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Identifying enablers and barriers to the implementation of the Green Infrastructure for urban flood management: A comparative analysis of the UK and China

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ABSTRACT

Climate change and urbanization are increasing the urban flood risk, which can cause adverse on socio-economic and environmental impacts. Green Infrastructure (GI) can reduce stormwater runoff and offer multiple benefits that have been initiated in the United Kingdom (UK) and China, namely Sustainable Urban Drainage Systems (SUDS) and Sponge Cities Program (SCP) respectively. Currently, the implementation of GI is restricted to small spatial (site specific) scale and facing several constraints such as financial investment and governance. that limited its fuller functions and potential. This study aims to identify the barriers and enablers for the adoption of GI by investigating SUDS and SCP in the UK and China, through twelve in-depth semi-structured interviews with stakeholders. Our results found that multiple benefits of the SUDS and SCP were identified, as the main enablers in both countries with reducing the stormwater runoff and alleviating peak discharge in the drainage system, also contributing to social well-being and climate adaptations. Some barriers found the current practices are facing challenges from financial, biophysical and socio-political circumstances in both cases. We conclude that it is beneficial to learn the comparative findings and experiences from both countries, which contributes to stakeholders for improving current GI practices, in prior to achieve more sustainable long-term deliverables.

1. Introduction

In recent years, the frequency, distribution and intensity of extreme weather conditions, particularly short-term rainstorms, has been growing, leading to surface-water accumulation and urban flooding. Flooding poses a grave threat to human life with the United Nations, estimating that flooding caused the death of 157,000 people and affected 2.3 billion people between 1995 and 2015 (Richard, 2016). Flooding also has knock-on effects for both economic and social development. The total cost of flood damage and associated losses is estimated at over $104 billion per year globally (Kundzewicz et al., 2014), and the urban flood risk is increased as a result of the expansion of more impermeable surfaces at the expense of more porous green spaces (Zhao et al., 2013). There has, therefore, been a large reduction in infiltration potential and an increase in overland flow that bypasses the natural stormwater storage and attenuation of the surface. This increases the storm runoff volume and decreases the response time, causing dramatic local increases in flood peaks (Wheater et al., 1982).

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The geographical distribution of flood risk is heavily concentrated in the countries with the highest populations. China incurs the highest socio-economic losses due to flooding followed by the USA and India. These losses not only impart significant costs to these countries but also have the potential to disrupt global supply chains (Biswas and Tortajada, 2016). In China 62% of 351 cities surveyed between 2008 and 2010 had experienced flooding, demonstrating that this is a widespread problem across the country (Feng et al., 2014). Since 2000, over 200 urban flooding events have affected Chinese cities to different extents annually and some medium and large Chinese cities suffer from frequent and severe floods (UNDP and NDRCC, 2017).

Flooding has also become increasingly problematic in the UK. It is ranked as the UK's most serious natural hazard, with more than one in six properties (around five million properties in total) and a high percentage of the nation's key infrastructure at risk (Environment Agency, 2015). The annual cost of urban flood damage is estimated to be around £270 million annually (between £500 million and £1 billion, with a further £1 billion spent on flood risk management (Penning-Rowsell, 2015). Floods in the UK tend to occur frequently due to its relatively small rivers (e.g., the Severn and the Thames), but can cause considerable problems for communities (Lo and Chan, 2017).

Despite the ongoing risk of flooding events and associated risks, both the UK and China are experiencing increasing urbanisation. Chinese cities are relentlessly spreading, paving over the country's green spaces (Chan et al., 2018). Similarly, urban sprawl in the UK currently occupied 22000 hectares of former woodland, farmland and wetlands, as planning reforms 'unlock the countryside' for further development according to a satellite survey (Mathiesen, 2015), with London losing 2.5 Hyde Park equivalents of green space annually (Luker, 2014). It is necessary towards a more sustainable and resilient transition of urbanisation in two countries.

1.1. Green Infrastructure approaches

Both China and the UK have highlighted the importance of taking steps towards sustainable urbanisation in order to adapt to and mitigate the impacts of increased flooding. From a general perspective, GI has the potential to allow cities to adapt to climate change and to mitigate its worst impacts (European Commission, 2013; Scott et al., 2017; Everett et al., 2018). GI is defined by the European Commission (2013) as "*a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services*". In the UK, GI is a broad term from green roofs and private gardens to the larger scale such as wetlands, forests and agricultural land, according to the UK Green Building Council (2015).

US EPA (2012) recognises in the US, GI as a tool that plays an important role on flood risk management in a smaller scale, stating that "*GI is an approach to wet weather management that uses soils and vegetation to utilize, enhance and/or mimic the natural hydrological cycle processes of infiltration, evapotranspiration and reuse*". GI could also be thought of as a technology (or group of technologies), and yet its recent use refers to a broader, conceptual approach to urban planning and layout. Therefore, GI could also provide a range of other benefits in addition to flood management.

There is an increasing evidence that incorporating GI into urban designs can relieve flood risks (Thorne et al., 2018; Carter et al., 2018; Mei et al., 2018). For example, Carter et al. (2018) demonstrated the loss of GI cover in the Urban Mersey Basin was responsible for increased volumes of runoff and higher flood risks. Mei et al. (2018) confirmed the effectiveness of GI for flood mitigation even under the most beneficial scenario by using an evaluation framework based on Life-Cycle Cost Analysis (LCCA) and the Storm Water Management Model (SWMM). Furthermore, Ashley et al. (2017) stated that "*GI is not drainage anymore; it's too valuable* ". According to Fenner (2017), multiple benefits can even occur coincidentally and are not developed or maximised in the original design.

