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Practitioner Perceptions of Mainstreaming Sustainable Drainage Systems (SuDS): A Mixed Methods Study Exploring Direct Versus Indirect Barriers

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Abstract: Sustainable drainage systems (SuDS) represent an opportunity to use stormwater management as a mechanism to deliver multiple co-benefits. They can play a key role in urban climate change adaptation, restoring nature, and increasing health and social wellbeing. Despite these benefits, their uptake is limited with many practitioners reporting barriers to implementation. To explore these barriers, and to define actions to unlock scaling, our mixed-methods study explored comparative perceptions of SuDS practitioners within the UK. Survey research (n = 48) provided an overview of broad experiences across a range of SuDS practitioners. Main barriers described were access to funds, difficulty retrofitting, cost to maintain, and the ownership of SuDS. Main issues having the least available information to support SuDS scaling were conflicts with corporate identity, cost to maintain, and collaboration between various stakeholders. Follow-up interviews (n = 6) explored experiences among a contrasting subset of survey respondents: those who experienced the highest number of perceived barriers and those who experienced the fewest barriers to SuDS implementation. From these interviews, key themes were identified that categorized the barriers for SuDS implementations: people-related elements; limiting practicalities; and informational factors. The findings were differentiated between indirect barriers (i.e., soft barriers, such as individual practitioner knowledge and capacity gaps linked to poor knowledge exchange) and direct barriers (i.e., hard barriers including specific gaps in SuDS data and knowledge experienced more universally). The importance of differentiating between knowledge-based (indirect) barriers that can be unlocked by improved information-transfer solutions and actual (direct) barriers that need further considered approaches and the generation of new knowledge to overcome is highlighted. Evidence-based policy recommendations for governmental and SuDS-based organisations are presented.

Keywords: sustainable drainage systems (SuDS); urban water management; blue/green infrastructure; climate change adaptation; practitioner engagement; nature-based solutions (NBSs); barriers

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1. Introduction

1.1. Problem and Need

The most recent IPCC climate change report highlights that human-induced climate change has led to more frequent and intense extreme events, consequences of which include

severe impacts to nature and people [1]. Globally, average precipitation has increased in more locations than decreased [1]. Using the UK Climate Projections (UKCP), the Met Office Hadley Centre predicts that in the UK, by 2070 (compared to 1990), winters will be between 1 and 4.5 °C warmer and up to 20–30% wetter [2–4]. Furthermore, it is projected that the intensity of rain will increase by up to 25% in the winter and up to 20% in the summer [4–6].

The impacts of flooding are increasing in the UK, impacting health and wellbeing, and causing infrastructure and economic damage [6,7]. Losses from the winter 2019 to 2020 flooding were estimated to be about £333 million [7]. To reduce these impacts, investment is needed in stormwater management systems to cope with the increasing demand [8]. The traditional approach to addressing urban stormwater management was the creation of larger flood protection infrastructure and increasing capacity in storm drain systems [9], known as grey infrastructure solutions. However, with increasing population density [10] and the frequency of extreme rainfall events [2–4], grey infrastructure solutions can rapidly become overloaded to such an extent that they either fail completely (causing local flooding) or overload systems leading to the release of combined stormwater and raw sewage into local rivers [11]. In urban areas, where natural landscapes have largely been replaced with hard impermeable surfaces, the pressures on these grey infrastructure systems can be reduced by replicating natural catchment processes that slow flows and reduce flow volumes [12]. In recent years, natural catchment mimicry approaches to urban stormwater management have developed globally following a variety of methodologies including: Sustainable Drainage Systems (SuDS), Water Sensitive Urban Design (WSUD), and Sponge Cities [5,13–16]. Natural catchment mimicry approaches can include purely engineering solutions such as rainwater harvesting and storage tanks with flow controls, which are focused on a single, or very narrow range of targeted benefits [16]. They can also include blue-green infrastructure (BGI) approaches that have the co-benefits of bringing greenspace and nature back into urban areas [17,18]. Such re-naturing approaches have been recognised as critical to enhancing the resilience of urban systems [19]. When delivered in a way that restores and enhances biodiversity, provides a range of diverse environmental, social, and economic benefits, and is co-created with local stakeholders to deliver specific outcomes, this concept moves beyond the basics of BGI to represent nature-based solutions (NBS) to societal challenges [20–23]. Applying such a solutions-based, and multifunctional benefits delivery approach to natural catchment mimicry represents a strong economic argument for bringing nature back into cities [24]. Nevertheless, such approaches remain in their infancy compared to their potential [25].

1.2. Sustainable Drainage Systems (SuDS)

In the UK, the predominant emerging approach to stormwater management is sustainable drainage systems (SuDS) [12]. The additionality of SuDS in terms of providing a more sustainable solution to manage stormwater and excess surface water than traditional water management approaches including providing multiple co-benefits [16,26,27], has also led to SuDS emerging as a leading stormwater management approach globally [28]. SuDS typically includes a range of different solutions (from nature-inspired to nature-based) in combination as a management train that delivers stormwater management benefits in areas of flood risk, and in areas where pressure on existing storm management systems needs to be reduced [16].

In addition to water management, SuDS co-benefits have been reported as including the following: conserving and restoring biodiversity [29,30], improving water quality [31], and urban cooling [32,33]. There is also evidence that SuDS components such as green roofs and walls can reduce air pollution [34] as well as noise pollution [35]. Adopting such

approaches plays a key role in addressing sustainable development challenges, through adapting against the negative impacts of climate change [22,25].

Beyond the environmental sustainability benefits, SuDS also represent a pathway for driving positive social and economic change [36], for example, by increasing connectedness and sense of community [36,37], reducing fear of crime [38], and improving health and mental wellbeing [39]. Economic benefits can result through direct and associated costs savings made as a result of SuDS rainwater management compared to other methods [7]. There is also evidence that, if designed appropriately, green infrastructure SuDS can increase property prices [40], particularly if properties are close to green spaces [41], and play a role in working towards a green economy by diversifying income, providing jobs relating to green skills, and supporting deprived communities while also being environmentally resourceful [42,43].

1.3. Reported Barriers to SuDS Roll out

SuDS, and particularly NBS approaches to SuDS, share a common methodological origin with other concepts that promote the maintenance, enhancement, and restoration of biodiversity to deliver multifunctional benefits [44]. As such, they also share many of the challenges in relation to the complexity of mainstreaming them into planning and practice. This means that the implementation and mainstreaming of SuDS is limited despite an increasing evidence-base emerging on the potential multifunctional benefits of BGI and NBS approaches to climate adaptation in urban areas [45–49]. Several studies have explored the reasons for this with a range of different barriers identified [50]. For example, the role of public perceptions and public acceptability of SuDS can be an influencing factor in the likelihood of uptake [51–55]. Public awareness and understanding around the purpose and function, plant choice and maintenance, and mess and littering are all challenges that can play a role in residents' acceptance of NBS, including SuDS [51,55]. Urban governance has been shown to be important in public perceptions of BGI investment [53]. A correlation between the performance of practices associated with urban BGI for flood management and attitudes towards its stewardship has also been identified [56].

