in a tool that is applicable for project-scale cases but is not intended for use on a city-wide or landscape level. Since practitioners stressed the need for applicability on small GI projects, the NSC-BM still responds to specific demands from practice. Both spatially explicitness and scalability were however identified as characteristics that would enhance GI tool performance in chapter 2.

Another limitation arising from the tool lacking spatially explicitness, is the absence of benefit transfer functions. Ideally, estimating the economic value of ecosystem services based on studies in one location or context is conducted through benefit transfer functions enabling the translation of values to different locations or contexts. Although this approach may be economically advantageous, neither the current version of the NSC-BM nor other existing valuation tools incorporate this practice. Moreover, incorporating benefit transfer functions entails compromises on the simplicity and usability on the tool, highlighting the inherent accuracy-complexity trade-off.

In approaching GI from different angles: spatial planning, ES generation, economic and biophysical valuation, political-institutional context, and stakeholder analysis, one important dimension is not considered in this thesis. The socio-economic impact of greening is largely disregarded. As a growing field of interest in GI literature, the social justice component – encompassing equity and gentrification – is not fully addressed in this thesis. Especially in the development of tools and methods for the valuation of GI, integrating this dimension has great potential to identify and prioritise locations that deserve more attention in GI implementation. Social justice and equity are intricately linked to GI provision. In a way, this linkage between wealth and access to green is demonstrated in Chapter 3, where financially well-performing municipalities are more likely to invest in green. This could further exacerbate inequality.

In Chapter 2 we also emphasised the need for comprehensive (economic) valuation. Another limitation of this thesis therefore is the absence of the concept of ecosystem *disservices.* In Chapter 4, we found that residents value proximity to the hypothetical GI case only partially, preferring to be close to the neighbourhood park, but not too close. A possible explanation for this observation is this notion of ecosystem disservices. Further research and extensions to GI valuation tools should accommodate for the adverse effects that people may perceive from GI. Given the relatively limited body of research on disservices and the fact that practitioners did not reference it in their needs and expectations of tools, it was deliberately not included in the development of the NSC-BM.

Chapters 3 and 4 make use of stated preference methods. Inherent to the adopted stated-preference approaches, there is a dependence on the hypothetical scenario. This makes stated-preference methods susceptible to *hypothetical bias*. The hypothetical nature results in overestimations of respondents' willingness-to-pay (Loomis, 2011). Several precautions were taken in the experimental designs to reduce this bias as much as possible. The DCE designs both had clear consequentiality aspects tied into the choice options (Carson & Groves, 2007). This means that respondents' future utility is impacted by the choice that is made. As a result, it is explicitly stated in the experiments how the results will define the provision of GI, thus that the probability of payment equals the probability of provision (Mitani & Flores, 2014). However, the choice task in Chapter 3 (which scenario would be chosen in your municipality?) was different from the choice task in Chapter 4 (which scenario do you prefer?). The consequentiality aspect is therefore slightly less explicit in Chapter 4 than in Chapter 3, which might contribute to respondents overstating their WTP. Further, we never offered more than two choice options (and an opt-out) (Carson & Groves, 2007). In Chapter 3, the cognitive burden for respondents in the hypothetical set-up was higher, since it was not asked which alternative *they* preferred, but the alternative they believe would be picked in *their municipality*. Since this method has not been observed in previous studies, the absolute willingness-to-pay was not considered, and only relative trade-offs were analysed. Nevertheless, DCEs remain a useful tool to value non-use or non-marketed goods and services.

The local political decision-making context can hardly be generalised to other regions, countries, or continents. This thesis' conclusions apply to Flanders, Belgium, and the results are dependent on the specific socio-economic and geographical characteristics. In Chapter 4, the contextual specificity is explicitly stated, which emphasises the need for value assessments with local residents, confirming previous research (Ordóñez Barona, 2015). However, some conclusions can be generalised. Firstly, the conclusions on toolkits, their features, and their applicability in Chapters 2 and 5 draw from an international research context (UK, the Netherlands, France, and Belgium). Therefore, these observations are valid for the Western European context at least. The NSC-BM might require specific local inputs in that sense but provides a solid starting point as a framework. Secondly, the short-termism that we found in Chapter 3. Short-termism or lack of long-term thinking was identified before as a barrier for GI implementation in UK by O'Donnell et al. (2017), indicating that it serves as a reasonable hypothesis for future research. Chapters 3 and 4 conclude with the call for indicators that evaluate and motivate local decision-making for GI. The relevance of such indicators extends beyond the Flemish level, applying to broader contexts as well. Generally, the underlying message (and motivation of this research) of effectively incorporating the multifunctional nature of GI into decision-making is universal.

6.5 Further research

This thesis concludes by identifying avenues for further research on several of the research fields addressed in this thesis.

From an economic point-of-view, the rather narrow interpretation of the term *business model* in Chapter 5 implies concrete future research avenues. While value demonstration is one element of a business model, translating this into capitalising on this added value is another. Concretely, future research on GI implementation should focus on bridging value demonstration with value capturing and financing of GI. Research into GI or NbS financing is on the rise (den Heijer & Coppens, 2023; Mell, 2021; Toxopeus & Polzin, 2021; Zimmerman et al., 2019). Since this will probably need insights into ES values, effectively integrating both concepts through applicable and easy-to-use tools for local authorities would entail significant added value.

From the ecological point-of-view, advances should be made so that we thoroughly understand the influence that connectivity of GI elements has on expected ES impacts. The network aspect of GI is currently impossible to appreciate in tools or methods, limiting the potential for local officers to consider the added value in spatial planning. Further, including blue infrastructure in valuation methods more explicitly. While the NSC-BM incorporates certain types of blue infrastructure, it inadequately addresses the intricate interactions between blue and green infrastructure components. Especially since blue-green infrastructure (BGI) is becoming more and more ingrained as a *new* concept (Liao et al., 2017; Suleiman, 2021), accommodating for this by implementing estimating valuation methods into tool development is imperative. Further, we only found evidence of the value that residents attribute to biodiversity in Chapter 4, hence we couldn't integrate it into the decision-makers' DCE anymore. For future research it would be highly relevant to investigate the importance of biodiversity aspects in GI decision-making processes.

From the socio-economic point-of-view, further research into citizen involvement and activation in GI implementation is recommended. This implies both preference orientations in different types of GI – referring to the narrow GI neighbourhood park case in chapter 4 – as thorough research into motivating to green on private property. Methodologically, stated-preference methods – such as DCEs and BWS – can be designed to accommodate for other GI types. In the context of climate adaptation, street scape green infrastructure would be highly interesting to research. Stressing the urgency of building climate adaptivity into our urban landscapes, policymakers need insights into which types of GI residents demand, and how acceptance or participation to GI implementation can be enhanced. In this dimension, means to actively incorporate the social justice component of GI into readily applicable methods for practitioners should be sought. Inclusive valuation methods, where metrics on accessibility/distribution of GI are linked to socio-economic data (e.g., through spatially explicit tools) can contribute to facilitate making this dimension operational at the local level. Besides that, stated-preference techniques can be applied to research how residents perceive GI across different socio-economic or ethnic groups. In that respect, studying the temporal and spatial subjectivity of the experimental results through repeating the experiments in different locations is a potential avenue for further research.

From the political-institutional point-of-view, further research should aim to get a deeper understanding of the dynamics at the local level. As mentioned in Chapter 1, local politics is less researched, notwithstanding the importance for climate adaptation in practice. In Chapter 3, the political process was reduced to project planning and design *after* the designation (in the spatial execution plan) of a site as green space. However, we expect that the largest portion of political behaviour takes place before this designation. Given the relevance of (re)designation in the context of the Flemish building shift, further understanding these dynamics can be helpful to foster local GI implementation. Next, the short-termism and administrative siloes in local spatial planning should be addressed. Consequently, we suggest that future research should investigate potential alternative local management solutions that not only surpass temporal constraints, such as electoral cycles, but also overcome disciplinary barriers associated with silo-thinking. Such solutions should aim to remove green infrastructure implementation (and spatial planning in general) from the political game – thus implying local institutional reforms. To overcome administrative siloes, one should investigate the budgeting practices in local municipalities, since the siloes often originate this. With respect to (some of) the identified barriers in this thesis, it is proposed to integrate valuation tools and indicators as a potential approach to implement standardised practices effectively and consistently for monitoring the quality and quantity of local GI. Therefore, it is recommended that future research investigates the feasibility and operational strategies to support this approach, and to identify relevant metrics with a specific focus on the local level. Besides this, academic research should further and proactively progress in democratising and improving the dissemination ES knowledge.