Therefore, allowing urban enhancement GI schemes to reach their full potential by more proactive development is possible through careful co-design. These benefits can include promoting healthier lifestyles that lead to increased well-being, supporting the green economy, improving biodiversity and ecological resilience, and delivering multi-functional services such as flood protection, water purification, air quality improvements, and climate change mitigation and adaptation (UK Green Building Council, 2015). There is a growing consensus that GI can provide exciting opportunities for the delivery of significant environmental, social and economic benefits (see Table 1).

In the UK and China, there has been an increasing awareness of water quality and flow protection and the associated benefits of GI (UK National Ecosystem Assessment, 2011; Liquete et al., 2016; Fenner, 2017; Chan et al., 2018). In the UK, Sustainable Urban Drainage Systems (SUDS) were widely introduced in order to combine the conventional below-ground sewer drainage systems as a hybrid solution to solve flow and surface water quality issues (O'Donnell et al., 2017).

Similarly, other approaches are using green sustainable drainage solutions to remove, store, divert and delay surface water runoff, in order to relieve the pressure on urban drainage capacity during the storms, but also enable to generate multiple benefits. These approaches are popular and common, have been initiated worldwide in the last few decades. These include Best Management Practices (BMPs) initiated in the 1970s (Schueler, 1987), and more recently the Low Impact Developments (LIDs) in the USA and Canada (United States Environmental Protection Agency, 2000), and the Water Sensitive Urban Design (WSUD) in Australia (Whelans et al., 1994;

Table 1
The identified multiple benefits of GI from various authors

Multiple benefits of GI	Evidence and Examples
Environmental benefits	The protection and improvement of ecosystem services (Tzoulas et al., 2007; McMahon, 2009; European Commission, 2010; UK Green Building Council, 2015; O'Donnell et al., 2017).
	Landscape connectivity enabling the movement of wildlife and increasing biodiversity (Fabos, 1995; Dramstad et al., 1996; Leitao and Ahern, 2002; Wright, 2011).
	Environmental protection and conservation, microclimate mitigation (Natural England, 2009; Benedict et al., 2012; UK Green Building Council, 2015).
Social benefits	Improvement of mental and physical health (TEP, 2005; Tzoulas et al., 2007; Northwest Regional Development Agency, 2008; Natural England and the Campaign to Protect Rural England, 2010; Mell, 2010; Ashley et al., 2018).
	The connectivity of urban and rural neighbourhoods, the provision of settings for culture, sport and recreation, enhancing local distinctiveness, social inclusion and sense of community (Environment Agency, 2005; Kambites and Owen, 2006; Mell, 2010; Ashley et al., 2018).
Economic benefits	The provision of an 'enhanced environmental backdrop' to boost economic growth by attracting skilled workers and tourists to cities, and to boost products from the land and recreation and leisure (Environment Agency, 2005; TEP, 2005; ECOTEC, 2006; Northwest Regional Development Agency, 2008).
	Increasing land and property values (Nicholls and Crompton, 2005; CABE, 2005; Northwest Regional Development Agency, 2008; McMahon, 2009; Collinge, 2010; Zhang et al., 2018).
	Decreased costs associated with mitigating climate change, improving flood management and enhancing wellbeing (CABE, 2005; Northwest Regional Development Agency, 2008; Collinge, 2010).

Wong, 2006; Mouritz, 1996). In China, the Sponge City Concept was purposed by President Xi Jinping in 2013 along similar principles to the LID Scheme (Chan et al., 2018; Zhang et al., 2016). Chinese cities that were selected by the Sponge City Program(SCP) will be used to absorb excessive water from excessive precipitation and river floods and store it for future use during prolonged dry periods (Tang et al., 2018).

1.2. A comparison of SUDS in the UK and the Sponge City concept in China

A schematic classification of terminology, which is related to the GI, SUDS and Sponge City Concept, according to the specificity (techniques vs. broad principle) and range of application (urban stormwater vs. the entire of urban water cycle management system) has been developed shown in Figure 1 (Zevenbergen et al., 2018). There is a clear overlap between these terms as they all follow two broad principles in terms of channel geomorphology and ecology: mitigating the hydrological changes as much as possible towards natural conditions or local objectives, and improving water quality. The overlap explains the extent of the similarity of the underpinning ideas as well as the dynamic and multi-dimensional nature of terms used (Fletcher et al., 2015).

There are some subtle differences of the way to express these underpinning principles within their own local development and institutional context (Fletcher et al., 2015). SUDS is used more when describing stormwater control techniques primarily associated with structural measures (e.g. ponds, swales), while the SCP contains more overarching principles in that it manages the water resources, water quality and water ecology on a large scale, which can include cities, regions and river basins. SCP can be argued as being an innovative redesign and application of the LID principles in line with Chinese national policies and situation. SUDS and SCP can both be considered under the broader principles of GI, which encourage multiple benefits by integrating drainage designs and natural water-bodies to provide better amenities for public (Wang et al., 2017) and to enhance ecosystem services provided by artificial water bodies and green spaces.

1.3. The aim of the study

Despite GI being successfully applied in many cities around the world, and having been proven to be a cost-effective solution for flood risk management (Dhakal and Chevalier, 2017) and with the multiple benefits of GI being increasingly recognized (Raymond et al., 2017), large-scale uptake of GI in many places has been slow and its implementation has not reached its full potential (O'Donnell et al., 2017). Overall understanding of GI has been found to be weak and has varied widely among case studies (Qiao et al., 2018; Sussams, 2012; Thorne et al., 2018). In order to face up the challenges of climate change and rapid urbanisation, barriers and enablers of GI should be identified and understood if the implementation of GI is to be improved.