Beyond public perceptions and the public acceptability of urban BGI and NBS approaches, a number of complexities and issues have been reported as hindering the growth of SuDS. This includes issues around economics, legalities, policy, and logistics [45,57–59]. Early work into barriers to SuDS [60] categorised barriers within various stages of the SuDS implementation processes: pre-application, consultation, decision, and appeal stages. More recently, Deely et al. [61] conducted an extensive literature review and presented five categories of barriers: institutional and governance, socio-cultural, knowledge, technical and biophysical, and funding and markets. Whilst this provides a useful framework for exploring SuDS barriers, it does not reveal the impeding factors within the SuDS implementation processes.

More details on some of the challenges faced by stakeholders and practitioners have been presented. A large-scale survey among Australian urban water practitioners explored the premise that risk perceptions can hinder engagement with alternative water systems (e.g., stormwater harvesting systems), with factors such as age and years' experience in the industry influencing risk perceptions [62]. Qualitative research among researchers and practitioners also from Australia suggests that definitions and clear frameworks and managing expectations may be useful in uptake and implementation [63]. Further recent research from Australia highlights six main challenges including finances, innovation and evaluation tools, capacity, institutional arrangements, and policy [64].

Due to the multidisciplinary approach needed for SuDS implementation, achieving buy-in from multiple stakeholders can itself create a challenge [65]. Stakeholders can

also be a critical factor in both creating and unlocking SuDS upscaling. Understanding perspectives of key stakeholders can help better understand some of the barriers and enablers faced by these actors [66]. For example, while stakeholders can see challenges associated with urban BGI and NBS (such as installation, financial, biophysical, and socio-political), they also perceive the benefits (such as managing stormwater, climate change adaption, and increased social wellbeing) [28]. A UK case study involving a variety of stakeholders (local authority, university, and the Environment Agency (the Environment Agency is responsible for taking a strategic overview of the management of all sources of flooding and coastal erosion (UK Government n.d))) reported that maintenance issues were perceived as challenges to the growth of SuDS [65]. This finding is echoed by case study work indicating that maintenance and stewardship are key components to the successful longevity of NBS [47]. SuDS are typically bespoke, and generic approaches are not always suitable for individual localities, presenting further challenges in their implementation and delivery [67].

Institutional factors can constrain the implementation of SuDS, namely the lack of legislation, the power of private commercial interests, and the lack of resources in local authorities [67]. Institutional readiness factors can also be limiting; these include strategic goals and institutional fragmentation [59], and prioritization [68] to adopt and upscale BGI and NBS approaches for water management. Dorst et al. [45] identified three structural conditions within that contribute to barriers to urban NBS; they are grouped into regulatory, financial, and urban development domains. Attempts have also been made to nuance barriers by adding a human dimension into their conceptualization, including attitudinal barriers (e.g., emotions and beliefs) and contextual barriers (e.g., legal and political aspects) [69].

1.4. The Nuance of Actual Barriers Versus Knowledge Barriers

In addition to the *actual direct barriers* presented in the previous section, research has shown that while key actors and stakeholders do show interest in NBS/BGI adoption, including its use in SuDS, *lack of knowledge* can play a role in preventing uptake [25]; knowledge gaps can include the lack of information on costs (including construction and maintenance), lack of examples and demonstrations, and lack of a framework, as well as a lack of financial incentives to support private people and organisations, and a lack of knowledge on construction and maintenance costs [70]. The lack of knowledge can present in two distinct ways: actual knowledge lacking across the sector related to specific aspects of SuDS implementation, or knowledge that has been generated, but remains inaccessible to specific individuals within the sector. These knowledge gaps can potentially present themselves as *indirect barriers* to the uptake of alternatives to grey infrastructure solutions [44,45,65]. For example, achieving much-needed stakeholder buy-in can be undermined by a lack of access to evidence and monitoring of implemented SuDS [65].

Workshop research by Kabisch et al. [44] among NBS-related experts identified four main NBS knowledge gaps. These related to (i) the effectiveness of NBS (particularly limited in cities); (ii) relationship between NBS and society (such as place and human–nature interactions impacts); (iii) the design of NBS (such as how NBS can integrate with grey infrastructure); and (iv) implementation aspects (such as administrative tools for implementing NBS). Elements of these knowledge gaps are echoed in various research studies. For example, Cotterill and Bracken [65] argue that there is a lack of accurate performance data, indicating logistical constraints of installing sensors as the reason. More recently, there has been a call for more information communication around the broader benefits of NBS, specifically the non-tangible benefits of NBS (such as increased recreation and well-being), common framing, and communications [68].

Dorst et al. [45] provides further insights into *knowledge gaps as challenges* within urban NBS, including NBS approaches to SuDS mainstreaming, suggesting that a lack of knowledge around policy goals related to the potential of urban NBS (e.g., climate change mitigation, economic, and biodiversity benefits) and also a lack of knowledge and knowledge exchange on NBS performance (e.g., technical knowledge evidence of benefits) are barriers.

Following a systematic literature review and quantitative content analysis, the top barrier for NBS implementation was a lack of expertise and knowledge, with the second ranked barrier being a lack of evidence on performance and co-benefits [71]. This was in contrast to the comparison with 'grey' solutions implementation (ranked tenth and eleventh, respectively) [71]. These findings suggested that information and knowledge gaps need addressing to facilitate the mainstreaming of NBS approaches to the level of traditional 'grey' approaches to water management.

Whilst there are numerous studies highlighting barriers associated with climate change adaption implementation, some of them are conflicting [50]; they tend to be descriptive and lack detail and explanation around what causes these barriers [50]. NBS barriers can be interdependent and, to address the complexity of the barriers that exist, it is important to acknowledge the interdependencies of challenges [50,72]. A deep understanding of the underlying factors of barriers can help to reduce or remove them, and taking an actor-centred research and comparative approach is needed to better understand these underlying barriers [50]. Such an actor and comparative approach allows for diverse and similar barriers to be explored from different actor perspectives (e.g., those experiencing/managing barriers, including those experiencing common barriers very differently).