6.6 Policy recommendations

The interdisciplinary research in this dissertation gives evidence to policy recommendations.

Multidisciplinary and holistic appraisal of spatial processes should be mainstreamed in policy. Moreover, the local level should be supported with the tools and legislation to align different overarching strategic visions (European, national, regional). ES/GI valuation tools as introduced in this dissertation can be one instrument to facilitate the uptake of scientific or informed decision-making. From our examination of the Flemish case, we conclude that the monitoring and measurement for both GI quantity and quality would benefit from being embedded in policies. However, local municipalities should be given the handles to translate such a policy. In that respect, jointly applying GI/ES valuation tools and enforceable indicators (e.g., 3-30-300 rule) could provide a worthwhile avenue.

Further, in municipalities, spatial planners are often occupied with permitting. To facilitate the permitting process, it is worthwhile for policy makers to explore how GI valuation tools can contribute. Furthermore, adopting standardised approaches not only simplifies the permitting process, but it also serves as a means to support transparency between the applicant and the overarching policy. After all, spatial planning is a social process that aims to integrate a strategic vision. In that sense, GI/ES valuation tools can have a bridging role between policy goals and practical implementation on the ground. As we stipulated in this concluding chapter, these tools should be further complemented with methods to involve citizens. After all, the climate and biodiversity crises – especially in a region with 33% land take – can only be addressed by building support and engaging all stakeholders. Moreover, this community involvement should – similar to when applying GI valuation toolkits – be done from the start of a project. This early involvement is crucial for fostering a shared understanding among all stakeholders.

In Chapter 3 we clearly saw how the size of municipalities influences the barriers that they face to implement GI. Smaller municipalities, in particular, exhibit a deficit in knowledge and experience. Here lie quick wins for overarching governments to address this gap. It would be beneficial for provinces or regional bodies to establish collaborative platforms focused on spatial planning and multidisciplinary subjects. These platforms can serve as valuable tools for smaller municipalities, fostering knowledge exchange and integration into policy. This collaborative approach has the potential to pool expertise and build capacity, particularly benefiting smaller municipalities. Nonetheless, it is worth noting that the permitting issue mentioned above frequently hinders practitioners from allocating time to engage in these practices.

On a regional or national level, GI and ES knowledge transfer between science and policy should be facilitated. In the Nature Smart Cities project, the interdisciplinary collaboration between researchers/academics and practitioners contributed to the significance of the work. From a policymaker's perspective, organising platforms or mechanisms to enforce the interaction between these two stakeholders will contribute to ensuring that scientific research and local GI implementation are mutually reinforcing.

On a European level, the financing of GI and NbS should be a key area of interest to realise the ambitions in the field of climate adaptation and mitigation. In our research we find that the investment costs are the biggest stumbling block for local authorities, which is the case elsewhere in Europe as well. In defining strategies to facilitate the financing, it is essential to consider how to engage local authorities, especially those local authorities that lack the capacity to participate in the larger research programs.

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Appendices

Appendix 2. Supplementary materials Chapter 2

Appendix 2-A

	Toolkit	Economic Valuation?	Compreh ensive?	Additional remarks
1	Environmental Protection Agency (EPA) Green Long-Term Control-EZ Template			
2	Water Environmental Research foundation BMP Select Model			
3	Virginia Runoff Reduction Method			
4	Werf BMP and LID whole life cycle cost modeling tools			
5	CNT Green values national stormwater management calculator	x		
	CNT: A guide to value green infrastructure	x	x	
6	CNT Green values stormwater management calculator	x		
7	Chicago Department of Environment Stormwater Ordinance Compliance Calculator			
8	EPA Stormwater Management Model (SWMM)			
9	Delaware Urban Runoff Management Model (DURMM)			
10	Stormwater Investment Strategy Evaluator (StormWISE) Model			
11	Program for predicting polluting particle passage through pits, puddles, and ponds (P8 Urban Catchment Model)			
12	Long-Term Hydrologic Impact Assessment (L-THIA)			
13	GI Valuation Tool Kit	x	x	
14	EPA System for Urban Stormwater Treatment Analysis and Integration (SUSTAIN)			
15	RECARGA			
16	Model for Urban Stormwater Improvement Conceptualization (MUSIC)			
17	Low-Impact Development Rapid Assessment (LIDRA)			
18	WinSLAMM (Source Loading and Management Model for Windows)			
19	i-Tree Streets	x	x	Out-of-use
20	i-Tree Hydro			
21	Ostrich SWMM			
22	i-Tree Eco	x	x	
23	UFORE	x	x	Predecessor of i-Tree Eco
24	Climate Leadership in Parks (CLIP)			
25	Farm Carbon Assessment Tool (FCAT)			
26	Multifunctional Landscape Assessment Tool (MLAT)			
27	Nature Value Explorer	x	x	
28	B£ST	x	x	
29	CAVAT	x	x	
30	INVEST	x	x	
31	HEAT	x		
32	Helliwell	x		
33	Pandora 3.0			
34	Adaptation Planning Support Toolbox			
35	Smart City Planner			

	Toolkit	Economic Valuation?	Compreh ensive?	Additional remarks
36	Urban Water Optioneering Tool (UWOT)			
37	i-Tree Design	x		
38	TESSA	x	x	
39	ARIES	x	x	Not fully accessible yet (30/09/2019)
40	Corporate Ecosystem Services Review (ESR)			
41	EcoServGIS			
42	MangroveCarbon			
43	Ecosystem Valuation Toolkit by Earth Economics	x	x	Only for EE members and developers
44	LEED			
45	MIMES			
46	Natura2000	x	x	Too old, last version: 2009
47	Co$ting Nature		x	Urban areas are set to zero
48	Social Values for Ecosystem Services (SolVES)			
49	Envision			
50	Ecosystem Portfolio Model (EPM)			
51	InFOREST			
52	EcoAIM			
53	ESValue			
54	EcoMetrix			
55	Natural Assets Information System (NAIS)			
56	Benefit Transfer and Use Estimating Model Toolkit			
57	Green Infrastructure Co-Benefits Valuation Tool	x	x	
58	TEEB City			
59	EcoPLAN-SE	x	x	
60	LUCI			
61	Greenkeeper	x	x	Not published yet (30/09/2019)

Appendix 2-B

a) Type of Green Infrastructure

A toolkit can be designed to value economic/biophysical impacts of specific green infrastructure solutions (e.g. green roofs/green walls). Considering the targeted end-user of toolkits from the urban planning and the intended purpose of such tools in the context of this review, toolkits that were to provide straightforward guidance in valuating common green infrastructure installments are preferred over toolkits that don't provide this guidance. Hence, table 5, which translates the performance of toolkits on every criterion on an intuitive +/- based scale, depicts '++' if a toolkit were to explicitly account for different GI types and '--' if a toolkit were not.

b) Subject of valuation

It is observable that half of the toolkits adopt an ecosystem services approach to valuating. On the other hand, toolkits sometimes provide a self-defined set of 'benefits' from green infrastructure. Because introducing new typologies presents the additional threat of confusing local development planners and to aim at aligning public space decision making with scientific research, sticking to the ecosystem services framework or similar published typologies is preferred. On the +/- scale, toolkits to have used the ecosystem services approach (or another published and accepted framework) are scored with '++', toolkits to introduce their own types of benefits are given '--'.