Furthermore, there have been few studies that compare GI approaches to urban flood water management in general, but lack of understanding in terms of SUDS and SCP. Although there are many cultural and political differences between the UK and China, their aims of managing urban flood water by GI approaches are essentially the same. Therefore by learning lessons from each other, GI could be successfully implemented in both countries.

This paper aims to identify the barriers and enablers of GI approaches to urban flood water management, specifically SUDS in the UK and SCP in China in order to make recommendations for improving the effectiveness of their implementation and informing future visions. The paper begins by reviewing the background for the development of GI and their functions in urban flood management across the two countries. Next, it identifies the enablers and barriers of GI application through semi-structured interviews before concluding by discussing the similarities and differences between the UK and China and offer recommendations to improve GI adoption in the future.

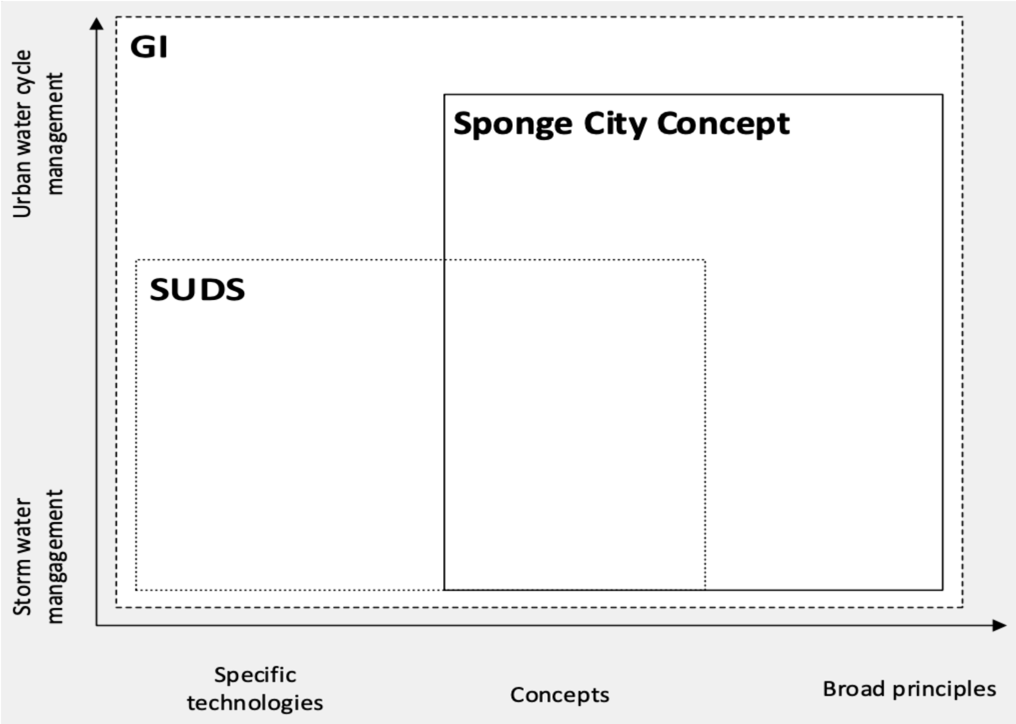

Figure 1: A classification of terminology of GI, SUDS and Sponge City Concept based on their main focus and specificity, adopted after Zevenbergen et al. (2018)

2. Methodology

In order to gain an understanding of the barriers and enablers to the development of GI for urban flood management, semi-structured interviews were conducted with a range of professionals in the fields related to GI approaches in both the UK and China. Semi-structured interviews were chosen as the most appropriate method as it allows for the ideal mixture of 'methodological rigour and dramaturgical spontaneity' (Cloke et al., 2004). It allows the interviewees to explore all relevant information and additional important points that they may not aware originally considered (Barribal and While, 1994). The interviewees were selected from a range of organisations that aimed to provide an overview of the following professional remits in the field of SUDS/SCP, namely (1) developers or landowners/managers, (2) policymakers or urban planners, (3) project managers, (4) local authorities or community representatives, (5) academic researchers and (6) private sectors (e.g. consultants). A multidisciplinary group of twelve well-informed stakeholders were selected as interviewees for this study.

We attempted to alleviate the potential self-selection bias by selecting interviewees who had sufficient knowledge of water and flood management techniques, urban planning and environmental and land management techniques, or who were involved with various projects linked to SUDS or SCP. In this way, the interviewees could be representative of their respective countries, given the diverse range of experience across the UK and China. During the interviews, the interviewees were asked a series of open-ended questions, which allowed them to talk about their different projects and allowed them to give their own perspectives. Although semi-structured interviews are generally limited to one issue from an anecdotal perspective, they have been shown to be highly insightful due to the experience of the stakeholders involved. A standard set of questions were developed and used as a basis for all the interviews, while keeping in line with semi-structured interview methodology. These were used flexibly to allow details of specific experiences from the interviewees and the projects they had been involved with to be obtained.

The interviewees were involved in the design and implementation of GI used for urban water management, such as those who work for local authorities and developers as well as landscapers, non-governmental organisations, and scholars in the related fields and professions. Initial contact was made with potential interviewees through email and interviews were then arranged at a time and place of the interviewees' choosing. The initial email gave a brief introduction to the project, its aims and an overview of the topics and proposed questions including a project overview, enablers and barriers to GI application, stakeholders, strategic planning of the project, informed planning and delivery, legacy and future management, and comparisons between the UK, China and other countries.