1.5. The Present Study

While previous research offers overviews of barriers to the mainstreaming of SuDS and urban NBS, they lack depth and nuance exploring the contrast between practitioners who perceive lots of barriers, and those that do not. This study adopted a mixed-methods approach to explore the juxtaposition between direct and indirect barriers from a practitioner perspective. A survey was used to identify practitioners who perceive high barriers and high gaps in knowledge and, by contrast, those that perceived low barriers and low gaps in knowledge. A subset of survey respondents with contrasting responses was then interviewed to better understand the varied nuances in perceived barriers to SuDS mainstreaming between those perceiving few and those perceiving many. The overall aim of the study was to identify, explore, and differentiate the nuanced barriers experienced when delivering and mainstreaming SuDS. Specifically, differentiating between barriers linked to a lack of access to existing knowledge for certain individuals, and actual barriers faced more universally by SuDS practitioners.

The following sections outline the present study, which formed part of a city-wide small-scale SuDS pilot implementation project scaled-out across London, UK. Section 2 presents the results of analysis from Phase 1, an online survey among practitioners who were all professionals within the discipline. Section 3 presents the results of the key analysis of Phase 2 of the research, which was qualitative interviews with a sub-set of respondents to the online survey. Section 4 provides a synthesis of both research perspectives, reflects on the strengths, limitations, and next steps, and draws insights leading to sector-wide recommendations in relation to SuDS evaluation, knowledge exchange, and priority areas for research.

2. Methods

The study design comprised a two-phased approach. The objective of the first phase was to explore the diversity of experiences of SuDS implementation across a broad range of practitioners. The second phase was to explore in greater depth the contrasting experiences of practitioners who perceive many barriers compared to those that perceive very few.

2.1. Phase 1 Study

2.1.1. Design and Recruitment

For the first phase, a quantitative survey targeted those who work in organisations (both public sector and private sector) associated with SuDS implementation. There was a specific focus on SuDS practitioners (individuals whose organisation roles include a component of SuDS planning, delivery, and/or management). The survey was designed to give a holistic overview of drivers and barriers experienced by those individuals. This included a range of questions exploring organization and individual roles, the extent of their role that involved SuDS implementation, the culture of SuDS in their organisation, and their experience of SuDS drivers and barriers. The survey options were based on drivers and barriers that have been highlighted in previous research. These were supplemented with additional potential drivers and barriers identified by the research team and the project steering group. The steering group comprised a series of individuals involved in the management and funding of the London Strategic SuDS Pilot Study—a funded programme to unlock the scaling of small-scale SuDS across the Thames catchment in London, UK.

Potential respondents for the survey were identified through the network of individuals who work with SuDS in and around London (UK), and were known to the research team and/or the steering group. The link was shared among this network initially. This network was then used to snowball to direct contacts of the network within their organisations. The survey included background information about the project and informed consent as per University ethics protocols.

2.1.2. Data Analysis

Descriptive statistics were used to compare the responses. This included a comparison of the mean scores for issues perceived to be direct barriers, and those related to lack of access to information. IBM SPSS Version 29 was used for statistical analysis. Tests of normality were conducted, most variables indicated normal distribution. However, because not all corresponded to normal distribution, a non-parametric comparative analysis, Wilcoxon Signed Rank Test, was carried out to statistically compare responses.

2.2. Phase 2 Study

The second phase of the study comprised a series of qualitative semi-structured interviews to explore in greater depth the perceived challenges and opportunities related to rolling out SuDS with participants who completed the online survey.

2.2.1. Design and Recruitment Procedure and Analytical Approach

At the end of the Phase 1 survey, respondents were asked to indicate whether they would be interested in taking part in one-to-one interviews. Nineteen survey respondents expressed an interest to take part in the follow-up interviews. Of the nineteen, six respondents were selected for participation in further interview. The aim of the Phase 2 interviews was to explore the practitioner experience of SuDS implementation from the contrasting experience of practitioners who perceived many barriers to implementation with those that experience few. As such, the sub-sample of respondents selected for Phase 2 interviews was not selected to be representative of the original survey sample population. Instead, it was

selected to represent the outliers in terms of responses to the initial surveys. This approach was taken in order to identify those barriers which were experienced by all practitioners (direct barriers), and those barriers that were perceived to exist by some, but not by others, indicating that they were due to lack of knowledge/experience by some practitioners (indirect barriers). This approach inevitably resulted in a small sample size, but the experiential design was such that the quality of experiential information gathered would be more valuable than through a representative sampling approach of all of the respondents.

Despite the small sample size, follow-up interviewees for the post-survey discussions comprised a diverse range of respondents. This included a variety of organisation types, and respondents with contrasting responses to perceived barriers and the availability of information questions. All six participants were interviewed (after giving informed consent as per the University's ethics protocols). They included two individuals from different London Borough Councils; two people from non-London councils; one person from a central government organisation; and one person from a private water company. Interviews were conducted online and lasted approximately one hour each.

The interviews were broadly framed to explore the responses that the participant had indicated in their survey as having high/low barriers to SuDS and a high/low availability of information, with discussions focusing on those topics to obtain a deeper understanding of those perceptions. This enabled comparative exploration, and better understanding, of the nuanced barriers faced by the diversity of participants.

2.2.2. Data Analysis

To explore the comparative challenges and opportunities experienced by the participants related to their SuDS implementation, qualitative analysis was carried out on the interviews. The recordings were transcribed, and the transcripts were analysed using thematic analysis, which provided a six-step framework for identifying, analysing, and reporting patterns in the data [73]. The initial thematic analysis was carried out by the lead author, the results of this were then verified by the broader research team.

3. Results

3.1. Phase 1 Study

3.1.1. Participants

Forty-eight people responded to all, or most, of the survey which provided meaningful information. Most (88%) of the organisations represented by the survey responses came from the public sector (including water/utility companies, councils). About 8% came from the private sector, with 4% from NGOs. About 80% of survey respondents identified SuDS as a core component in their organisation's role.

The survey explored the role of participants in SuDS implementation. Most participants felt that finance was applicable to their role (n = 42), with planning (n = 28) and delivery (n = 28) also rated highly in applying to their role. When asked to select the role aspect of SuDS that was most relevant to their role, most responded to implementation (n = 13), with slightly fewer saying it was finance (n = 9), and slightly less involved in the delivery of SuDS (n = 6).

3.1.2. Survey Measures and Results

The survey explored the breadth of experiences of respondents engaged in SuDS work:

Experience of SuDS implementation. Respondents were asked about their experiences in SuDS implementation in terms of *planning, delivery, and stewardship*. Responses were on a five-point Likert scale: 1 = None at all, 2 = A little, 3 = A moderate amount, 4 = A lot, and 5 = A great deal. Respondents were most experienced with the planning of SuDS, with

40% indicating they had a lot/a great deal of experience of planning, compared to 27% experienced in delivery and 16% experienced in stewardship. This data confirmed the survey group were indeed professionals with substantial experience in the discipline.