c) Time requirement

Because – ceteris paribus – toolkits that require less time to be executed, are preferred in the steps of public planning and decision making of efficiency reasons. Toolkits that require the least amount of time to pass through the whole valuating process are scored with '++', over toolkits that require an average amount of time that are scored '0', to toolkits that require a lot of time for various reasons and are scored '--'.

d) Expertise requirement

In public sector decision making, especially in towns and small cities, the availability of subject-matter experts on specific topics is lacking. Ideally a toolkit could be utilised by all stakeholders involved from the idea development stage until the approval process. For widespread use, it is preferable that valuation exercises can be executed without the need to consult academics for every step along the process. Hence, intuitive toolkits that provide the guidance for reliable output to be generated by non-experts are rated '++', over toolkits that require a moderate amount of expertise input (0), to toolkits that require a lot of consultation with field-level experts for reliable outcomes and are rated '--'.

e) Quantification

An expression of benefits in numbers is extremely important in public decision making. Since grey infrastructure can often be expressed relatively straightforward into tangible figures and UGI is typically competing with grey infrastructure, having quantified proof of the relevance of urban green is necessary. Especially in urban environments, where green infrastructure competes with traditional grey infrastructure, quantification contributes to making trade-offs. Note that not all benefits can be traditionally put into numbers, often qualitative assessments are inevitable and still provide useful input for the business case of GI. Although all the selected toolkits aim at providing at least methods to economically value green infrastructure or ecosystem services, tools might invest more effort into valuating either the biophysical impacts or the economic impact more profoundly. In order to support the business case for green infrastructure elaborating on both aspects is important. Linking back to the scoring model, toolkits to focus on both biophysical and economic valuation and provide qualitative support where necessary are scored '++'. Because the scope of this review paper is focused on the base for the business case for green infrastructure in cities, toolkits that focus on the economic quantification of benefits, supported by qualitative support for 'invaluable' benefits, are scored with a '+'. Toolkits that don't include this qualitative support over economic quantifications were scored with '0'. If the quantification of impacts is given in biophysical units, together with occasional translations into monetary units, toolkits are given the score '-'. Finally, if toolkits merely provide guidelines on how to execute quantifications, a score of '--' is given, since this does not fit in the scope of the quick decision-support tool that is envisioned in this review.

f) Biophysical soundness

'++' is given to toolkits that utilise academic standards to conduct value estimations and more importantly: spend additional attention to specific urban ecosystem services, while including the notion of feedback between ecosystem services. Toolkits to utilise academic standards and include urban ecosystem services are scored '+'. The minimum that is acceptable within this criterion – scored '0'- is utilising academic standards. Not committing to academic standards while still attempting to create a comprehensive assessment is scored '-'. If a toolkit did not utilise academic standards, and did only provide a partial assessment of benefits, it is scored '--'.

g) Economic soundness

Tools that comply with academic standards to valuate benefits monetarily, as well as take extensive account in calculations of the principle of double counting, while elaborating into providing economic performance indicators (NPV, TEV, IRR, BCR, …) are scored '++'. If tools comply with economic standards and calculate economic performance indicators, they are given '+'. A '0' score was given to toolkits that comply with academic standards. If toolkits do not comply with academic standards, but includes economic performance indicators it is scored '-'. Finally, toolkits that do not comply with academic standards in valuating and provide no additional base for the business case (economic performance indicator), it is scored '--'.

h) Adaptability

In terms of adaptability, tools that would be completely open-source are considered '++': this means that the end-user would be able to adapt the values that are used to calculate impact, can alter the methods for valuation and can even add possible spatially explicit benefits to the services that are valuated. A '+' was given if toolkits' methods and default values can be adapted to local needs. Further, the minimum requirement '0' was given when toolkits allow the end-user to adapt the default values to provide more reliable local results. If toolkits fail at providing the user with this minimum criterion, they are scored '--'.

i) Scalability

Since towns and cities are often interested in specific added value of a certain planned GI design, it is necessary that a tool can operate at project level. Besides this, planning and management of parks and larger urban green areas requires larger scale application as well. If toolkits are easily transferable over different spatial scales, they are scored '++'. The minimum requirement within the scope of this review is that tools are capable of assessing the added value of an urban green infrastructure investment , so '0' score is given if the toolkit can be applied at the site or project-scale. Toolkits are not suited for widespread use in the context of urban planning if they are not transferable in scale and are only suited for landscape-scale assessments, scored '--'.

j) Generalizability

The '++' score is given to toolkits that are easily generalizable over geographical and socio-economic situations, without additional effort or data required from the public planner/decision maker. A '+' was given to tools that need GIS data only to be applicable in different geographic contexts, since these generalizations generate better results thanks to the more detailed input data. Tools were rated '-' if they rely on benefit transfers methods solely in order to be used in different areas, which tends to generate unreliable outputs. '--' was given to toolkits that are not generalizable at all, due to the proposed methods or due to limited possibilities of the software they rely on.

k) Uncertainties

Regarding uncertainties, including a quantitative risk analysis (Monte Carlo or similar) to provide a probabilistic spread of the economic/biophysical added value, as well as including sensitivity analyses to address uncertainty is scored with '++'. Simple quantitative risk assessments, utilising confidence intervals and chance distributions to calculate average economic/biophysical value is scored with '+'. Introducing benefit values in ranges - supported by qualitative mentioning of uncertainties/risks - instead of mere point values is the least acceptable for a credible business case basis, scored with '0'. '-' is given if toolkits only qualitatively acknowledge the concept of uncertainties and risks. Finally '--' means that users are not made aware of risks/uncertainties, thus are not able to generate a realistic business case.

l) Scenario analysis

A critical component deciding on the suitability of a toolkit within the scope of this review: a tool should be able to straightforwardly evaluate different scenario's and compare these with each other and with the baseline scenario. '++' is given if toolkits meet said requirement, '--' if toolkits are not.

Appendix 2-C (1)

Criteria	Nature Value Explorer	i-Tree eco	GI-Val	CNT
Type of GI	Any that provides ecosystem services, different GI examples possible	Trees, urban forest	Green roofs, green space	Green roofs, trees planting, bioretention and infiltration, permeable pavement, water harvesting
Subject of valuation	Ecosystem services from a GI project	Value environmental functions (air quality, stormwater control, energy effects, carbon sequestration, carbon storage)	The '11 benefits framework', based on 11 self-defined categories of benefits: climate change adaptation and mitigation, water and flood management, place and communities, health and wellbeing, land and property values, investment, labour productivity, tourism, recreation and leisure, biodiversity, land management.	Selection of self-defined benefits from different types of green infrastructure.
Time requirement	Low: intuitive interface, no calculation time and low time requirement for data collection	Tree data collection might be time intensive (diameter of tree, breast height, species and genus names, etc.). For cities not included in the i-Tree database, additional time and expertise is needed for local data.	Applying toolkit itself: low. However, not GIS-based, so data collection to make locally adapted estimations might make it time-intensive.	Low, pre-defined equations are to be filled out with project-specific data.
Expertise requirement	Straightforward and detailed webtool, however not requiring any subject-matter experts. Detailed guidance in the process.	Every tree needs to be measured individually, ecology expert input required.	The toolkit itself is easy-to-use. Expert input is needed for reliable results; interpret when to adjust for double counting, make the distinction between economic value and economic impact, etc.	On itself, the guide could be used by non-experts. However, the guide is developed in US, for transfer to other geographic locations the consultation of experts is required.
Quantification	Combination of qualitative and quantitative output. Conservative approach of quantifying the ecosystem services: not all ecosystem services are quantified. The output is quantified both in biophysical units and monetary terms when possible.	Combination of monetization and quantification of yearly value in functional units (eg. tons of carbon stored) and estimated monetary value of ecosystem services. No qualitative support.	GI-Val quantifies the benefits monetarily. Biophysical quantification often omitted to immediately produce monetary values. No additional qualitative support.	Collection of guidelines for both biophysical and monetary quantification.
Criteria	**Nature Value Explorer**	**i-Tree eco**	**GI-Val**	**CNT**