A total of twelve interviewees from the UK and China (six from each country) were interviewed for between 30 minutes and one hour through face-to-face, Skype and/or phone interviews. The conversations were recorded and fully transcribed using the software Otter (Otter.ai, 2019) along with manual editing. Four of the interviews were conducted in Mandarin and were then professionally translated into English.

The analysis was initially inductive, with the meanings of each interviewee's statements synthesised into different 'nodes' using computer qualitative research software (NVivo 12), which is able to manage data and ideas and can visualise and query the data (Bazeley and Jackson, 2013).

Coding was used to manage the data in terms of identifying the similarities and differences under each node, including enablers, barriers, strategies to overcome the barriers, and the stakeholders of GI projects. Evaluation of the nodes revealed differences that are more detailed and identified other more issues, concerns and suggestions. The views from the Chinese and British interviewees were compared in terms of aims, design aspects, scale, stakeholder participation, planning processes and financial resources.

To supplement this qualitative analysis, a separate quantitative analysis was conducted of excerpt-counts in order to determine the total number of references for each node (O'Donnell et al., 2017). Quantitative coding enabled measuring of the frequency of the mentions related to each code to be measured in addition to the respondents' position or interest in the node. Respondents were identified and coded anonymously throughout this manuscript to maintain confidentiality.

3. Results

Five nodes emerged through coding, summarising the raw data related to drivers, barriers, strategies for overcoming barriers, stakeholders and comparisons. The de-

Table 2
Description of list of interviewees and information about their interviews.

Interviewee	Country	Occupation	Interview		
			Method	Date	Duration (mins)
Respondent 1	UK	Head of community working wetlands	Phone	2018/08/07	27
Respondent 2	China	Senior Engineer for urban drainage	Skype	2018/06/29	46
Respondent 3	China	University researcher	Face-to-face	2018/07/09	45
Respondent 4	UK	Senior program manager	Face-to-face	2018/07/27	41
Respondent 5	UK	Local authority	Skype	2018/07/12	32
Respondent 6	China	Researcher, hydrologist	Skype	2018/07/15	49
Respondent 7	China	University researcher	Phone	2018/07/29	49
Respondent 8	UK	Flood and drainage manager	Face-to-face	2018/07/06	42
Respondent 9	UK	CEng (Chartered Engineer)/Policymaker in environmental field, chair of a catchment water group, consultant on water management (SUDS)	Skype	2018/07/30	59
Respondent 10	UK	PhD student/Intern on SUDS evaluation in a water company	Phone	2018/08/16	27
Respondent 11	China	Consultant	Skype	2018/11/16	31
Respondent 12	China	Local government officer (flood evaluation)	Skype	2018/11/18	30

mographics of the interviewees including their country, occupation, interview method and interview time and duration are shown in Table 2. Respondents 2, 3, 6, 7, 11, and 12 discussed issues in China, while the other six discussed UK issues. Respondents 6 and 7 were also able to discuss the UK issues as they had worked in both countries.

3.1. Enablers to the implement of green infrastructure

Statements were regarded as being an enabler if the respondents used synonymous words such as “driver”, “enabler”, “support” and “motivation”. The frequency of each enabler for the GI implementation mentioned by respondents from both countries (see Table 3) found that multiple benefits are the main enablers for GI imple-

Table 3
The frequency with which each enabler to the GI implementation was mentioned.

Enablers of GI implementation	Each enabler mentioned	Frequency mentioned by interviewees
Multiple benefits	Surface water flooding control and management	12
	Microclimate adaptation (environmental cooling, carbon emission reductions, improvements in water quality and biodiversity)	6
	Social effects (facilitating local economies, improving quality of life and leisure activities)	7
	The effects of community values (providing educational value and mental health benefits)	4
Political buy-in	Political support from high-level stakeholders and the governmenance in the form of policies and regulations	6

mentation, as it was mentioned by 10 out of the 12 respondents.

One respondent implied that GI could bring multiple benefits.

"*Talking about multiple benefits, they're the obvious ones about how some nice public space will be improved, and providing successful GI improves people's quality of life and their health. And they facilitate the improvement of biodiversity and effective climate change mitigation* (Respondent 9)."

Among the multiple benefits, surface water flooding control and management were identified as primary functions, while others included social effects, the effects of community values and microclimate adaptation. One respondent has indicated that:

"*It's actually one indicator for cooling the urban environment. Another benefit is we looked into GI from a social perspective on how it helps to reduce crime and create a better living environment; how it can have an impact on local economies by creating* *new leisure activities; by looking into local climate issues; by reducing flooding and helping to reduce carbon dioxide emissions as well as going to environmental aspects looking to biodiversity and the microclimate matters* (Respondent 7)."

In addition, there were seven respondents who identified political support, such as that given by high-level stakeholders and governments as being important drivers for GI implementation. This was particularly noticeable among the Chinese interviewees, of which two of their responses are shown below:

"*It's quite top down in China I believe, so the notion of SCP is a great one and obviously, if the people with power decide it's something they want, it happens quite quickly* (Respondent 1)."

"*In China, if the government wants to do something it will do it; it will make sure it'll get done, and they've got the finance to support that* (Respondent 6)."

Similarly, another respondent from the UK also believed that political buy-in is an important driver.

"*In Hammersmith, from the council's point, the big driver for SUDS and GI is probably that the manager of highways really took this and thought we should do this good thing. The driver is from the top of the council, that the chief expected it to be the greenest borough, and we as highways have a lot of land that we can deliver that. I think now it's a political driver to do it* (Respondent 8)."

