

## **Problems with Nature-Based Solutions: A literature review of the barriers to implementing nature-based solutions in urban areas**

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### **Abstract**

Nature-based solutions (NBS) are posited as an important option for increasing urban resilience as the world shifts away from unsustainable forms of development including the traditional, “grey” infrastructure that has dominated the traditional cityscape. NBS can help mitigate flood and heat risks, provide ecosystem services, and offer new or better green living spaces for humans and wildlife. As a relatively novel form of infrastructure, they face a much wider variety of barriers to implementation than grey infrastructure. This review addresses the question, “what are the key barriers to implementing nature-based solutions in urban areas?”. Thirteen key barriers were identified in the existing literature: lack of professional expertise and resources, lack of public knowledge, performance uncertainty, contextual uncertainty, fear of negative consequences, fear of operational unknowns, insufficient interactions between key players,

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structural silos, path dependency, temporal mismatches, spatial constraints, valuation, and financial constraints. The review found that there is a complex system of interrelated informational limitations and institutional factors that work against the potential implementation of NBS in urban areas.

**Key Words:** nature-based solutions, resilient urban infrastructure, natural infrastructure implementation, barriers to uptake

## **Résumé**

Les solutions fondées sur la nature (NBS) sont présentées comme une option importante pour accroître la résilience urbaine, à mesure que le monde s'éloigne des formes de développement non durables, notamment des infrastructures traditionnelles "grises" qui ont dominé le paysage urbain traditionnel. Les NBS peuvent contribuer à atténuer les risques d'inondation et de chaleur, fournir des services écosystémiques et offrir des espaces verts nouveaux ou améliorés pour les humains et la faune. En tant que forme d'infrastructure relativement nouvelle, elles sont confrontées à une variété d'obstacles à la mise en œuvre beaucoup plus grande que l'infrastructure grise. Cette étude répond à la question suivante : quels sont les principaux obstacles à la mise en œuvre de solutions fondées sur la nature dans les zones urbaines ? Treize obstacles majeurs ont été identifiés dans la littérature existante : le manque d'expertise et de ressources professionnelles, le manque de connaissances du public, l'incertitude des performances, l'incertitude contextuelle, la peur des conséquences négatives, la peur des inconnus opérationnels, les interactions insuffisantes entre les acteurs clés, les silos structurels, la dépendance au sentier, les inadéquations temporelles, les contraintes spatiales, l'évaluation et les contraintes financières. L'étude a révélé l'existence d'un système complexe de limitations informationnelles et de facteurs institutionnels interdépendants qui s'opposent à la mise en œuvre potentielle des NBS dans les zones urbaines.

**Mots clés:** solutions fondées sur la nature, infrastructures urbaines résilientes, mise en œuvre d'infrastructures naturelles, obstacles à l'adoption des solutions

## **1.0 Introduction**

With more than half of the world's population living in cities and continued rapid urbanization, promoting safety and comfort in cities worldwide is now more important than ever before (Sarabi et al., 2019). There is growing recognition of the fundamental dependence of human-made urban systems on natural ecosystems (Wamsler et al., 2020). Nature-based solutions are posited as an essential option for increasing urban resilience while the world shifts away from unsustainable forms of development such as conventional ('grey', frequently concrete-based) infrastructure that have dominated the traditional cityscape. Urban areas have unique spatial qualities which increase their risk of climate hazards, and growing urban populations mean that more people will be impacted by urban climate change factors (Voskamp et al., 2020; Sarabi et al., 2019).

In this context, nature-based solutions (NBS) are gaining traction. NBS can help mitigate flood and heat risks, provide ecosystem services, and offer new or better green living spaces for humans and wildlife (Brokking et al., 2021). They can include small-scale interventions, such as planting trees to increase shade (Coombes & Viles, 2021), up to regional frameworks for increasing ecological connectivity (Brokking et al., 2021). The European Commission defines NBS as "actions inspired by, supported by, or copied from nature and which aim to help society address a variety of environmental, social and economic challenges in sustainable ways" (Voskamp et al., 2020). They have gained popularity on the global stage only within the last two decades, mentioned by the World Bank for the first time in 2008 (Ramírez-Agudelo et al., 2020). Since then, major international institutions have championed the NBS concept, including the European Commission (EC) and International Union for Conservation of Nature (IUCN).