Economic soundness	Only scientific and peer-reviewed literature based evidence is used for monetising methods. By using ordinal scales on many occasions, the accuracy of the modeling is reduced. The tool only generates a yearly expected value, no total economic value. Double counting is mentioned, but more guidance for non-experts;	Only a subset of amenity tree values is considered, leading to undervaluation. No consideration of cultural ecosystem services.	Unreferenced assumptions. Unstructured use of economic value and economic impact. Includes the base for a cost-benefit/TEV	The outcome is an annual benefit, no total economic value. Proposition of different economic valuation methods. Data to monetise are based on scientific literature.
Biophysical soundness	Large categorization of different types of urban green. No consideration of specific species (eg. type of street tree). Consideration of urban ecosystem services, however missing some important features. The guide of the toolkit acknowledges relatedness of ES vaguely. All calculations based on evidence from peer-reviewed literature.	Based on location specific precipitation and pollution data. Scientific approach to ecosystem service valuation of trees, especially when the user provides additional tree measurements. All is based on existing literature.	Insufficient reference of scientific literature. Often use of outdated numbers.	Not all ecosystem services are considered. Consistent referencing of scientific literature in quantification processes.
Adaptability	The tool relies on the built-in GIS and regional (Flanders) information. It is possible to manually modify input data for all users.	Few monetising principles rely on US default values, users are free to produce valuation data to localise benefit estimates.	In the tab ‘Values Library’, users can modify the numbers used for calculations (eg. Local electricity prices, property value premiums, etc.)	Complete freedom to modify.
Scalability	From parcel-scale to landscape-scale (max 250 ha.)	Plot sample or whole area inventory.	GI projects on any scale	Site-scale
Generalizability	Not generalizable. Toolkit is only defined for Flanders, Belgium. In theory, it is possible to apply NVE elsewhere, if all spatially explicit data are inputted manually.	Available in US, Canada, Australia, UK and most of the cities in Mexico and the European Union.	Generalizable anywhere. Unit values tailor made for UK, other geographic and socioeconomic contexts require expert input.	Not spatially explicit, general framework, widely generalizable if local input data to support reliability are available.
Uncertainties	For all quantitative output a lower bound and upper bound of expected return is calculated.	Point-based estimates, without sensitivity analysis. Although using average regional values to calculate, no uncertainty to local effects is built in the model	No guidance in dealing with uncertainties. Provides point values for each benefit	Only calculation guidelines for point values.
Scenario analysis	Yes	Possibility to make forecasts, however complex and timely process to create and compare different spatial planning scenario's	Yes	Yes

Appendix 2-C (2)

Criteria	TESSA	InVEST	EcoPLAN	GI cobenefits tool
Type of GI	Not specifically for GI	Any 'natural resource'	Any change in land cover and land use	6 GI assets: Raingardens and bioswales, Bioretention ponds, Pervious pavement, Wetlands, Urban forests, Green roofs.
Subject of valuation	Ecosystem services	Ecosystem services	Selection of 18 ecosystem services	9 benefits: stormwater flood risk reduction, combined sewer overflow reduction, stormwater capture for water supply, stormwater quality, urban heat island effect, environmental education, aesthetic value, air quality, carbon sequestration.
Time requirement	According to the guidebook, an assessment takes 49 person days on average per site. This entails planning, data collection, community workshops, etc.	Time requirement for data collection is mostly limited through the use of GIS-data. However, the user has to select and provide the relevant GIS maps. Moreover, familiarising with the interface requires time.	Timely process, many steps to follow. Complexity of the software interface lengthens the assessment time.	The objective of the tool is a quick, screening assessment.
Expertise requirement	Accessible to non-experts, it is however expected that users make adaptations to the calculations for reliable results, the 'guidance' addition to the toolkit allows non-experts to provide reliable outcome.	Expert input is required in different stages of the modelling process. Initially, recognising relevant ecosystem services dependent on the envisioned green infrastructure demands expert input. Moreover, because of the complexity of data formatting and modelling itself, users are expected to have profound digital and mapping skills. The InVEST interface does not contribute to the ease-of-use. The developers organise training workshops to facilitate usage.	EcoPLAN-SE indicates relevant ES based on project, which benefits accesibility for non-experts. The interface requires experience with programming (Python) and GIS treatment and processing. Training sessions are organized to familiarise.	Simple tool intended for a screening-level analysis. Accessible for non-experts, however, local values are advised for reliable outcomes.

Criteria	TESSA	InVEST	EcoPLAN	GI cobenefits tool
Quantification	No explicit quantification: guidelines to quantify are provided.	Not all models provide economic valuation, while biophysical valuation is always done.	Relies on maps (land cover, land use, soil texture), because these maps are often inaccurate or incomplete in urban areas, ES calculations are less reliable. Takes account of beneficiaries outside of the project area to quantify the ES. Both monetary and biophysical values are provided.	Only quantifiable benefits are considered for the seperate GI assets. Takes account of the timing of GI revenues. Results are only shown in dollar values. All quantifications are based on scientific literature.
Economic soundness	Only considers difference in two snapshots in time at site-scale, no total economic value calculation. Toolkit is cautious for double counting. The only toolkit to include opportunity costs into decision making process, as well as communicate about ecosystem services beneficiaries.	(Almost) every ecosystem service relies on a separate (peer-reviewed) model, introducing a risk for double counting, especially for less experienced users. More often than not, monetarization is omitted. The modelling exercise is limited to the generation of economic benefits (in some models), lacking the economic base for a credible cost-benefit analysis.	No total economic value, all monetary results are based on yearly economic impact. Explicit consideration of local supply and demand for ES. Double counting is not mentioned and is an issue in the framework. All relies on referenced literature.	Clear oversight of the economic side of GI assets, with graphical support, NPV, IRR, etc. Unclear why maintenance costs are not subjected to the discount rate in contrast to other costs and benefits.
Biophysical soundness	Through decision trees, process guides you to relevant calculation methods. All biophysical quantification advices are referenced and based on international standards (eg. IPCC). No real urban ecosystem services.	Wide array of ecosystem services can be assessed biophysically. The toolbox is focused on “terrestrial, freshwater and marine systems”, not urban (green) landscapes. Defined two models for urban ecosystem services (Urban Cooling model and Urban Flood risk mitigation model), omitting another important urban ES: Air Quality regulation. All is based on referenced literature.	EcoPLAN does not incorporate water quality regulation and flood prevention. However, takes account of typically urban ES: noise reduction, air quality regulation, urban climate regulation and residential environment. Some numbers and methods are outdated (e.g. air quality: only one polluent is considered and PM10 numbers should be reviewed). Correlation between ES is considered and interpreted. All relies on referenced literature.	The strict subdivision into 6 concrete examples of GI limits the applicability for alternatives or combinations. The benefit categories as they are proposed tend to overlap and typical urban ecosystem services are not considered. Calculations are often too minimalistic (e.g. every type of tree generates the same benefits, all types of green roofs result in the same benefits). No clear overview in the results of the biophysical impact.
Adaptability	Complete freedom to modify.	The modelling methods themselves are not adaptable, however high adaptability in input data to generate local results.	Users can adapt maps and other input data, however, the underlying models are fixed.	In the 'Regional Inputs' tab, users can adapt input data to more local contexts. Calculation methods are not adaptable, users cannot add benefit categories.