3.2. Barriers to the implement of green infrastructure

Statements were regarded as being a barrier if the interviewees' mentioned words such as "barrier", "challenge", "issue", "concern", "lack of", "problem", "risk" and "trepidation". A total of 23 references were identified as barriers, which were divided into three broad categories: biophysical, socio-political and financial.

The primary barrier identified was the insufficient funding to support the GI practices. It was mentioned frequently by ten of the respondents, and they emphasised this issue using words such as "biggest" and "mainly". The lack of funding (including ongoing maintenance) was considered as a barrier in both countries.

In the UK, developers are concerned about the high upfront investment costs meaning that SUDS is not considered to be a priority issue. In China, financial resources come mainly from government grants at this stage because GI does not directly generate economic benefits to attract private investment. The construction and maintenance of GI such as restored wetlands are expensive. For example, one respondent felt that financial issues were important for the implementation of GI in China.

"*The money is the biggest issue though many different bodies want to push the implementation of the project. The problem is where the money [comes] from. Bank loans might lead to financial imbalance. Currently, the SCP projects rely on government grants since it is difficult for communities and companies to foresee the profits, unlike highways and other large-scale public projects which can generate large, short-term profits* (Respondent 2)."

Another respondent from the UK agreed:

"*And to a certain degree, some sustainable drainage can be quite expensive, especially in cities like London, because there's so much underground, you might sometimes have to move a service like a utility, and it is just very expensive. And in the current economic climate, sustainable drainage doesn't feature highly; there are more important things, we've had our road budget reduced, and actually finding extra money for sustainable drainage is quite difficult* (Respondent 8)."

Financial pressures have a series of effects, one of which is the maintenance problem (mentioned by ten of the respondents), which is related to other issues such as engineering techniques, design, responsibility and monitoring in long-term management. One UK respondent mentioned that:

"*Maintenance responsibility is always an issue as this presents a financial burden to the organisation responsibility (or at least it is perceived to), because without the management and maintenance in place, GI can go either way, it can grow really wildly and become the proper natural environment, or it can completely even disappear if it is not being maintained properly* (Respondent 5)."

A respondent in China took a similar view when they noted the challenges posed by cost issues.

"*I think, in China, the biggest challenges are probably engineering challenges. And to make the engineering behind the designs workable in the long term, there may be cost issues regarding maintenance* (Respondent 6)."

The engineering challenges require previous case studies and project guidance for the practitioners to follow, but a lack of relevant monitoring data has caused difficulties for them to perceive the performance of SUDS and improve better. The UK respondents showed that GI projects were rarely monitored. Four of the respondents said they had tried to monitor project performance at a basic level, for example Australia Road project in London monitored water flow and water quality with the water companies as part of a partnership (Respondent 8), but most projects do not monitor performance.

"*We don't have funding for the equipment installation and external expertise, so we have to find additional funding to implement the proper monitoring programmes* (Respondent 5)."

Respondent 10 stressed the importance of monitoring.

"*Almost 90% of the SUDS projects have no form of monitoring...you have a big gap in knowledge of how much of the installations are beneficial, especially if you are interested in long-term performance...So, monitoring data is very, very important. And that's one of the main barriers as to why they don't understand how well SUDS perform in the UK or in England...* "

In China, pilot sites require monitoring to be included in the initial aims of the project (mentioned by Respondents 11 and 12). In China, the projects are mainly maintained by the municipal administration, while if it is a private project, the responsibility would be on the housing compound, which finds it harder to monitor outcomes. The short-term funds for maintenance are reserved and need time to test in China. In the UK, the interviewees mentioned that maintenance was the responsibility of a more diverse group, which includes local authorities, landowners, local communities and private contractors.

Additional challenges specific to GI are socio-political barriers, including the absence of political leadership and the developers' role at the planning stage; the insufficient power of GI in regulations and policies; and weak governance and unclear responsibilities due to several institutions being involved. This issue was mentioned by half of the interviewees.

In China, most of the developers are often solely focused on the economic benefits rather than the provision of ecosystem services. In the UK, the implication of SUDS is not currently mandatory when undertaking new projects. The National Planning Policy Framework (NPPF) is encouraged practitioners and planners to use SUDS but that is not obliged/mandated by legislation. In addition, the regulations surrounding SUDS are rather vague.

One respondent felt the role of developers has not been clearly identified through the urban planning process.

"*The biggest barrier, at least in the context of China, is probably the role of developers, which is something that's very difficult to bring into the picture. Developers are always looking at the economic benefits. And the policy part is quite important, because if it is not in the policy, then the whole idea of GI is ignored* (Respondent 7)."

A UK respondent also reflected that the current legislative system needs to improve.

"*There's no clear legislation about SUDS or GI in the UK. It's not clear who* *should adopt it and why, and who will benefit because although current legislation encourages the implementation of SUDS, it does not say that you have to implement it…* (Respondent 10)".

Another respondent reflected on the fact that the current planning system in the UK is lacking vibrant directions and policies for developers to follow.

"*Local authorities didn't realise there are no policies to encourage GI because the lack of a planning system with specific policies means that developers can ride roughshod over it, and there's such a big presumption for buildings to meet NPPF guidelines…* (Respondent 9)."

In fact, ten out of the respondents highlighted concerns about the lack of understanding, knowledge, education, awareness, and expertise surrounding GI, which is another key barrier to gaining support from local authorities and communities. The general public, industrial workers, engineers, contractors and designers were mentioned as lacking the understanding of GI, which is also a barrier to its implementation.

One of the Chinese respondents reflected upon the fact that stakeholders and decision-makers are lacking a significant understanding of detailed technical and specific information on GI design and construction.