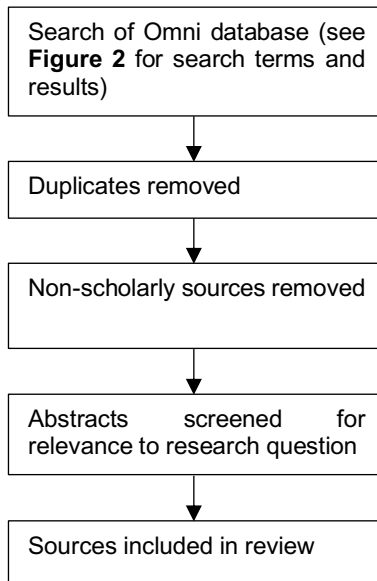
While NBS offer a valuable method of urban climate adaptation, as a relatively novel form of infrastructure, they face a much wider variety of barriers to implementation than traditional 'grey' infrastructure (Sarabi et al., 2019). A pivotal step to strategically overcoming such barriers is understanding them. This review establishes a broad overview of existing literature about the barriers to implementing NBS in urban areas by addressing the question, "what are the key barriers to implementing nature-based solutions in urban areas?"

## 2.0 Methodology

The scope of this review includes scholarly sources that directly address barriers to NBS implementation. Such sources may be directly focused on NBS implementation in specific urban areas, or may address overall patterns in NBS implementation. The review does not seek to address types of NBS, implementation methods or rationale for implementation, or enablers of NBS implementation.

This literature review was conducted using ‘Omni’, an academic search tool drawing on scholarly resources from 14 Ontario university libraries. Although the results from searching the selected database did not return adequate results to constitute a systematic review, PRISMA methods were applied where possible in the review process, resulting in a replicable and systematic method, outlined in Figure 1 (Page et al., 2021).

**Figure 1:** Overview of the Research Process



An initial search for all terms “nature-based solutions”, “barriers” (or challenges), “implementation” (or adoption) and “urban” in the title or subject fields yielded two results. Because there were relatively few academic publications accessible through Omni about all four topics concerning one another, subsequent searches included all combinations of two or three of the four terms, always including “nature-based solutions”. Figure 2 shows the total number of results yielded for each combination of search terms in the title and/or subject field.

**Figure 2:** Search Results from “Nature-Based Solutions” in Combination with Relevant Terms

Search Terms		Total Number of Search Terms	Number of Results
Nature-Based Solutions +	Urban, Implementation, Barrier	4	2
	Urban, Implementation	3	6
	Implementation, Barrier	3	6
	Urban, Barrier	3	21
	Implementation	2	16
	Barrier	2	46
	Urban	2	170

Newspaper articles, duplicates, and duplicates between searches were removed from the resultant sources. At this point, only scholarly articles and one book remained. The abstracts from the remaining sources were then reviewed to determine each one’s focus and relevance to the research question. Sources discussing NBS as a solution to urban or other challenges, sources discussing technical or physical aspects of particular NBS and sources that did not address the implementation, adoption, or barriers to implementing NBS in urban areas were excluded. The resultant list of sources included 12 articles and 1 book chapter.

To conduct the review, each source was scanned for the barriers to NBS implementation identified by the authors. Some

sources explicitly listed barriers while others presented them in use-case scenarios. All barriers identified within the reviewed sources were extracted to form a “master list” of 61 barriers. Finally, barriers from the master list were re-organized relative to one another based on similarities in their articulation to identify emergent themes. These themes were then assessed to identify broad “topic areas”, to which every barrier in the master list could be conceptually linked to at least one.

The topic areas are not all barriers themselves (though some are), but rather a method of grouping the barriers and articulating trends from the literature. This was done to note duplications, similarities, and interrelationships between them to allow key barriers to NBS implementation in urban areas to emerge. The resultant ten topic areas were used to recontextualize the original barriers identified in the literature in relation to one another, enabling the identification of a set of 13 key barriers to the implementation of NBS in urban areas.

### **3.0 Results**

#### *3.1 Timing and Geographic Distribution*

European university-affiliated researchers overwhelmingly authored the sources. In recent years, the dominance of European NBS research could be linked to the EC’s 2015 inclusion of NBS as a topic area for research grants (Ramírez-Agudelo et al., 2020). Only two articles reviewed were written or researched in non-European contexts, namely Nelson et al., 2020 (USA) and Qi et al., 2020 (China).