Criteria	TESSA	InVEST	EcoPLAN	GI cobenefits tool
Scalability	Site-scale	Different models seem to have different resolutions. The model itself claims to be applicable on local, regional or global scale. Site-specific calculations in urban areas are not possible due to the resolution.	Flexible in resolution: applicable from 5m x 5m to landscape-scale.	Restricted to the GI asset
Generalizability	Not spatially explicit, general framework, widely generalizable if local input data to support reliability are available.	Any user worldwide, possessing GIS-data of the relevant research area.	Methods are specifically designed for Flanders.	Generalizable, however this is only relevant if users possess local data.
Uncertainties	Additional guidance document on uncertainties, advising a qualitative (low-medium-high) categorization of uncertainty	Qualitative mentioning of uncertainties and risks in many models, one of the models (Marine Finfish Aquacultural Production) features uncertainty analysis (using Monte Carlo simulations) with confidence levels and standard deviations, others don't.	No	No
Scenario analysis	Yes	Yes	Yes	Yes

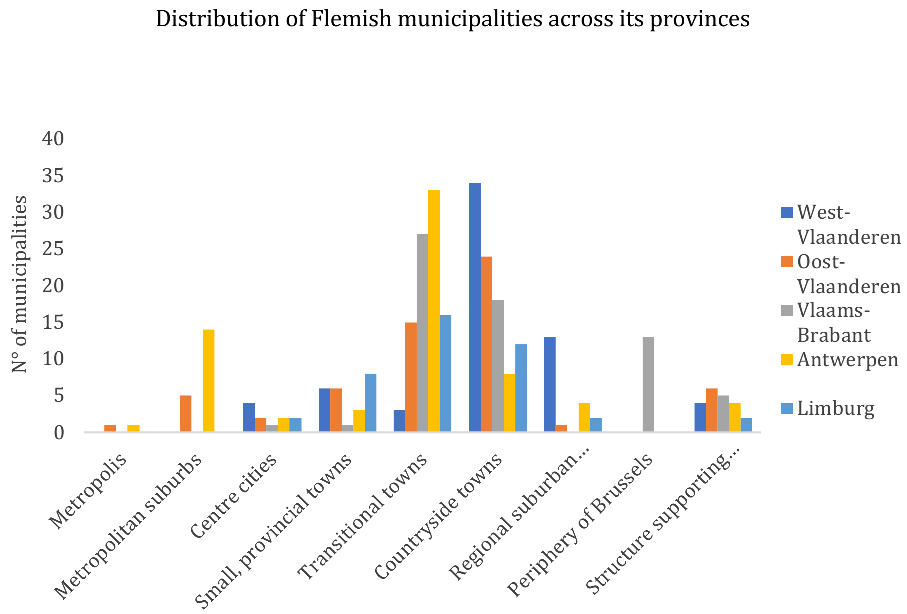
Appendix 2-C (3)

Criteria	CAVAT	B£ST
Type of GI	Amenity trees	Elements of 'Blue-Green Infrastructure'
Subject of valuation	The replacement value of a tree. Subject of valuation is a tree.	18 benefit categories, similar to - but differing from - the traditional ES framework.
Time requirement	Full version: higher. Time intensive measurements of individual trees are needed.	Four steps have to be gone through for a complete assessment. A quick coarse assessment is available for high-level indication of benefit ranges. Straightforward spreadsheet, but very dependent on user input, requiring time.
Expertise requirement	Full version requires expert inspection; it involves a site inspection and further investigation on internal decay detection. In general, trained, professional arboriculturists are needed.	Not restricted to subject-matter experts. If numbers are readily available, B£ST becomes an easily accesible tool. Since it is tailor-made for the UK, users of this tool outside of the UK should be more experienced with ES valuations. Clear overview of "minimum information requirements" supports accessibility.
Quantification	The output is strictly quantified in monetary values. No comprehensive quantification of the biodiversity and social, cultural values.	Very much focused on the pound-value of sustainable drainage measures and natural flood management measures. Although one can find biophysical values, the graphical results only support monetary output.
Economic soundness	Based on 'expert inspection'. Value of a tree is the sum of different attributes that result in reduction or increase of the base tree value. No scientific motivation for appreciation factors.	All quantifications rely on scientific literature, specifically from UK studies. Strong economic base for a business case on BGI. The focus of the assessment is on economic properties of BGI. This includes information on defining beneficiaries, providing funding ideas, calculating total economic value, generating NPV and BCR, …
Biophysical soundness	No acknowledgement of any ecosystem service (eg. carbon sequestration, biodiversity, climate regulation, etc.), difficult to assess biophysical method since it is the results of 'expert assessment'. Incorrect assumption that the value of multiple trees is equal to the sum of the separate tree values.	Complexity is added through defining its own benefit categories. For some benefit categories typical GI structures are mentioned (eg. Green roofs or green walls), while for others this is not the case. All quantifications rely on scientific literature.
Adaptability	Not adaptable, closed spreadsheet	Highly adaptable for input data and default values. Users can also add benefit categories.
Scalability	Ranging from a single tree to a forest	Ranging from project-scale to landscape-scale, however it is mentioned that many benefits only become relevant at larger scales.

Criteria	CAVAT	B£ST
Generalizability	In theory the toolkit can be applied to every tree/stock of trees	High dependence on default values, which are all specific to the UK.
Uncertainties	No accounting for uncertainty	Extensive mentioning of uncertainties and sensitivity analyses. Users have to identify confidence scores (on a likert scale) that are computed to differing valuations.
Scenario analysis	No	Yes, specifically designed comparison tool, up to four different scenarios.

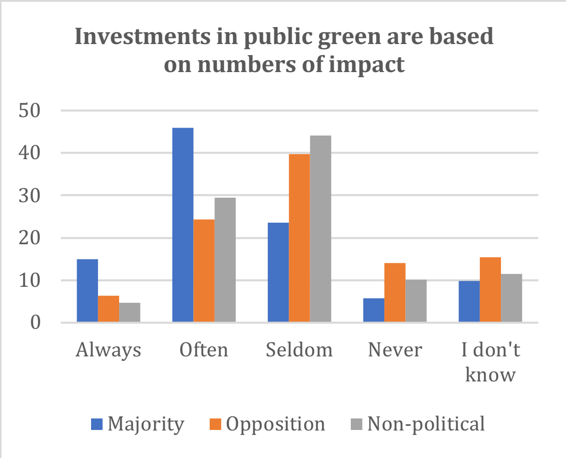
Appendix 3: Supplementary materials Chapter 3