Perceived organisational support for SuDS. Participants were asked to indicate whether they feel their organisation implements/supports implementation of SuDS widely (yes/no). A total of 71% (n = 34) of respondents felt that their organisation did; 29% (n = 13) felt that their organisation did not.

Perceptions of mainstreaming of SuDS in their locality. Respondents were asked the extent to which SuDS were already mainstreamed in their locality, and also the level they would like to have this mainstreamed. Participants were asked to provide a response on a Likert scale: 1 = Definitely not, 2 = Probably not, 3 = Maybe yes/maybe no, 4 = Probably yes, and 5 = Definitely yes. Most participants (98%) agreed that that they would like more widespread delivery of SuDS in their locality, with 92% of those agreeing responding 'definitely yes' and 6% stating 'probably yes'. A total of 2% responded to 'probably not' and 2% did not respond to this question. Around one-third (36%) felt that SuDS are currently being mainstreamed in their locality, with slightly more (40%) feeling that they were not. Around a quarter (23%) were ambivalent to this.

Perceptions of main benefits, co-benefits, and gaps in information. Respondents were asked what they perceived as key drivers. Examples included air quality, biodiversity and ecology, community cohesion and crime reduction, and drainage. Respondents were presented with three response options per driver and asked to indicate whether they perceived the driver as (a) a main (targeted) benefit to implement SuDS; (b) whether it is a co-benefit (an additional benefit, but not a key driver); or (c) whether they are unsure and that they would like more information available to them about it. A visual representation is shown in Figure 1, in order of main benefit first.

The top five main benefits of SuDS were perceived to be (1) drainage (95.7% of respondents); (2) flood risk reduction (91.1%); (3) climate change adaptation (85.1%); (4) water quality (56.5%); and (5) biodiversity and ecology (50%).

The top five main co-benefits of SuDS were perceived to be (1) air and building temperature (79.5%); (2) air quality (76.7%); (3) recreation (70.5%); (4) education opportunities (70.5%); and (5) health and well-being (69.8%)

The top five benefits respondents highlighted uncertainty and the need for further information for were (1) economic growth and inward investment (33.3%); (2) community cohesion and crime reduction (31.8%); (3) improving company profile (25.6%); (4) air quality (20.9%); and (4) carbon reduction and sequestration (18.2%).

Perceived barriers and information availability. Respondents were asked about perceived barriers and issues relating to information availability with regards to implementing SuDS (Figure 2). They were presented with a list of potential barriers. Respondents were asked to respond to whether each was a barrier, and if the barrier related to a lack of available information. These responses were presented as a drop-down menu with a 1–5 scale. For the barrier column: 1 = Not a barrier at all, 2 = a little barrier, 3 = moderate barrier, 4 = a lot of a barrier, and 5 = Very much a barrier. For the availability of information column, 1 = No information at all, 2 = a little information, 3 = moderate information, 4 = a lot of information, and 5 = Very much information.

The top five barriers identified were (1) access to funds (M = 3.68 out of a maximum five); (2) difficulty retrofitting (M = 3.53); (3) cost (to maintain) (M = 3.49); (4) the ownership of SuDS (M = 3.41); and (5) a lack of collaboration between various stakeholders (M = 3.28). The five issues with the least available information were (1) conflicts with corporate identity (M = 2.52); (2) cost to maintain (M = 2.53); (3) a lack of collaboration between various

stakeholders (*M* = 2.64); (4) the public acceptability of SuDS (*M* = 2.69); and (5) health and safety issues (*M* = 2.70).

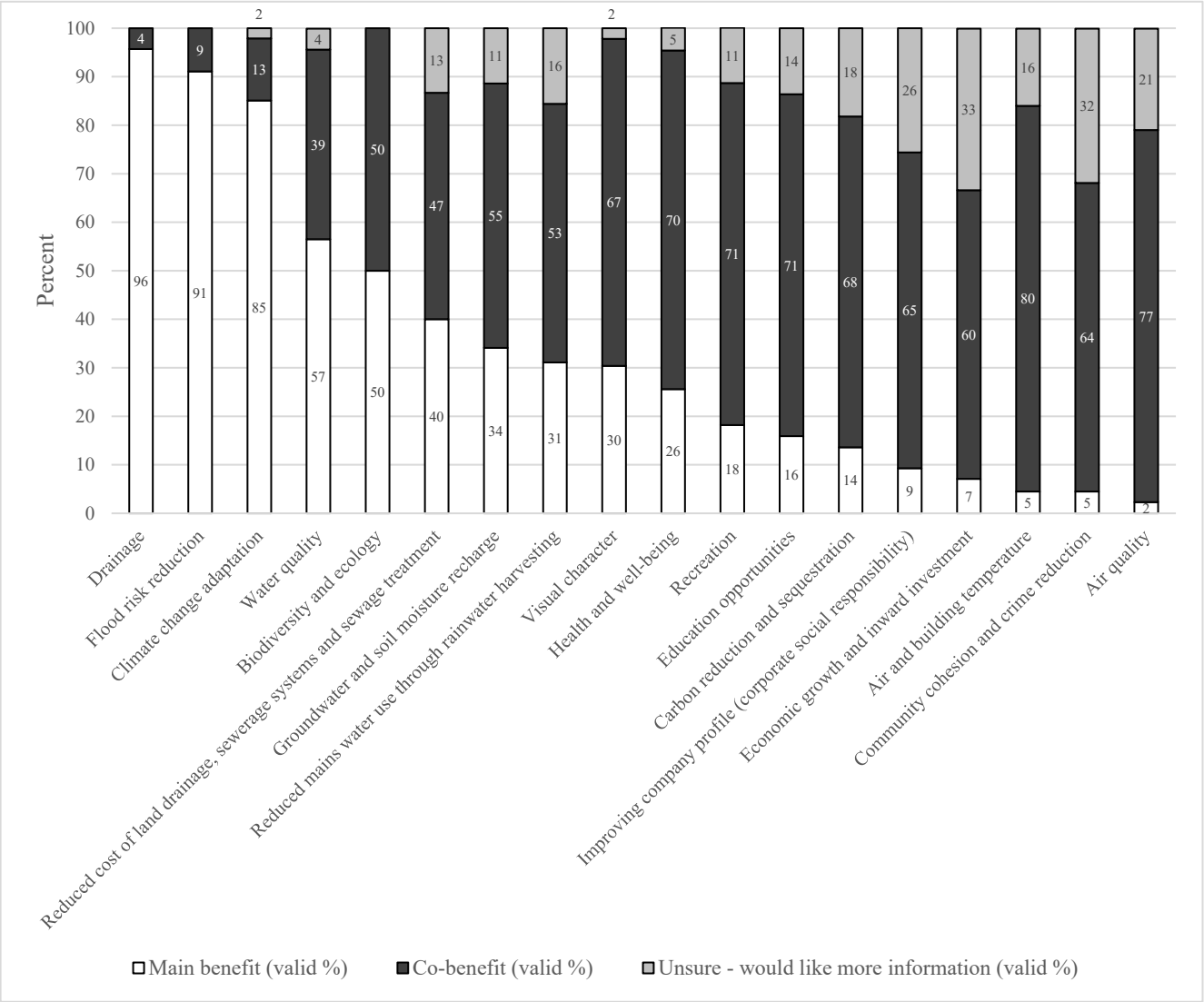

Figure 1. Perceived main benefit, co-benefit, and more information desired (%) (ranked by main benefit).