All sources except for two (Kabisch et al., 2016; and Droste et al., 2017, a chapter from *Nature-based solutions to climate change adaptation in urban areas*, lead-edited by N. Kabisch) were published between 2019 and 2021, indicating a growing scholarly interest in recent years. The recency of publications related specifically to barriers to implementation may also reflect an increasing body of NBS literature and an increasing number of real-world implemented projects available for analysis.

#### *3.2 Methods Used*

The sources reviewed mainly were based on secondary research and predominantly used scholarly publications, as well as publications and policy documents from governments and international institutions.

Literature reviews (Sarabi et al., 2019; Toxopeus & Polzin, 2021), critical reviews (Qi et al., 2020), and academic or argumentative analyses (Davies & Laforteza, 2019; Nelson et al., 2020) were common. Stakeholder workshops (Kabisch et al., 2016), focus group discussions (Brokking et al., 2021), stakeholder interviews (Voskamp et al., 2020), and expert consultations (Sarabi et al., 2020) were additional methods used as either the primary basis or supplements for discussion. Such workshops and interviews generally involved municipal officers/policy workers and some combination of policy workers or policymakers from other levels of government, subject matter experts, and well-informed members of society. They generally followed a similar mode of structured discussion as one another, described by Wamsler et al. (2020) as “applied participatory analysis” wherein participants contributed with both experiential data and meaning-making. Additionally, one paper (Sarabi et al., 2020) used Interpretive Structural Modeling to identify the relationship between the literature review and expert input-identified barriers to NBS implementation.

### *3.3 Aims and Theoretical Frameworks*

The sources reviewed can be generally classified into one of two categories concerning the research question: first, research about NBS barriers in general; and second, research about a type of particular barrier (e.g. financial) or implementation context (e.g. Chinese “Sponge Cities”).

The aims of the studies in the first category are generally similar. Kabisch et al. (2016) sought to identify contexts and indicators of potential NBS effectiveness in urban areas and examined existing barriers to NBS implementation. Sarabi et al. sought to understand the “taxonomy of dominant barriers to the uptake and implementation of NBS” (2020) after identifying key NBS implementation enablers and barriers through a systematic literature review (2019). Similarly, Nelson et al. (2020) aimed to identify “the challenges and emerging responses to advance the science and practice of NBS”.

These studies also sought to establish their own framework for the theoretical analysis of NBS. Each offers its own set of NBS implementation barriers or classification system for barriers identified by other authors, despite the significant overlap between some barriers identified. In particular, barriers identified by Kabisch et al.

(2016) are cited frequently among both categories of sources reviewed.

The second category encompasses a broader variety of goals and research questions. Most commonly, sources look at particular facets of municipal NBS uptake, and barriers to implementation are identified and discussed from that scenario (Voskamp et al., 2020; Wamsler et al., 2020). A 'lessons learned' lens is also sometimes applied, based on NBS implementation in particular regions (Brokking et al., 2021), for a particular purpose (Ramírez-Agudelo et al., 2020), or both (Qi et al., 2020). Finally, studies also address specific barriers and situations in-depth, such as financing NBS (Droste et al., 2017; Toxopeus & Polzin, 2021), the 'path dependence' barrier (Davies & Laforteza, 2019, defined as "a concept where active memory conditioned by past decisions has a controlling influence on decision making" [p. 406]), and using NBS on heritage sites (Coombes & Viles, 2021). Five of the studies explicitly utilize the EC definition of NBS.

The theoretical frameworks used in the literature reviewed are generally qualitative and not theory-driven. Rather, the sources selected generally ask about the political and socio-economic nature of NBS implementation and seek to answer their research questions through qualitative means (except for Sarabi et al., 2020). Depending on the research question, it was also common for authors to offer a set of recommendations or even develop their own framework for NBS implementation.

#### **4.0 Topic Areas of Key Barriers**

Although each source identified a unique set of barriers to implementing NBS in urban areas, common barriers emerge throughout the literature reviewed. These barriers were rarely identically articulated, but all fit within one or more of ten interrelated topic areas. Readers may note that as more topic areas are introduced, more interrelationships between new and previously introduced topics and barriers arise. A graphic representation of the primary and secondary relationships between the topic areas and barriers discussed is included (Figure 3) to demonstrate their complex and interrelated nature.