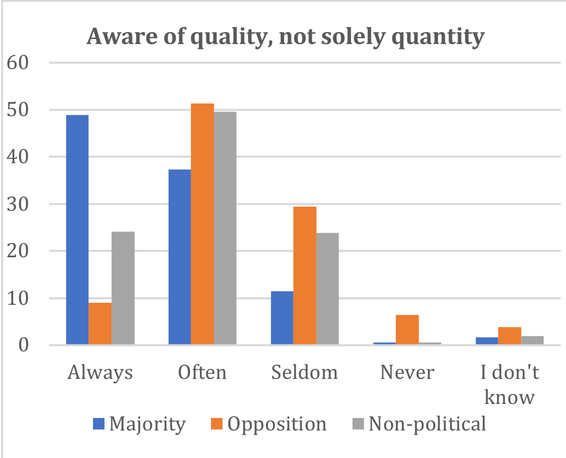
Appendix 3-A

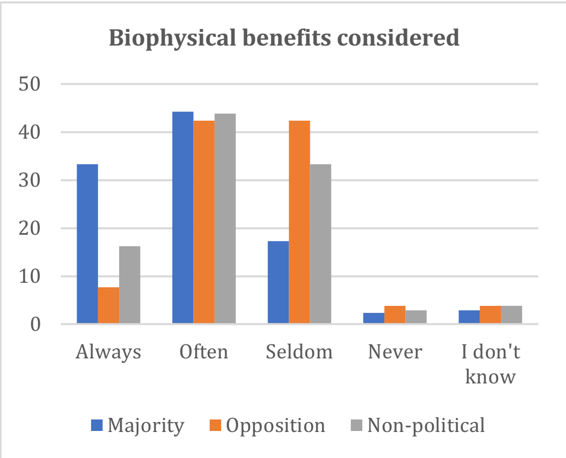


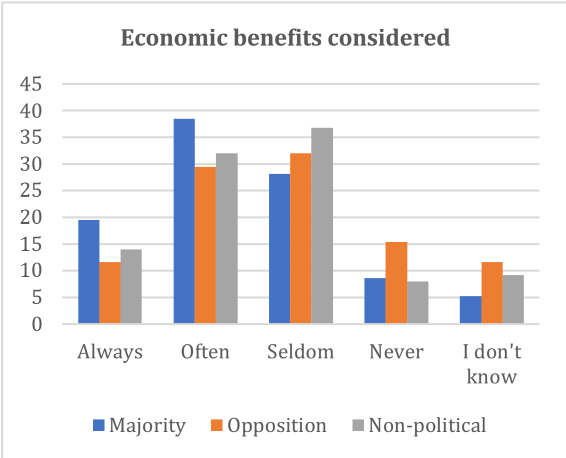
		West-Vlaanderen	Oost-Vlaanderen	Vlaams-Brabant	Antwerpen	Limburg	Aggregate
Metropolis	*Number of respondents*	-	8	-	26	-	34
	Percentage of municipalities represented (%)	-	*100*	-	*100*	-	*100*
Metropolitan suburbs	*Number of respondents*	-	13	-	37	-	50
	Percentage of municipalities represented (%)	-	*100*	-	*93*	-	*95*
Centre cities	*Number of respondents*	19	4	4	8	5	40
	Percentage of municipalities represented (%)	*100*	*100*	*100*	*100*	*100*	*100*
Small, provincial towns	*Number of respondents*	11	14	1	14	17	57
	Percentage of municipalities represented (%)	*67*	*83*	*100*	*100*	*88*	*83*
Transitional towns	*Number of respondents*	5	18	37	81	38	179
	Percentage of municipalities represented (%)	*67*	*73*	*74*	*88*	*81*	*80*
Countryside towns	*Number of respondents*	30	22	19	10	18	99
	Percentage of municipalities represented (%)	62	58	78	63	58	64
Regional suburban towns	*Number of respondents*	30	3	-	9	6	48
	Percentage of municipalities represented (%)	92	100	-	100	100	95
Urban periphery of Brussels	*Number of respondents*	-	-	11	-	-	11
	Percentage of municipalities represented (%)	-	-	62	-	-	62
Structure supporting cities	*Number of respondents*	12	7	8	12	11	50
	Percentage of municipalities represented (%)	100	100	100	100	100	100

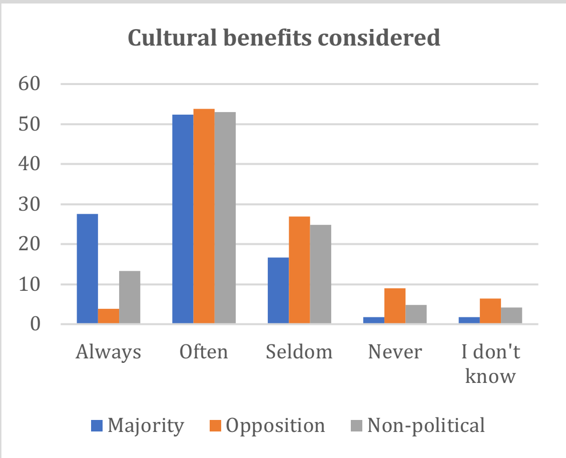
Appendix 3-B


Investments in public green are based on numbers of impact
50
40
30
20
10
0
Always
Often
Seldom
Never
I don't know
Majority
Opposition
Non-political


Aware of quality, not solely quantity
60
50
40
30
20
10
0
Always
Often
Seldom
Never
I don't know
Majority
Opposition
Non-political


Biophysical benefits considered
50
40
30
20
10
0
Always
Often
Seldom
Never
I don't know
Majority
Opposition
Non-political


Economic benefits considered
45
40
35
30
25
20
15
10
5
0
Always
Often
Seldom
Never
I don't know
Majority
Opposition
Non-political


Cultural benefits considered
60
50
40
30
20
10
0
Always
Often
Seldom
Never
I don't know
Majority
Opposition
Non-political

Appendix 3-C

1. High investment costs

Level		Mean
Urban periphery of Brussels	A	1,000
Regional suburban towns	B	0,917
Small, provincial towns	B	0,907
Metropolitan suburbs	B	0,894
Countryside towns	C	0,857
Transitional towns	C	0,844
Structure supporting cities	D	0,792
Metropolis	D	0,781
Centre cities	E	0,676

2. Conflicting priorities

Level		Mean
Urban periphery of Brussels	A	0,818
Regional suburban towns	B	0,708
Metropolis	C	0,656
Centre cities	C	0,649
Transitional towns	C	0,618
Small, provincial towns	D	0,574
Structure supporting cities	D	0,563
Metropolitan suburbs	E	0,511
Countryside towns	F	0,469

3. Lack of long-term thinking

Level		Mean
Urban periphery of Brussels	A	0,818
Metropolitan suburbs	B	0,702
Small, provincial towns	C	0,648
Transitional towns	D	0,613
Centre cities	E	0,568
Regional suburban towns	EF	0,542
Structure supporting cities	EF	0,542
Countryside towns	F	0,510
Metropolis	G	0,406

4. Convincing dwellers

Level		Mean
Countryside towns	A	0,622
Centre cities	AB	0,595
Regional suburban towns	B	0,583
Small, provincial towns	B	0,556
Metropolitan suburbs	C	0,511
Transitional towns	C	0,503
Urban periphery of Brussels	CD	0,455
Structure supporting cities	D	0,417
Metropolis	E	0,344

5. Lack of knowledge, insight, and awareness of GI

Level		Mean
Transitional towns	A	0,601
Metropolitan suburbs	AB	0,574
Structure supporting cities	BC	0,563
Urban periphery of Brussels	ABCD	0,545
Countryside towns	CD	0,531
Regional suburban towns	DE	0,500
Small, provincial towns	E	0,463
Metropolis	F	0,344
Centre cities	F	0,324

6. Insufficiently proven added value of GI

Level		Mean
Small, provincial towns	A	0,611
Countryside towns	B	0,541
Transitional towns	B	0,538
Metropolitan suburbs	BC	0,532
Metropolis	BCD	0,500
Structure supporting cities	CD	0,500
Regional suburban towns	D	0,458
Urban periphery of Brussels	D	0,455
Centre cities	E	0,378

7. Convincing planners/developers of GI approach

Level		Mean
Centre cities	A	0,730
Metropolis	B	0,563
Urban periphery of Brussels	BC	0,545
Metropolitan suburbs	C	0,511
Transitional towns	C	0,503
Structure supporting cities	D	0,458
Countryside towns	D	0,449
Small, provincial towns	D	0,444
Regional suburban towns	D	0,438

8. Lack of (local) political support for GI

Level		Mean
Urban periphery of Brussels	A	0,727
Small, provincial towns	B	0,444
Structure supporting cities	BC	0,438
Transitional towns	CD	0,405
Countryside towns	DE	0,398
Regional suburban towns	DE	0,375
Metropolitan suburbs	E	0,362
Metropolis	F	0,313
Centre cities	F	0,270