"*Another barrier to SCP is that many people do not understand the technology. Although the Chinese central government published a technical guidance, it is not very detailed or comprehensive. It provides a general concept, lacking parameters for design. The construction departments of various municipalities have published* *some technical specifications, but they are not unified and are immature, and many parameters have not yet been identified and established* (Respondent 2)."

Two respondents mentioned the lack of understandings about GI (i.e. SUDS) in the UK as well.

"*There is a lack of understanding about SUDS. For a lot of people involved in the drainage industry, they tend to understand traditional drainage; sustainable drainage is a new area for them. There is a lot that needs to change* (Respondent 1)."

"*A lot of highway engineers are traditionally-minded and are used to working in engineering projects, we need to change such mindset…I think they all say the public consciousness around it, that there is a massive cultural change needed within the relevant authorities* (Respondent 4)."

As identified above, insufficient financial support, the weakness of the GI policies and regulations, the maintenance of GI, and the lack of knowledge and understanding of GI were the barriers that were mostly mentioned.

Three other barriers included the lack of evidence of benefits (Respondent 4), space constraints for retrofitting urban areas (Respondent 5), sluggish planning process (Respondent 6), and the difficulty of project assessment and the eagerness for quick profits (Respondent 12), received fewer references and were mentioned by fewer respondents when compared to the barriers mentioned above. Biophysical barriers were classified as minor barriers compared to the socio-political and financial barriers.

Appendix A summarises the responsibilities, contributions, challenges and benefits for the related stakeholders (i.e. local authorities/governments, local communities, developers/land managers, the private sector, NGOs/volunteers and academic researchers) to GI, which indicated the lack of involvement of the private sector and NGOs/volunteers in China, more challenges for local communities and more government power in China, and the difficulties of involving developers in both countries.

3.3. Strategies for overcoming barriers

During the interviews, all respondents were asked about the future of GI and made suggestions on how its adoption could be improved. Statements reflecting ideas for overcoming barriers were identified if they included words such as 'need' (e.g. 'needs to change', 'it just needs', 'I think it/they need'), 'think', 'suggest', 'recommend', 'could/should', 'make sure' and 'ensure'. Most suggestions were proposed based on the barriers that the participants had referred to previously, and the positive impact of new actions were discussed by some of the respondents. It was found that most respondents could identify general strategies for overcoming the barriers to GI, such as imparting knowledge and raising awareness. Some respondents explained these in more in-depth and highlighted some specific actions that it should be taken.

The solutions to overcoming barriers of GI implementation were sub-divided into nine categories including the raising of knowledge and culture change, more sustainable financial mechanisms, greater funding for technical innovation and expertise, changes of legislation, more stakeholders involvement, more pilot studies and experiments, low maintenance of GI, and the promotion of governance. Addressing misconceptions, prejudices and disconnects are common suggestions.

The most prominent strategies - raising understanding and awareness, community engagement and communication, and cultural shift and changes - are more generic and apply to all GI projects that modify the local environment. It suggests that general improvements in education and outreach can tackle specific GI barriers relating to lack of knowledge and understanding. This strategy empowers decision-makers and local communities to take action. A respondent mentioned the importance of knowledge transfer.

"*It comes down to making people aware of it, giving people knowledge of what it can do and how it works* (Respondent 9)."

Another respondent suggested that some practices, such as improving education and media reporting perhaps is a good way to increase public awareness of GI (i.e. SCP) in China.

"*I think the government needs to take some actions like education and news through social media after the construction by encouraging citizens to visit the project, and promoting awareness of the success of the SCP project* (Respondent 3)."

"Cultural change" or "cultural shift" was mentioned 19 times, mainly by UK respondents. Respondent 4 mentioned it most (11 times) and highlighted that massive cultural change is needed within the relevant authorities and the public to understand the value and benefits of GI. The organisation he worked in has run some successful public education programmes and he believes that large-scale cultural change is needed in the whole organisation, which could then affect political decisions.

"*I think that's increasingly in the future where we might try it and through community education, and then start trying to enable cultural-political change within politicians, which I think is quite a big job.*"

At a higher level, the political problems associated with changing legislation, regulation, and planning guidelines were proposed by six of the respondents. For instance, Respondent 1 mentioned that there was a need to: "*improve a legal requirement to produce and deliver a GI strategy*". Respondent 10 commented that governments needed "*to enable SUDS by improving our knowledge and make it mandatory policy*". Respondent 9 also suggested putting GI in the very early planning stage.

"*The changing of legislation will solve many other problems at the root. Enhancing the knowledge and assigning responsibilities to corresponding stakeholders are needed to ensure legislative clarity*".

The generation of new knowledge and policy needs the contribution of pilot studies and experimental projects. Respondent 12 mentioned that in China:

"*The concept of Sponge City should be integrated into the construction requirements of any new city blocks in the future. They should adhere to the implementation guildelines and have careful supervision and monitoring, but they should not be too fixated on short-term results and profits*".

Respondent 7 also believed that SCP projects are expected to generate a new round of knowledge in the context of China, when given that, in the next two or three years, but probably from 2020 onward, those experimental projects would be evaluated, and then new policies and practices would be produced during this process.

Another concern is to overcome financial problems, which was referred to by all of the Chinese respondents as well as two of the UK ones. Adequate financial resources and new financial mechanisms could help improve technical innovations.

Since maintenance has been one of the key barriers to GI implementation, any corresponding solution should include the design of low-maintenance GI in the early planning stages.

In addition, other ideas such as more transparent governance, stronger collaboration, better early-stage planning and greater stakeholders involvement were also suggested for improving the adoption of GI.