Generally, the higher scores for perceived barriers corresponded with the lower scores for available information.

To explore this pattern further, statistical comparative analysis was carried out to examine differences between issues perceived as barriers and the availability of information. The means, mean difference, n, and standard deviations (*SD*s), as well as the results of the Wilcoxon tests and *Z*, and *p* values are presented in Table 1. Broadly, the results indicate that there were significant differences between perceptions around barriers and perceptions around the availability of information. Thirteen of the seventeen paired comparisons showed significant differences between their scores. A notable point of interest included access to funds, which was seen as a relatively high barrier (*M* = 3.70) with a low availability of information (*M* = 2.73). Planning scored relatively high in terms of information available (*M* = 3.39) while at the same time did not rate highly as a barrier (*M* = 2.36). Perceptions around benefits tended to score low as a barrier (*M* = 1.70) with people responding relatively neutrally around the information that is available on the benefits (*M* = 3.00).

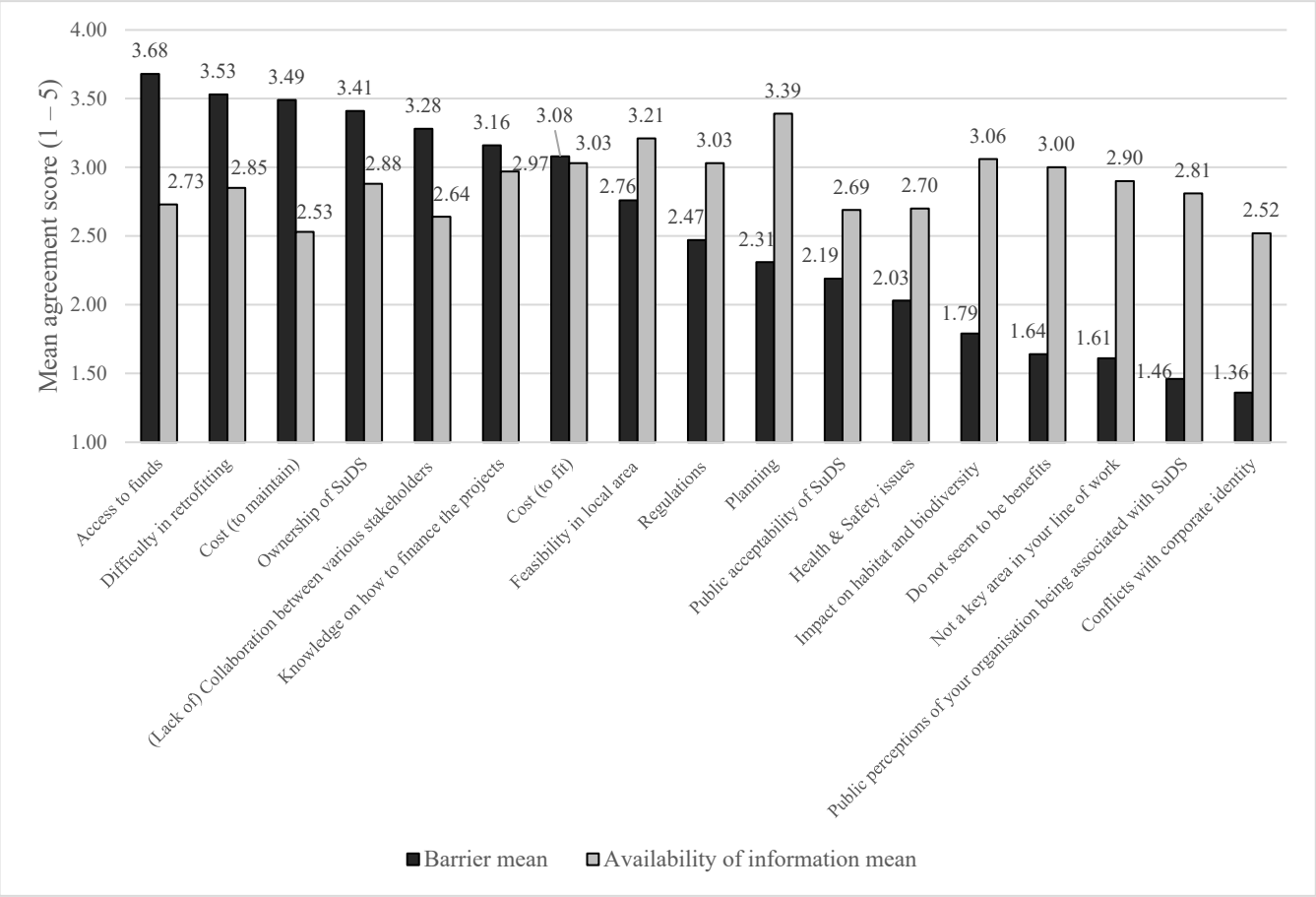

Figure 2. Perceived barriers and availability of information (%) (ranked by barriers).

Table 1. Results from paired samples analysis comparing mean scores.

	Mean	Mean Difference	N	*SD*	*Z*	*p*
Feasibility in local area		−0.35	34	1.52	−1.42	0.16
Barrier	2.85					
Available information	3.21					
Knowledge on how to finance the projects		0.15	32	1.84	−0.63	0.53
Barrier	3.12					
Available information	2.97					
Access to funds		0.97	32	1.61	−2.95	0.00
Barrier	3.70					
Available information	2.73					
Planning		−1.03	32	1.65	−3.14	0.00
Barrier	2.36					
Available information	3.39					
Regulations		−0.63	31	1.54	−2.11	0.04
Barrier	2.41					