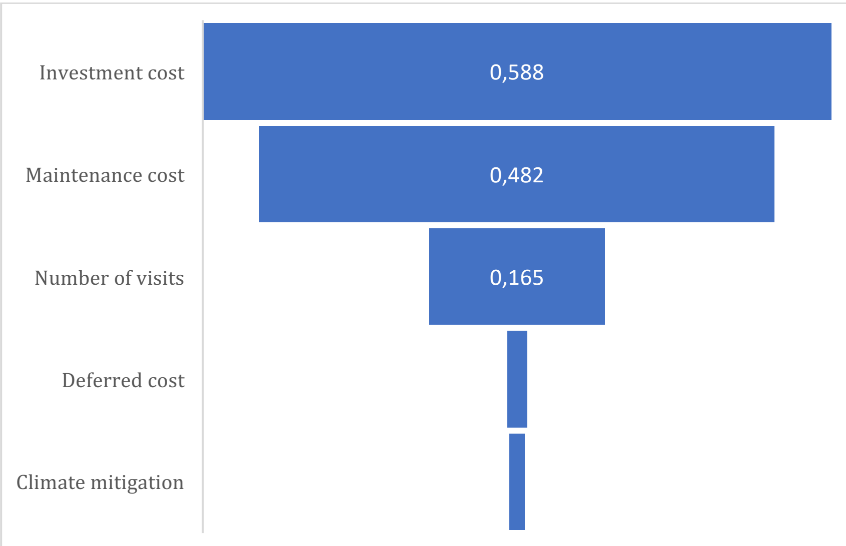
9. Stick to the status-quo

Level		Mean
Urban periphery of Brussels	A	0,455
Metropolis	B	0,375
Metropolitan suburbs	B	0,362
Transitional towns	C	0,324
Countryside towns	D	0,296
Small, provincial towns	D	0,278
Regional suburban towns	D	0,271
Structure supporting cities	D	0,271
Centre cities	E	0,189

Appendix 3-D

Term	Posterior Mean	Posterior Std Dev
Investment cost [500000-350000]	-2,773***	0,213
Investment cost [650000-500000]	-1,375***	0,216
Maintenance cost [20000-10000]	-1,992***	0,192
Maintenance cost [30000-20000]	-2,618***	0,253
Deferred cost [20 years-10 years]	0,915***	0,121
Deferred cost [30 years-20 years]	-0,735***	0,165
Number of visits [25000-10000]	1,066***	0,131
Number of visits [40000-25000]	1,284***	0,172
Climate mitigation [15-5]	0,469***	0,166
No Choice Indicator	-11,113***	0,879
Goodness of Fit Measure		**Value**
-2 * Avg Log Likelihood		-2656,32

Appendix 3-E



Appendix 3-F

List of municipal characteristics researched:

- Province
- Population
- Population growth (2016-2021)
- Population density
- Gross added value growth per capita (2009-2019)
- Gross added value per capita
- Mean income
- % of built surface
- % of budget spent on spatial planning
- % of budget spent on public green
- % of budget spent on spatial planning and public green
- Ratio inhabitant/neighbourhood green
- Number of full-time equivalents at municipality
- VRIND-classes
- BELFIUS-classes
- Financial result
- Financial result per capita
- Mayor’s covenant (YES/NO)

Appendix 4. Supplementary materials Chapter 4

Appendix 4-A

Appendix 4-B

Question	Multiple choice options
What do you believe is the consensus within the scientific community on climate change?	a. Climate change is real and is caused by human activity. b. Climate change is real, but it is unsure whether it is caused by human activity. c. Climate change is not real. d. There is no consensus.
Which iconic goal was established in the 2015 Paris Agreement?	a. Reduce global temperatures by 0.5°C. b. Reduce global temperatures to the pre-industrial average temperature. c. Limiting the warming to no more than 1°C above the pre-industrial average temperature. d. Limiting the warming to no more than 2°C above the pre-industrial average temperature.
According to my understanding, the term "climate adaptation" encompasses the following	a. The prevention or mitigation of climate change by reducing greenhouse gas emissions. b. The adjustment of natural and human systems to the current and anticipated consequences of climate change.
I believe that the Flemish government aims to make public spaces climate-resilient by...	a. 2030 b. 2040 c. 2050

Appendix 5. Supplementary materials Chapter 5

Appendix 5-A

Nature Smart Cities Business Model step-by-step guidance document can be downloaded here.

Appendix 5-B

Nature Smart Cities Business Model technical manual can be downloaded here.

Appendix 5-C

Birds			**Butterflies**	**Bees**	**Amphibians**
Greenfinch (*chloris chloris*)	Jay (*Garrulus glandarius)*	Dunnock/Finch (*Prunella modularis)*	Peacock (*Aglais io)*	Tawny mining bee (*Andrena fulva)*	Common toad (*Bufo bufo*)
Wood pigeon (*Columba palumbus)*	Great tit (*Parus major)*	Collared dove (*Streptopelia decaocto)*	Brown sandpiper (*Maniola jurtina)*	Orange-tailed mining bee (*Andrena haemorrhoa)*	Alpine newt (*Ichthyosaura alpestris)*
Great spotted woodpecker (*Dendrocopos major)*	House sparrow (*Passer domesticus)*	Blackcap (*Sylvia atricapilla)*	Large skipper (*Ochlodes sylvanus)*	New garden bumblebee/tree bumblebee (*Bombus hortorum)*	Smooth newt (*Lissotriton vulgaris)*
Robin (*Erithacus rubecula)*	Chiffchaff (*Phylloscopus collybita)*	Wren (*Troglodytes troglodytes)*	Speckled wood (*Pararge aegeria)*	Ivy bee (*Colletes hederae)*	Green frog (*Pelophylax kl. esculentus)*
Common coot (*Fulica atra)*	Magpie (*Pica pica)*	Blackbird (*Turdus merula)*	Great cabbage white/small cabbage white (*Pieris rapae)*	European orchard bee (*Osmia cornuta)*	Common frog (*Rana temporaria)*
Moorhen (*Gallinula chloropus)*	Green woodpecker (*Picus viridis)*	Song thrush (*Turdus philomelos)*	Large skipper (*Polygonia c-album)*		

Appendix 5-D

Cultural ecosystem service	Reference
Physical and mental health	
Does this scenario provide an environment that help people relax and reduce stress? Does this scenario provide opportunities for people to socialise with neighbours? Does this scenario provide opportunities for volunteering and 'giving back'? Does this scenario encourage active outdoor exercise? Does this scenario reduce ambient noise, promote peace, quiet and tranquillity, and so contribute to people's mental health? Does this scenario provide space for sport and active play? Does this scenario provide green elements in a densely urban area? Does this scenario improve shading in the area to improve thermal comfort?	Nguyen, P.-Y., Astell-Burt, T., Rahimi-Ardabili, H., & Feng, X. (2021). Green Space Quality and Health: A Systematic Review. International Journal of Environmental Research and Public Health, 18(21), 11028. MDPI AG. Retrieved from http://dx.doi.org/10.3390/ijerph182111028 Martin, L. et al: 'Nature Contact, nature connectedness and associations with health, wellbeing and pro-environmental behaviours' J. of Environmental Psychology 68, April 2020 Coventry, P. A., Neale, C., Dyke, A., Pateman, R., & Cinderby, S. (2019). The Mental Health Benefits of Purposeful Activities in Public Green Spaces in Urban and Semi-Urban Neighbourhoods: A Mixed-Methods Pilot and Proof of Concept Study. International Journal of Environmental Research and Public Health, 16(15), 2712. MDPI AG. Retrieved from http://dx.doi.org/10.3390/ijerph16152712 Nasution, A. D., & Zahrah, W. (2014). Community perception on public open space and quality of life in Medan, Indonesia. Procedia-Social and Behavioral Sciences, 153, 585-594. Bloemsma, L. D., Wijga, A. H., Klompmaker, J. O., Hoek, G., Janssen, N. A., Lebret, E., ... & Gehring, U. (2022). Green space, air pollution, traffic noise and mental wellbeing throughout adolescence: Findings from the PIAMA study. Environment International, 163, 107197. Annerstedt, M., Östergren, PO., Björk, J. et al. Green qualities in the neighbourhood and mental health – results from a longitudinal cohort study in Southern Sweden. BMC Public Health 12, 337 (2012). https://doi.org/10.1186/1471-2458-12-337 Danielle F. Shanahan, Brenda B. Lin, Robert Bush, Kevin J. Gaston, Julie H. Dean, Elizabeth Barber, and Richard A. Fuller, 2015: Toward Improved Public Health Outcomes From Urban Nature
Social cohesion	
Does this scenario encourage people to spend more time in the public realm? Does this scenario offer opportunities for local people to meet and socialise, e.g. providing benches, spaces for picnics? Does this scenario increase opportunities to participate in community activities? Does this scenario provide space for activities and events to take place? Does this scenario make local residents likely to feel more happy/proud to live in the locality and therefore less likely to move away? Does this scenario help to reduce anti-social behaviour? Does this scenario contribute to a sense of place and visual identity?	Berger-Schmitt, R (2002). 'Considering Social Cohesion in Quality of Life Assessments: Concepts and Measurement', Social Indicators Research, 58(3), 403-428 Kearns, A and Forrest, R (2000). 'Social Cohesion and Multi-Cultural Urban Governance', Urban Studies, 37(5–6): 995–1017 Council of Europe (2001) Strategy for Social Cohesion Cheong, PH, Edwards, R, Goulbourne, H and Solomos, J (2007). 'Immigration, Social Cohesion and Social Capital: A Critical Review', Critical Social Policy, 27(1): 24–49. Jenson, J. (2010) Defining and Measuring Social Cohesion (Commonwealth Secretariat and UN Research Institute for Social Development) Zetter et al., (2006) Immigration, Social Cohesion and Social Capital: What are the Links?, (York: Joseph Rowntree Foundation)