**Figure 3:** Primary and Contributing Relationships between Topic Areas (left) and Key Barriers (right)



#### 4.1 Lack of Knowledge

Barriers related to a lack of knowledge have to do in part with the relative recency of NBS as a concept. The first key knowledge barrier is ‘lack of professional expertise and resources’. Key players lack the technical and multi-sectoral expertise needed to design and implement NBS in municipal planning (this linked to the ‘silos’ barrier discussed in section 4.5, whereby differences in departmental or sectoral knowledge and priorities traps actors and knowledge in their silos) (Wamsler et al., 2020). There are presently very few NBS-forward design standards and maintenance guidelines for municipalities to rely upon for the challenges to their particular contexts (Sarabi et al., 2020). There are also few NBS training programmes, particularly the level of training available for grey infrastructure (Davies & Laforteza, 2019). These all contribute to a “lack of expertise, know-how, or competence” among professionals (Voskamp et al., 2020, p.

9). This knowledge gap filters down to the public, members of which are not exposed to NBS and therefore do not learn about them (Voskamp et al., 2020). Thus, the second key barrier is 'lack of knowledge within members of the public'. NBS frequently goes unrecognized as an emerging concept because there is general cultural unawareness of NBS and overall public apathy (Coombes & Viles, 2021).

#### *4.2 Uncertainty*

In Sarabi et al.'s (2019) literature review, the most frequently mentioned barrier to successful NBS implementation and uptake was "uncertainty regarding implementation processes and effectiveness of the solutions". It was referenced by 18 papers, doubling the next-most referenced barrier, "inadequate financial resources".

The first key barrier related to uncertainty is 'performance uncertainty': whether or not the NBS will achieve the desired aims. Accordingly, Sarabi et al.'s 2020 paper analyzing interrelationships between barriers identifies functionality and performance uncertainties as one only of four "driving barriers". The existence of functionality and performance uncertainties has a significant impact on triggering other barriers but is dependent on few other barriers itself (Sarabi et al. 2020). Since NBS is a form of long-term infrastructure but is still a relatively new concept, uncertainty regarding its efficacy, risks, and consequences serves to favour existing infrastructure methods (Ramírez-Agudelo et al., 2020). This barrier is also related to the 'lack of professional expertise and resources' barrier.

The second key uncertainty barrier is 'contextual uncertainty'. For instance, climate change-driven weather patterns and extreme events render climatic predictions unreliable, thus inhibiting the development of overarching NBS implementation guidelines, further reinforcing the 'lack of professional expertise and resources/public knowledge' barriers (Qi et al., 2020). Additionally, NBS might reach their full potential through wider-scale implementation. Although NBS could nurture significant ecosystem services and restore fragmentation, the connectivity-enhancing potential of NBS remains formally unproven (Brokking et al., 2021).

### 4.3 Fear

While unconventional approaches like NBS can trigger excitement, they can also induce fear. As such, ‘fear of negative consequences’ is the first key barrier in this topic. For instance, Coombes and Viles’ (2021) analysis of how NBS can be used to support urban built heritage discusses the perception of “nature as a threat” as a barrier to implementation. In the context of urban built heritage, preserving existing conditions and avoiding change is idealized (Coombes & Viles, 2021). Thus, there is significant fear among heritage conservationists of material damage from biodeterioration, loss of heritage values from changed aesthetic, and altered conservation practices from new types of upkeep (Coombes & Viles, 2021). Ramírez-Agudelo et al. (2020) expand, pointing to how NBS implementation might lead to ecosystem *disservices* such as drowning risk areas or increased mosquito population, further contributing to public nervousness (also related to section 4.4 ‘participation’).

Fear as a topic area for barriers to NBS implementation is thus deeply intertwined with both knowledge barriers and uncertainty barriers and plays an NBS-averse role in participation. ‘Fear of operational unknowns’ is the second key fear barrier. “Fear of the unknowns”, as explained by Kabisch et al. (2016), further integrates fear with post-implementation risks such as the ‘operational unknown’ of new maintenance procedures (similar to Coombes & Viles’ altered upkeep issue) as well as confidence in its effectiveness. The long time between implementation and results contributing to this barrier is reflected in the ‘temporal mismatch’ barrier discussed in sections 4.7 and 4.8.