Table 1. *Cont.*

	Mean	Mean Difference	N	*SD*	*Z*	*p*
Available information	3.03					
Impact on habitat and biodiversity		−1.28	31	1.53	−3.58	0.00
Barrier	1.78					
Available information	3.06					
Public perceptions of your organisation being associated with SuDSs		−1.31	31	1.69	−3.42	0.00
Barrier	1.50					
Available information	2.81					
Public acceptability of SuDSs		−0.44	31	1.44	−1.67	0.09
Barrier	2.25					
Available information	2.69					
Cost (to fit)		0.06	32	1.48	−1.14	0.89
Barrier	3.09					
Available information	3.03					
Cost (to maintain)		1.00	33	1.26	−3.73	0.00
Barrier	3.53					
Available information	2.53					
Difficulty in retrofitting		0.70	32	1.47	−2.50	0.01
Barrier	3.55					
Available information	2.85					
Health and Safety issues		−0.67	32	1.36	−2.56	0.01
Barrier	2.03					
Available information	2.70					
(Lack of) Collaboration between various stakeholders		0.61	32	1.46	−2.29	0.02
Barrier	3.24					
Available information	2.64					
Conflicts with corporate identity		−1.13	30	1.50	−3.39	0.00
Barrier	1.39					
Available information	2.52					
Do not seem to be benefits		−1.30	32	1.61	−3.70	0.00
Barrier	1.70					
Available information	3.00					
Ownership of SuDSs		0.47	33	1.46	−1.74	0.08
Barrier	3.35					
Available information	2.88					
Not a key area in your line of work		−1.23	29	−1.23	−2.84	0.01
Barrier	1.67					
Available information	2.90					

Overall, the results revealed that perceived barriers and perceptions on information were distinct, yet related, and that participants perceived that information accessibility and sharing was a key component of many of the barriers.

3.2. Phase 2 Study

3.2.1. Interview Findings

Three overarching themes captured the recurring and salient topics within the interview data: (i) people-related elements associated with SuDS; (ii) Limiting practicalities associated with SuDS; and (iii) informational factors. Each of the broad themes also comprised subthemes. The recurring themes and subthemes across participants are summarised in Table 2. These themes were supported with a selection of accompanying verbatim extracts from the interviews. To assure organisation anonymity of those taking part, any organisation names which are attached to the participants have been excluded and replaced with ORGANISATION, location names have been replaced with PLACE, and individual people identified have been replaced with NAME.

Table 2. Summary of themes and subthemes identified within interviews.

Themes	Subthemes
1. People-related elements associated with SuDS	– Attitudes and perceptions – Skills and expertise – Collaborations – The public
2. Limiting practicalities associated with SuDS	– Physical limitations – Funding limitations – Timing limitations
3. Informational factors	– Available information – Understanding the information – Lack of transferable knowledge models

People-Related Elements Associated with SuDS

The involvement of different actors was identified as key throughout the different phases of SuDS implementation and scaling, with a specific focus on the varied disciplines and roles in the process of developing and delivering SuDS This included roles internal to the organization and those external. How required participants can vary dependent on project context (e.g., in relation to implementation location: schools, scout huts, cemeteries, the NHS, etc.) was also raised. Barriers and opportunities related to this are aligned with the subthemes: attitudes and perceptions; skills and expertise; collaborative difficulties; and public attitudes.

Attitudes and Perceptions

Generally, participants felt that SuDS were being seen as more common within their organisations and more common compared to a few years ago. Despite this, there was a sense of still some way to go. Participants identified attitudes of people to SuDS, particularly internally, as key to whether the organisation generally, or projects specifically, would be seen as a priority. Having someone internally, particularly in a powerful position with influence within an organisation, was seen as key to making a difference to the approach of the organization, and driving a positive and supportive attitude in an organization towards SuDS. Such an organizational switch was seen as a critical step to an organization prioritizing funding for SuDS initiatives.

Conversely, having people within organisations or on project-specific teams who do not have a positive attitude towards SuDS, was reported as a barrier to the growth of SuDS as a whole. For example, the below interview extract describes how working with someone who perhaps did not have a positive attitude towards SuDS impacted their ability to deliver on the SuDS project.

> "*I think the first person [on the project] had been delivering a kind of traditional grey infrastructure for a very long time, and was getting towards the end of their career and had a proficient track record and rightly so you know that the kind of standard drainage would work. Yeah, we know that works as it's been installed for 150 years or something, but wasn't convinced with the concept of SuDS. Whereas the second person [who later joined the project] had experiences of it being delivered successfully, and had seen that it worked, so they were willing to put in the extra effort and work with us to make it work*." (Participant 1)

There was also a barrier identified in relation to knowledge stagnation that may be contributing to an inertia of SuDS development, and a need to change messaging to drive forward mainstreaming.

> "*You know, there's a whole fundamental shift change that's needed to attitudes with regards to getting this in. And it really frustrates me that I can go to presentations at conferences and it's the same stuff from 10 years ago. . .but SuDS are still sold as new and innovative*." (Participant 3)

Skills and Expertise

Having the necessary skills and expertise in a SuDS delivery team was identified as a key need. Participants identified that SuDS require multidisciplinary skills and expertise, and that this can be challenging to provide in a single team. Having, or lacking, these skills and expertise was seen as a key factor for determining the success of mainstreaming SuDS. Having a core in-house team of people with expert knowledge was seen as advantageous in terms of SuDS as this provides a strong foundation for reacting to funding opportunities. A particular risk that was identified was skills and expertise being held by a single individual in an organization. This highlighted the importance of both staff retention and development to retain staff with experience and expertise. It was also identified that some of the staff retention and development problems could be related to management attitudes.

> "*London borough ORGANISATION retained an in-house team of engineers [. . .] rather than outsourcing it to consultants. So, ORGANISATION was in a fairly fortunate position when the flood water management came in that we already had this core of engineers with local knowledge or local expertise and understanding of what the flooding and drainage problems were*." (Participant 5)

> "*Some managers are quite proactive and wishing to see their team skills developed and their employees develop. Other managers are more concerned if they start to go down that road that they are encouraging their staff members to leave. Who doesn't want to get better then to go on and take those skills elsewhere*." (Participant 3)

Examples of solutions and schemes contributing towards developing and retaining expertise were identified. For example, a scheme that employs a graduate for five years. Over those five years, there is guaranteed training and development, and if they progress though this and obtain a Master's degree as part of the process, they are guaranteed to move up two employment grades by the end of the five years. The aim is to create fully qualified engineers that are professionally and financially satisfied with their progress and more likely to stay on.

Collaborations

Internal and external collaboration was seen as an important driver of SuDS due to the interdisciplinary nature throughout the conceptualisation, implementation, and legacy phases. Collaboration as a theme complements the skills and expertise theme by bringing additional expert knowledge to delivery teams. This can also represent a pathway for bringing new knowledge and ideas into in-house teams.