3.4. Differences between GI approaches in the UK and China from the interview analysis

The differences of GI in the UK and China were categorised into five aspects based on the answers given in the interviews: aims, design aspects, scale, stakeholder/public participation and planning processes, and financial resources.

First of all, the space and investment scale of projects in China are generally on a larger scale than the UK ones considering the size of the country and its population. Some of the respondents noted that the scale of the projects is often very different between China and the UK.

"*The scale of SCPs in China is much larger than SUDS in the UK. I think this is an interesting thing, the sort of socio-political, you know; we've got quite an archaic system in some ways in the UK* (Respondent 4)."

"*In the UK, most projects are small scale, like community scale, and the money comes from communities. The reason is that compared to China, the UK is much smaller, both in terms of population and area, so the projects do not cost as much as they do in China* (Respondent 2)."

The planning process of projects is different as well. In China, it tends to be top-down, with less public and stakeholder participation, meaning that projects tend to get pushed through faster, though there is a corresponding lack of transparency. The UK, in contrast, tries to get more stakeholders involved in the project, which helps to create more initiatives from the bottom up. However, the overall process is slower.

One UK respondent noted the governance system is different between the two countries.

"*I am afraid the Chinese approach and the UK approach differ. It's quite top down in China, I believe, so the notion of SCP is a great one and obviously if the people with power decided it's something they want, it will happen quite quickly...while for most people here in the UK it's very different - there are a lot of stakeholders and the money is not always available* (Respondent 1)."

Another respondent from the UK noted that although the participation process in the UK is able to include a wide range of opinions from stakeholders, it could be a challenge because:

"*In the UK, I think the whole planning process is a big challenge and trying to go into communities and go through the stakeholders' workshops, just to get everything works, a lot slower in the UK, so that's always quite a big challenge to actually get things agreed with all stakeholders in a meaningful way* (Respondent 6)."

The financial resources also vary between the two countries. One respondent reflected that the tax system in the two countries is different in terms of generating project funds from the taxpayers.

"*China has an advantage in that it is a heavy tax country compared to UK, which means the financial department and the National Development and Reform Commission will grant the money to approve big projects like public-interest projects* (Respondent 2)."

Interestingly, one of the Chinese respondents from China suggested that the Public-Private-Partnership (PPP) scheme could be a new way of tackling the financial challenges of implementing GI in future.

"*Now, PPP is trying to get more private investment, rather than just rely on the government public funds* (Respondent 6)."

In China, funding comes mainly from government grants, and PPP is an innovative financial mechanism for SCP that can attract more private investment. However, this scheme is still at the pilot stage and is therefore not mature.

By contrast, the funding for SUDS in the UK comes from a wide range of sources, ranging from the EU to the UK water companies and local authorities; however, the budget for SUDS in local authority could run out in a few years. Some factual and technical barriers in the UK have also caused such difficulties in raising enough funds to cover the duration of the project.

"*In our case (UK)...it's quite a wide range and you can get quite different areas of funding because its multiple benefits* (Respondent 5)".

"*...Mainly from local authorities, but I think that funding dries up after only one or two years, and then there'll be no more* (Respondent 8)."

4. Discussion

There has been an increasing awareness of the benefits of GI regarding water quality and flow protection in recent years in both the UK and China (UK National Ecosystem Assessment, 2011; Liquete et al., 2016; Fenner, 2017; Chan et al., 2018). Despite significant differences in the political and social systems of the two countries, this study has found a number of similarities regarding the enablers and barriers for the implementation of GI strategies to urban flood management.

A key similarity identified by this study is the importance of multiple benefits of GI as a main enabler for GI implementation. This is concurrent with other studies such as Natural England (2009); Arup (2014); O'Donnell et al. (2017). However, multiple benefits can be viewed by decision-makers as being too broad and not specialist enough (Luker, 2014). Multiple benefits are often perceived as ancillary rather than being the primary purpose of GI (Finewood et al., 2019). The available scale will also be a limitation in ensuring the multiple benefits that can be achieved.

In addition, the beneficiaries of GI need to be elucidated. The beneficiaries identified in this study by the respondents (see Appendix A) are the public as the number one priority, and others including the government/local authorities, local communities, land developers and managers and the private sector such as water companies. The main beneficiaries of GI would be residential neighbourhoods, because GI would reduce flood risk, increase community resilience, and lead to a better quality of life and for an education purpose. However, the effectiveness of GI, taking an example of concave green land in one of the sponge cities - Shanghai varies spatially, implying sound spatial planning and a potential combination with other flood mitigation measures (Du et al., 2019). For land developers and asset owners, they make profits due to the elevated property value added by GI. Regarding the benefits to government, such as extra work for the construction industry and urban design institutions, they save costs and investments in drainage pipes by conserving more water. In the long term, the government could decrease costs alongside mitigating climate change and flood management, as well as improving health and wellbeing (CABE, 2005; Northwest Regional Development Agency, 2008; Collinge, 2010). There will be a cultural shift to boost the green economy and form a healthy developing cycle.

The importance of social effects and microclimate adaptations were mentioned by respondents in both countries as being among the benefits that GI can provide. GI is valued by communities, not only for stormwater management but also for opportunities to distribute benefits through capital expenditure, job creation, expanded green spaces for recreation and education, and related economic growth across the community (Finewood et al., 2019). In contrast, grey infrastructure lacks involvement and engagement with community sustainability initiatives.