### 4.4 Participation (Stakeholder and Public)

Both ‘lack of knowledge’ barriers are pertinent for stakeholder and public participation. The various factors fundamental to social sustainability and the cross-sectoral nature of NBS necessitate robust stakeholder and participation in NBS implementation (Nelson et al., 2020). But participation and equity among stakeholders has proved challenging due to limited understanding, fear, and unequal relations (Nelson et al., 2020). In some cases, the public view of NBS implementation has generally been fearful (Coombes & Viles, 2021) and in others, it has been downright counterproductive (Wamsler et al., 2020) due in part to lack of awareness, interest, and support

(Sarabi et al., 2020). On the other hand, NBS implementation has also been linked to gentrification, displacement, and social justice issues, demonstrating why meaningful input from a well-informed public is imperative for NBS implementation (Ramírez-Agudelo et al., 2020; see also Townsend et al., 2020).

The third key participation barrier is ‘insufficient interaction between relevant players’. Even though NBS implementation requires participation from a wide variety of stakeholders, they tend not to interact even internally within organizations (Ramírez-Agudelo et al., 2020; see also sections 4.5 and 4.10). This compromises public perceptions and the social dynamics that influence NBS uptake (Ramírez-Agudelo et al., 2020).

#### *4.5 Silos*

NBS are complex, cross-sectoral systems, so “silos” issues act as a significant barrier to NBS implementation. Classified under several names (“sectoral silos” by oft-cited Kabisch et al., 2016; “silo structure” in Wamsler et al., 2020; “institutional fragmentation” and “silo mentality” by Sarabi et al., 2019 and 2020, respectively), the first silo topic barrier is ‘structural silos’. This barrier prevents the effective collaboration between departments, sectors, and institutions needed for smooth NBS implementation due to actors being ‘siloed’ and kept away from one another (Sarabi et al., 2020). Knowledge becomes intra-departmentally trapped even within offices, and sector- or department-specific decision-making structures are subject to these ‘structural silos’, allowing the package of merits NBS can offer to be easily overlooked (Kabisch et al., 2016). Prescriptive departmental mandates and structures thus contribute to the failure to recognize overarching NBS benefits or properly ascribe ownership or financial stability to projects (thereby linking this barrier to those within the ‘path dependence’, ‘valuation’, and ‘finance’ topic areas) (Sarabi et al., 2019).

‘Insufficient interaction between relevant players’ is the second key barrier in the ‘silos’ topic. Collaborative governance and planning discussed in the preceding section is identified as a cornerstone for NBS implementation (Voskamp et al., 2021). However, it is impaired by silos that prevent the interaction needed for successful NBS implementation progress (Voskamp et al., 2021). The ‘silos’ topic area and barriers can also act as barriers to various public initiatives

beyond NBS implementation, mainly through financial constraints and pre-determined budgetary spending (Droste et al., 2017).

#### *4.6 Path Dependence*

'Path dependence' is, according to Davies and Laforteza (2019), the most critical barrier to NBS uptake. This key barrier refers to decision-making being confined to the basis of past decisions, and this dependence contributes to resistance to change (Sarabi et al., 2019). NBS are not 'normal' solutions that decision-makers are accustomed to (Davies & Laforteza, 2019), whereas the path to implementing grey infrastructure is well-trodden and appealing to risk-averse individuals, including planners and municipal officers, and policy makers (Sarabi et al., 2020). These points are related to 'lack of professional expertise and resources', 'fear of negative consequences', and 'fear of operational unknowns'.

'Path dependence' is also related to issues of infrastructure integration, which are a reflection of the 'contextual uncertainty' barrier. NBS would benefit from being considered together with conventional infrastructure to address problems and reduce urban risk factors but are considered a separate entity (Nelson et al., 2020). Therefore, NBS are not given a comparable budgetary allowance to grey infrastructure and are not worked into existing infrastructural systems. For example, in Chinese "Sponge Cities" the small-scale NBS implemented were unable to form an integrated flood management system but had not been fully integrated with existing engineered assets, which likely would have improved performance (Qi et al., 2020).

Additionally, 'path dependence' is linked to the "paradigm of growth", identified by Kabisch et al. (2016) in which urban development prioritizes the expansion of built-up areas and infrastructure. The purpose of investments is to facilitate economic growth, to the detriment of green spaces, NBS, and their budgets (Kabisch et al., 2016). This contributes to the 'financial constraints' and 'valuation' barriers discussed later.

#### *4.7 Policy*

Policy, especially at the municipal level, is extremely important to the implementation of NBS in urban areas. Lack of political will, lack of long-term commitment, and lack of sense of

urgency among policymakers have been identified as having the strongest impact on all other barriers, independent of other barriers' impact on them (Sarabi et al., 2020).