> "*If you try to do everything in-house, [. . .] there might [. . .] be a risk of stagnation, you wouldn't actually be exposed to enough new ideas*." (Participant 5)

Collaboration is particularly important for exploiting emerging opportunities. For example, if work and disruption are needed for one reason (e.g., road works) it may present an opportunity for other simultaneous works (e.g., SuDS). Working in an isolated and fragmented (siloed) way may mean that such opportunities are missed. Collaboration, done formally or informally, can mean that opportunities are not missed. The interviews provided insights into how collaborations can be achieved:

> "[*Before Covid*] *We did used to invite people to the entire team meeting [. . .] once in a while. The first half an hour would be for a manager or senior member of another team to come in and talk to us about what they do and we can form those relationships, talk about what we all get up to and where we can help each other out*." (Participant 3)

The Public

The role of the public, public engagement, and public attitudes was also acknowledged but the extent that this was seen as a barrier varied. Generally, there was consensus that public understanding of, and interest in, flooding risk and SuDS related to their own direct experience (i.e., either having been flooded, or experiencing disruption and/or cost related to SuDS). Communications around SuDS were identified as not strong enough and a need for more SuDS education was highlighted as a more general need, rather than currently where this only occurs locally related to a specific SuDS scheme. Corresponding with the survey results, participants did not identify public perception as being a particular barrier to mainstreaming SuDS.

The communication of the co-benefits of SuDS (e.g., health and wellbeing, traffic calming, etc.) was identified as a way to obtain greater public engagement, as these may be issues they are more engaged in than flooding, particularly if they have not experienced flooding:

> "*We'd sell them more as kind of a wider kind of public realm improvement greening up, helping to improve air quality, make them nicer places, improve health and wellbeing, calm traffic. [. . .] Including such an element of those types of projects helps to sell them because then people can then see, usually that they're hoping to deliver kind of environmental benefit as well*." (Participant 5)

It was acknowledged that building relationships with the public was important. Participants identified public engagement and communication conducted by an external organization, rather than directly from the council, as a mechanism to reduce barriers. The third-party organisation was seen as a buffer, to ensure engagement focused on the SuDS project, rather than spilling over into broader council issues.

3.2.2. Limiting Practicalities Associated with SuDS

The second theme related to more practical aspects that can represent barriers to SuDS: physical limitations, funding limitations, and timing limitations.

Physical Limitations

Physical challenges can represent a barrier to implementing SuDS, particularly in urban areas, and in relation to local and regional area boundaries. This included the challenges of working on congested streets with lots of buried utilities, and multiple other considerations., and the challenges of regional boundaries not corresponding with watershed boundaries.

Physical limitations were identified as a barrier for both retrofit and new developments. This was seen as a planning issue that could be avoided with early consideration. Typically, SuDS were described as an afterthought after master planning:

> *"this is where the building is going to be" [. . .], "OK, how are we gonna fit in managing water around it?" "Oh, now we're constrained by levels because we can't put our storage at the top of a hill."* (Participant 6)

Funding Limitations

Participants identified barriers in relation to sources of funding. One participant broadly indicated there are two broad types of funding—internal funding or external funding (third party, e.g., from water companies, local government, regional development funding, and the Department for Education). Accessing funding, both capital and maintenance, was a commonly cited barrier to mainstreaming SuDS. Maintenance costs and ownership were particularly highlighted as problematic, including having the knowledge and tools to be able to maintain SuDS.

> "*I think a big barrier to the rain garden project involvement was concerns over maintenance. Without having got the right equipment do we know what to do or it's a bit more than just cutting the grass where we don't know how to do that? Who's gonna [. . .] take responsibility for that? That's always a problem, right? [. . .] Reluctance to try something new because of the worry about how you look after it*." (Participant 6)

In parallel to this concept of risk related to a lack of experience of maintenance, another indirect finance-related risk included political risk related to public trust in a local authority. There was an indication that investment in SuDS was not necessarily a barrier per se, but the political risk of a bad investment in SuDS (i.e., SuDS projects being invested in but not happening) was a funding barrier:

> "*Those risks are often not actual pure financial risks because [. . .] it's rare to waste significant amounts of money on the project. That doesn't happen. It's more of potential political risk if you say you're going to do something*." (Participant 5)

Timing Limitations

Time cycles and the timing of SuDS was also seen as problematic, and perceived as lengthy in terms of lead-in and completion time. This was particularly highlighted in relation to the five-year AMP (an asset management plan (AMP) period is a five-year time period used in the English and Welsh water industry in the UK) cycle, and the fact that, if there is no available funding in the current plan, then there would be a long duration before new funding could be ring-fenced.

Timing was also raised as an issue related to theme one and the challenge of retaining in-house expertise over the long duration that some SuDS projects can take from conceptualization to completion and maintenance. Timing was also recognized as critical in relation to ensuring that initial secured funding continues at least into the first few years of the maintenance phase of a project to prevent a lack of maintenance funding being a barrier to delivery:

> "*we have to [. . .] do a sort of sleight of hand to convert some of it, if possible, into surplus to come in the future, [. . .] call it commuted sums, but it may not be permitted by the funding criteria. [. . .] So either allow the use of their funding for maintenance, or if they could require very tight sort of maintenance funds to be set aside, you know? You know so that people like me don't have to argue for, it's just a given*." (Participant 4)

3.2.3. Informational Factors

The third broad theme identified was perceived informational challenges around SuDS. This included subthemes of available information, understanding the information, and a lack of transferable knowledge models.

Available Information

Participants stated that there is a good amount of *general* information available on SuDS compared to a decade ago. However, they also stated that improvements were still needed, particularly in terms of updating available information as the sector has developed. A lack of widespread distribution of information was also highlighted as a barrier, particularly the lack of integration of SuDS information into other policies, such as place-making and climate policy, to mainstream it.

Specific information around monitoring data was a topic that lacked consensus. Some perceived a lack of monitoring data, but others stated that sufficient data was available on short-term performance, and that it was only long-term performance data and scaled performance data that were missing.

> "*I really think we need some of these longer-term studies with different types of SuDS measures—with different levels of maintenance as well, to see exactly what they're gonna do because they really need to stack up against grey solutions*." (Participant 1)

> "*There needs to be lots of proof of concept at scale with monitoring so you can actually say that you know this thing is genuinely stopped that amount of water going in that pipe under these storm conditions and the models support it, and then we could start to move things forward*." (Participant 2)

Understanding the Information

Another issue identified was how understandable and actionable the information that could be accessed was. Due to the multidisciplinary nature of SuDS, understanding information that is provided to help unlock barriers to implementation may require a broad knowledge-base and ability to discuss with others in the field, which is not always possible:

> "*They would be there [. . .] one afternoon a week to provide their planning officers with some guidance, [. . .] just to be someone there to ask questions to [. . .] better equip them with the information to be confident*." (Participant 6)

Lack of Transferable Knowledge Models

To mainstream SuDS, developing transferrable conceptual, practical, financial, and informational models was identified as a sector need.