Does this scenario support people, and/or groups of people, who are socially or economically marginalised? Does this scenario increase volunteering and informal support within the local community?	

Aesthetic appreciation

Does this scenario provide an aesthetically attractive place to live or work in? Do people value the area for its contribution to the local landscape or streetscape? Does this scenario make outdoor activities more enjoyable? Does this scenario include an attractive mix of different landscape elements? Does this scenario promote people's engagement with the natural world? Does this scenario create, or add to, a sense of place and visual identity? Do people enjoy spending time in and around this scenario area? Does this scenario contribute towards civic pride in the locality?	Brook, I. (2019) 'Aesthetic Appreciation of Landscape' Chapter 3 in Howard, P. et. al. (eds) 2019 The Routledge Companion to Landscape Studies 2nd edition, London: Routledge. Pp. 39-5 Tieskens, K. F. et al, (2018) 'Aesthetic appreciation of the cultural landscape through social media: An analysis of revealed preference in the Dutch river landscape' in Landscape and Urban Planning 177, p 128-137 Rolston, H. (1995) 'Does aesthetic appreciation of landscapes need to be science-based?' British Journal of Aesthetics, Vol. 35, No. 4, October,1995 Tribot, A.S et al (2018) 'Integrating the aesthetic value of landscapes and biological diversity' Proc. of the Royal Society B: Biological Sciences, Vol 285 issue 1886 Anne-Sophie Tribot, Julie Deter and Nicolas Mouquet. Integrating the aesthetic value of landscapes and biological diversity. Published:05 September 2018 Saito, Y. (1984) 'Is There a Correct Aesthetic Appreciation of Nature?' The Journal of Aesthetic Education Vol. 18, No. 4 pp. 35-46 Natural England (2009) Experiencing Landscapes: Capturing the cultural services and experiential qualities of landscape (Cheltenham: Natural England)

Education

Does this scenario include interpretation to help people understand its value? Does this scenario provide opportunities for engagement with nature? Does this scenario enhance people's understanding of ecology and landscape? Does this scenario provide opportunities to attract visits from schools and from other groups wanting to understand its value? Does this scenario raise awareness of climate change and actions to mitigate its effects? Does this scenario serve as an example that might inspire other municipalities? Does this scenario improve opportunities to volunteer and develop skills and capabilities?	Natural England (2009) Experiencing Landscapes: Capturing the cultural services and experiential qualities of landscape (Cheltenham: Natural England) IALE (2017) Landscape Education and Awareness Raising in the 21st Century (European Landscape Ecology Congress, Ghent, Sept 2017) Reason, P. (2007) Education for Ecology: Science, Aesthetics, Spirit and Ceremony Management Learning 38 (1) 27-44

Recreation, and Tourism by external visitors

RECREATION

Does this scenario provide a variety of opportunities for informal sport, play, and other physical activity? Does this scenario provide access to green space for local people? Does this scenario provide play and recreation opportunities for children and young people? Does this scenario promote participation in active physical exercise, for example walking, running, and other sports? Does this scenario promote equality of opportunity in play and recreation regardless of gender, ability/disability, and economic status? Does this scenario promote rest and relaxation? Does this scenario encourage people to spend more time outdoors?	Cortinovis, C., Zulian, G., & Geneletti, D. (2018). Assessing Nature-Based Recreation to Support Urban Green Infrastructure Planning in Trento (Italy). Land, 7(4), 112. MDPI AG. Retrieved from http://dx.doi.org/10.3390/land7040112 Nasution, A. D., & Zahrah, W. (2014). Community perception on public open space and quality of life in Medan, Indonesia. Procedia-Social and Behavioral Sciences, 153, 585-594. Mytton OT, Townsend N, Rutter H, Foster C. Green space and physical activity: an observational study using Health Survey for England data. Health Place. 2012 Sep;18(5):1034-41. doi: 10.1016/j.healthplace.2012.06.003. Epub 2012 Jun 17. PMID: 22795498; PMCID: PMC3444752. Annerstedt, M., Östergren, PO., Björk, J. et al. Green qualities in the neighbourhood and mental health – results from a longitudinal cohort study in Southern Sweden. BMC Public Health 12, 337 (2012). https://doi.org/10.1186/1471-2458-12-337 Martin, L. et al: 'Nature Contact, nature connectedness and associations with health, wellbeing and pro-environmental behaviours' J. of Environmental Psychology 68, April 2020

TOURISM by external visitors

Does this scenario improve the attraction of the area to non-local visitors? Does this scenario provide space for events such as festivals, fairs, and entertainments? Does this scenario promote additional employment in jobs supporting tourism and visitors? Does this scenario increase the likelihood of the area to be featured in local tourist guides to the city/region? Does this scenario enhance the environmental setting of a heritage or cultural asset? Does this scenario offer a range of attractions to visitors? Does this scenario have sustainable transport links to other areas popular with visitors? Does this scenario promote responsible, sustainable and universally accessible tourism, addressing the 2030 Sustainable Development Goals?	European Commission (2020): European Union Tourism Trends Visit Britain: 'Research and Insights: Analysis by destination type' at www. Visitbritain.org [accessed 22 Nov 2021] World Tourism Organisation: 'Join is on the 2030 Journey' at www. Unwto.org/tourism4sdgs [accessed 22 Nov 2021]. Font, X and McCabe, S;(2017) 'Sustainability and marketing in Tourism: its contexts, paradoxes, approaches, challenges and potential' in J. of Sustainable Tourism, 25, 869-883 Gregroy-Smith, D., et al (2017) 'An environmental social marketing intervention in cultural heritage tourism: a realist evaluation' in J. of Sustainable Tourism, 25 1042-1059.

Attractor for companies

Does this scenario improve the appeal of the area to businesses and encourage them to set up or relocate in this locality? Does this scenario improve the appeal of the area to potential customers for businesses operating in this area? Does this scenario provide an attractive environment for employees to work in?	Scottish Government (2017):Terms of Reference for Inward Investment Forum at Inward Investment Forum minutes: November 2017 - gov.scot (nrscotland.gov.uk) [Accessed 22 November 2021] Liverpool City Region (2020): Inward Investment Strategy (draft) at Inward Investment (merseytravel.gov.uk) [Accessed 22 November 2021] Invest Glasgow (2021): Greenprint for Investment at Cover - GLASGOW GREENPRINT FOR INVESTMENT (foleon.com) [Accessed 22 November 2021]

Does this scenario enhance the infrastructure that businesses need to operate more economically?

Does this scenario allow local businesses to adopt greener ways of working, to associate themselves with green ideas, or to deliver against environmental commitments?

Does this scenario increase business resilience and reduce the risk of climate-related loss or damage to businesses operating in the area?

Does this scenario reduce the carbon footprint of business, and/or mitigate any environmental damage created by business activity?