'Temporal mismatch' is the first key barrier within the policy topic area. Elected representatives are motivated by projects with high-impact outcomes in the short term, and NBS's long-term and uncertain performance undermines political will, particularly in contexts involving competing interests (Sarabi et al., 2020; Nelson et al., 2020). Like many other sustainability issues, the risk perception of the issues that NBS aims to solve are inaccurate while creating a harmful sense of security (Sarabi et al., 2020).

'Lack of professional expertise and resources' and 'path dependence' are also key barriers related to policy. Politicians and government officials have little pre-existing knowledge regarding NBS, but also need to be convinced that it is a wise, and urgently needed investment (Voskamp et al., 2020). Conversely, government workers who would theoretically support NBS such as unelected municipal officers or planners do not have the regulatory means or budgetary autonomy to force their implementation in new developments (Brokking et al., 2021; Droste et al., 2017). Here too, the 'insufficient interactions between relevant players' barrier works against NBS implementation in urban areas.

When NBS implementation is conducted at the municipal scale, there is a lack of top-down guidance towards implementation (Wamsler et al., 2020), including a lack of supportive policy and legal frameworks (Sarabi et al., 2020). Per the 'path dependence' barrier, present regulations in many municipalities are developed with conventional infrastructure in mind (Sarabi et al., 2019). Finally, the existing regulations that would most support NBS implementation do not form complete frameworks and may be scattered among many policies and structural silos (Nelson et al., 2020).

#### *4.8 Spatial and Temporal Constraints*

'Spatial constraints' is a key barrier that refers to the problem of not having appropriate places to implement NBS in urban areas (Sarabi et al., 2020). NBS requires more land to deliver results than conventional infrastructure and particularly in urban contexts, land is limited (Sarabi et al., 2019). Where appropriate places do exist, property ownership complexities can arise, as municipalities have little

influence over privately owned land (Wamsler et al., 2020). Landowners may be more interested in private gain from the use of their land (Sarabi et al., 2020).

'Temporal mismatches' is the second key barrier within this topic area. These tie into the path dependence in institutional settings. Administrative cycles are far quicker than the NBS life cycle, described as a "disconnect between short-term actions and long-term goals" (Kabisch et al., 2016). The long-term planning required for consistent funding, maintenance and monitoring of NBS is frequently not undertaken or not upheld between administrations (Sarabi et al., 2020). Evaluation timeframes are also not well-suited to NBS, which support the implementation of short-term projects over NBS with long-term impacts (Nelson et al., 2020). Temporal constraints in the context of barriers to NBS implementation are complex and wide-ranging.

#### *4.9 Valuation*

The first key barrier within this topic is 'valuation' itself. The exact benefits and costs of NBS are estimated with significant uncertainty, leading to difficulties with the economic valuation and pre-implementation cost-benefit analysis (Nelson et al., 2020). The numerous (and sometimes unexpected) functions of NBS are not lent well to the dominant valuation and accounting methods (Toxopeus & Polzin, 2021). Moreover, since the benefits of NBS are accrued over the long term, current economic valuation methods undervalue the long-term benefits NBS offer (see additional source Hanley, 2013). These benefits are particularly undervalued relative to upfront costs, and undervaluation contributes to the spatial and financial constraints barriers (Nelson et al., 2020). Thus, the 'temporal mismatches' barrier plays a key role here, too. While the many benefits of NBS are perceived to be less valuable due to long time horizons for delivery, the upfront costs are high. 'Valuation' and 'temporal mismatches' thus act in sync as significant barriers to NBS implementation for both private owners and public institutions (Sarabi et al., 2020).

#### *4.10 Finance*

There are significant limitations associated with NBS's financeability (Voskamp et al., 2021). Thus, 'financial constraints' is the first key financial barrier. Financing NBS from existing resources is very difficult and intertwined with many other barriers to NBS implementation and issues within municipal budgets (Sarabi et al.,

2019). For one, the structure and purpose of municipal budgets are subject to the 'path dependence' barrier and are generally unsupportive of funding NBS and other unconventional infrastructure and there is little spending autonomy (Droste et al., 2017). Alternatively, if upfront investment is to come from external sources, the financial resources required for maintaining novel approaches in municipal budgets may be insufficient, discouraging initial investment (Qi et al., 2020; see also Thorn et al., 2021).

'Lack of knowledge within members of the public', 'lack of professional expertise and resources', and 'valuation' also form secondary barriers within this topic area. Due to few incentives, financial or otherwise, to encourage private actors to partake in NBS implementation, who already view initiatives like NBS as a municipal government's responsibility (Sarabi et al., 2020).