> "*It's about [. . .] taking that and making it into a sausage machine where you can just keep churning these things through or, if next time you're not that interested in SuDS, you're interested more in green walls—the special purpose vehicle structure and the contracting and how some of the contributions will be different, but they can just be done again*." (Participant 2)

> "*What we're trying to do is [. . .] source some capital funding [. . .] so that we can build a pipeline of projects on the shelf. [. . .] get them to the point of going out to tender for*

a contractors etc. and keep on the shelf so [. . .] we can just go look for at least one that would fit your criteria." (Participant 3)

4. General Discussion

4.1. Synthesis of Survey and Interview Findings

The mixed-methodological approach to investigating practitioner perceptions of SuDS barriers and knowledge enabled a high-level review of current general perceptions and more detailed nuance in relation to contrasting practitioner experiences.

Broadly, our results corresponded to previous studies in relation to perceived benefits of SuDS [25,30,31]. Reported barriers also mirrored those reported previously, including attitudinal barriers and contextual constraints [69], and economics, legalities, policy, and logistics [45,57–59]. Our study identified public perceptions as not being a barrier per se, which contrasts previous research [51,55]. Instead, this study highlighted attitudes towards SuDS stewardship as a barrier [51,55,56], perhaps reflecting a shift in public opinion. Corresponding with other studies, institutional factors, including attitudes and prioritisation within organisations [59,68] were also identified as key barriers to mainstreaming SuDS. Additional barriers identified in this study also correspond with those reported in some previous studies: governance, socio-cultural, knowledge, technical and biophysical, and funding and markets [61].

The actor-centred participatory process adopted in this study also highlighted that an improvement is still needed in cross-departmental communication among both internal and external agents due to the multiple skillsets that are required when working with SuDS.

This study advanced previous understanding by taking a comparative approach to its actor-centred research, (as encouraged by [50]), exploring the nuance of the reported barriers and issues of information availability, accessibility, and usability [74].

The comparative assessment of barriers to SuDS implementation mainstreaming identifies both direct barriers and indirect barriers. *Direct barriers* are those that can be categorised as hard barriers, such as practical technical limitations due to local context, and lacking or inappropriate funding. They also include gaps within SuDS data and broad knowledge (e.g., discipline knowledge gaps) that need to be addressed through further research and monitoring. *Indirect barriers*, by contrast, were identified as soft barriers, including individual practitioner knowledge and capacity gaps through a lack of access to training and development, and the inaccessibility of key SuDS knowledge to all practitioners. It was found that barriers could be both direct and indirect. For example, funding limitations were direct barriers (when insufficient and/or unsuitable funding was available) and indirect barriers (a lack of the transfer of knowledge on how to access the funds that are suitable and available, and how to use them creatively). The quantitative findings identified a general correlation between increasing information available and decreasing the perception of barriers by practitioners. The qualitative research highlighted the importance of knowledge exchange for increasing information availability and, particularly, sharing experiential learning across practitioner networks. Practitioner to practitioner sharing has the potential to address direct and indirect barriers, driving forward sector-wide change beyond just an individual knowledge level.

These findings correspond with previous studies' identified knowledge gaps around SuDS and the barriers that this creates [44,45,61,65,68] and that actor networks are a key component to supporting some practitioners to overcome many of these barriers [66].

Despite this acknowledgement that some barriers relate to poor practices in relation to the sharing of experiential knowledge, the study clearly identified areas where sector-wide information gaps remain, particularly relating to long-term performance data. Participants also highlighted challenges in relation to developing and retaining in-house expertise in a

rapidly evolving sector. Mirroring the findings of [72], the study also found that barriers were interrelated to a greater or lesser degree.

This study builds on previous findings by adding depth to the current understanding of perceived and experienced barriers, and adding nuance to the understanding of the balance between direct and indirect barriers. The study has highlighted direct factors that are currently limiting the sector-wide mainstreaming of SuDS, and confounding indirect factors (such as a lack of effective knowledge transfer between the relevant actors key to SuDS implementation), that create limitations on an individual/local basis.

4.2. Strengths, Weaknesses, and Future Research

Addressing a need identified in BGI/NBS literature [50], this study increased understanding of the perceptions of people who work in organisations relevant to the planning, delivery, and stewardship of SuDS. The mixed-methods approach enabled greater interrogation of the understanding generated by the initial online survey results, providing a juxtaposition between those who experience numerous barriers and those that have found ways to navigate many of these. It was clear from the interviews that, for those participants who perceive many barriers, improving and updating knowledge transfer from successful and challenging case studies would be of immense value. Whilst this study was only focused on London, UK, and therefore numbers are relatively low, many of the outcomes would be expected to be transferable to other urban areas globally. To fully understand this transferability nationally and globally, replication across other study areas and participants would be valuable. Also, a larger sample size for the quantitative work would increase the power in the statistical analysis and the representativeness of practitioner experiences in different contexts.

4.3. Conclusions

An overarching recommendation for actors in governmental and SuDS-based organisations relevant to water management is to work openly and collaboratively to share experiential learning. This must include both successes and failures in SuDS implementation. It is of particular importance to capture and share this knowledge from individuals with the greatest track records (and thus least perceived barriers). Such knowledge transfer can help to unlock the indirect, soft, knowledge and awareness barriers still faced by many practitioners. Specific recommendations to address both the direct and indirect barriers include the following:

- National government and centralised SuDS-based organisations should prioritise capturing and making available the data from the long-term monitoring of the environmental, social, and economic performance of SuDS to address gaps in knowledge around long-term data.
- Local authorities should engage with organisations who are maintaining SuDS to provide a collaborative approach to understanding the effects of different maintenance approaches on the long-term performance of SuDS.
- National and local governments should make SuDS more inclusive within their policy frameworks to enable the awareness and implementation of SuDS. This should include embedding SuDS concepts into wider environmental policies.
- Local authorities, water companies, and the national curriculum should work towards increasing public awareness and understanding of SuDS through the provision of SuDS information and education more generally.
- Organisations need to attract and retain SuDS expertise. This can be improved by establishing career opportunities/progression and training linked to SuDS within organisations.

- Organisations can develop informal associations and knowledge exchange processes within their own workplaces (e.g., coffee mornings, invited guest talks into other internal meetings, setting up a regular internal seminar programme, or other informal knowledge exchange networks).
- Governments and water operators should offer more openly accessible water knowledge networks to facilitative informal and formal peer-to-peer networks.
- Case studies developed for knowledge exchange should include more of the 'how' and less of the 'what' in order to support the development of a community of practice.
- National government should develop (based on good practice case studies) standardised financial planning of SuDS schemes to include a period of maintenance funding incorporated into the initial capital funding.

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