When private financiers partake in financing NBS implementation, structural silos also arise as a barrier. In these cases, coordination and collaboration between public and private financiers becomes challenging, and the 'insufficient interactions between key players' barrier also comes into play (Toxopeus & Polzin, 2021). Moreover, privatized infrastructure can also result in higher costs and operational difficulties (Toxopeus & Polzin, 2021). Even within government, NBS's many benefits can fall through the cracks between silos, making it unattractive for any single department even if it is a good investment in its own right (Droste et al., 2017).

## **5.0 Discussion and Concluding Remarks**

### *5.1 Discussion of Key Barriers and Interrelationships*

Thirteen key barriers arose from the ten initial topic areas: lack of professional expertise and resources, lack of knowledge among members of the public, performance uncertainty, contextual uncertainty, fear of negative consequences, fear of operational unknowns, insufficient interaction between relevant players, structural silos, path dependence, temporal mismatches, spatial constraints, valuation, and financial constraints. No barrier was referenced by less than two topic areas, and some topic areas were relevant to almost all barriers.

Despite each identified barrier's direct relevance to the research question, it is important to note that these barriers are



relatively arbitrary. Some barriers could be combined, while others could be expanded into two or more. The exact issues that work as barriers to particular projects are context-dependent. Some will prove to be far more important than others. But overall, there is a complex system of interrelated informational limitations and institutional factors that work against the implementation of NBS in urban areas.

## *5.2 Limitations and Research Gaps*

This literature review was subject to several limitations. First, the scope of the research did not include historical background on NBS, technical concerns, or issues with barriers to implementing in non-urban contexts or particular urban contexts. Moreover, the scope did not include related concepts. The search terms used excluded research on such concepts, which could have offered alternative barriers or perspectives on the implementation challenges of specific NBS in cities, and also excluded synonymous words like “uptake” which could have limited the search results. Terms like “green infrastructure”, “low-impact development” and “natural climate solutions” could have been included to identify additional technical and socio-economic barriers or add additional nuance to the barriers identified. Additionally, only one database of sources was used to identify sources, which may have limited results. Finally, this review does not consider alternative paradigms to NBS currently under investigation as a result of the limited research scope. This may have limited results pertaining to barriers to implementation of NBS aimed at harnessing certain co-benefits, such as human well-being factors, such as physical and mental health benefits.

Despite the acknowledged limitations, patterns in the literature reviewed reveal several research gaps. Firstly, the existent literature on NBS is highly Eurocentric. Authors sometimes address the applicability of their work to other concepts (e.g. Droste et al., 2017 state, “[with] respect to concrete legal provisions, we refer to the case of Germany. However, similar public finance restrictions can be found in many other developed countries.”), but the body of literature is dominated by European perspectives and precedents. However, different regions experience other challenges and barriers. One article (not included in this review because it did not address NBS implementation) was based on case studies in Sub-Saharan African peri-urban areas and identified financial barriers as the most important problem for mainstreaming NBS (Thorn et al., 2021). However, the structure and issues of municipal finance in the case study cities of

Windhoek and Dar es Salaam are vastly different from those described by Droste et al.

Another research gap includes the social justice issues with NBS touched on briefly by Ramírez-Agudelo et al (2020). Their references for this point are focused on NBS post-implementation. However, more research could be done on how social justice issues prevent the implementation of NBS in the first place, and how such issues can be pre-empted. Similarly, the literature reviewed referred to extensive background work regarding political and economically driven barriers to NBS implementation, but less information exists with regards to social issues. The literature also did not incorporate either equity or gender-based analysis lenses.

For example, in Canada there are substantial (and well-founded) concerns of NBS becoming a perpetrator or new form of carbon colonialism (Indigenous Climate Action, 2021) and yet significant barriers to the involvement of Indigenous communities in NBS planning also exist (Townsend et al., 2020). Although Ramírez-Agudelo et al., state “NBS is considered to be a ‘European’ concept” (2020), land stewardship based on traditional knowledge has been undertaken by Indigenous Peoples for centuries (Nelson et al., 2020). Seeing as physical infrastructure within cities can contribute significantly to social justice and injustices such as environmental racism and gentrification (Ramírez-Agudelo et al., 2020), more work can be done on making NBS implementation a positive solution for all communities.

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