The findings in both countries showed that high-level buy-in was identified as an enabler. In China, political buy-in, commitment and leadership need to be strong at the national level, while within the UK political buy-in happens more at the local level and vary between different local councils. In some cities or local communities, the leaders are in favor of GI because of the demand for more open space, localised flooding and higher environmental quality. In some other places, the leadership is lacking as local decision-makers such as mayors are not willing to push GI, even if their communities try to pressurise them to do. This is because they are not obliged to adopt GI measures (Šakić Trogrlić et al., 2018). Despite these differences, both countries would benefit from further research on how best to demonstrate the benefits of GI to high-level stakeholders so that they can invest in the projects.

One of the most highly cited barriers in this study was a lack of funding for GI projects. This finding agrees with earlier studies (Tryhorn, 2010; Thurston, 2011; Porse, 2013; Keeley et al., 2013; Copeland, 2014; Huron River Watershed Council, 2014; Dhakal and Chevalier, 2017). Despite the cost-effectiveness and multiple benefits of GI compared to grey infrastructure, the lack of financial support for GI is surprising.

Legal restrictions discourage investments of public funds in private properties, and developers often do not have a strong motivation to build GI projects since investment costs are often greater than economic profits in the initial period (Keeley et al., 2013). The investment scale for GI is larger in China than in the UK. The greater initial investment for SCP in China is different to SUDS projects in the UK, where developers provide small financial incentives if sustainable flood management is incorporated into local development plans and adheres to non-statutory standards (Lashford et al., 2019). It is estimated that investment in SCP construction will be between 100 million RMB (equivalent to £11 million) and 150 million RMB (about £17 million) per square kilometer (Ministry of Finance of China, 2015).

PPPs are encouraged to provide finance for SCPs because further funding sources need to be found. The Chinese government's funding plans only last for three years, but some factors suppress interest in the projects including inadequate investment and return estimates, perceived high costs of design, construction and maintenance for SCP and inadequate public engagement. Therefore, the role of PPP in the construction of SCPs is still limited. According to the Ministry of Finance of China (2015), 56% of PPP projects are still at the identification stage and only ten projects entered the implementation phase. Grants and municipal funding are the main financial resources for most projects in China, and the barrier in the next stage of promoting the SCPs (namely, expanding the SCP and GI into larger areas in Chinese cities) is the fact that they are increasingly relying on PPP.

The PPP financing model has been chosen to bridge the huge investment gap for the SCP, which has numerous advantages. This is the big difference between

China and the UK. The UK could learn from this in order to find more investment sources. However, some critical risk factors for PPP projects of GI should be noted in advance such as inadequate policies and regulations, project fragmentation and unclear catchment area boundaries (Zhang et al., 2019). Therefore, the PPP for GI projects should have an explicit project boundary in order to efficiently establish the payment mechanisms and performance evaluation criteria.

A key problem for the financing of GI stems from the lack of mature markets for most ecosystem services due to the limitation of current evaluation tools to monetise them. There are many tools and procedures to assess the wider benefits of SUDS, but few have provided a monetised result (Ashley et al., 2017). In the USA, the Center for Neighborhood Technology developed a monetisation tool for SUDS (Center for Neighborhood Technology, 2007); in the Netherlands, the Teeb urban tool has been developed for valuing blue-green infrastructure (BGI) (Van Zoest and Hopman, 2014); while in the UK, CIRIA has developed the Benefit Evaluation of SUDS Tool (B£ST) for assessing and monetising the financial, social and environmental benefits of BGI (CIRIA, 2015). In the updated 2019 version, 15 monetised and three non-monetised benefits could be assessed and calculated.

However, B£ST does not account for every individual circumstance or site-specific nuance which relies on the user to contextualise the scheme into the framework of the tool, nor does it provide a detailed distributional analysis of where the benefits will accrue (Fenner, 2017). There are still some risks that there are overlaps between amenity as defined and valued in B£ST and other monetised benefits (particularly water quality, biodiversity and recreation), the guidance highlights the need to avoid double counting in this context (Ashley et al., 2018; Ossa-Moreno et al., 2017). There are some financial and economic analysis for SCP in China but without a commonly used tool for free. The benefits of SCP projects in the economic assessment are quite limited compared to B£ST with 18 types of benefits (Liang, 2018). The analysis from the perspective of the project manager shows the SCP should not be invested in, because the water projects are financially unfeasible. China lacks such monetised tools to evaluate wide multiple benefits of SCP and socio-cultural effects are not put into the assessments.

Hence there is a shared research priority between both the UK and China regarding the monetisation of the benefits of GI and the development of new funding streams. In the future, research about the monetisation of GI using more methods such as the investigation of relationships between "willing to pay (WTP)" and interpretations of the nature and function of GI are strongly recommended for China. Assessments of the success of SCP through modelling and evaluating of the impact of GI could provide enough evidence that GI should be given priority in the future projects, which will then increase the confidence of decision-makers to take the the initiative and their further potential engagement in the process more fully.

The study also found that maintenance cost is a barrier to the implementation of GI. This was particularly the case for the UK, which has a more decentralised system than China. In some cases, confusion about who owns and maintains GI, or poor coordination between those responsible for the work can also cause problems. For example, the interviewees in the Newcastle Case Study (O'Donnell et al., 2017) mentioned that securing for maintenance funding was mentioned as a barrier with over half of interviewees. Moreover, due to the fear of improper maintenance and attitudes to avoiding the perceived burden of risk, landowners often balk at taking responsibility for maintenance, and discourage the installation of GI on their land. It is therefore imperative that the involved key stakeholders such as landowners, developers and local authorities are educated as to the cost-benefits of GI in urban cities, which is important for reinforcing funding support and for help in clarifying maintenance responsibility.

In both countries, barriers to GI and sustainable water management extend beyond the financial into relevant biophysical and socio-political spheres. Socio-political barriers were perceived to exert a more significant negative effect on the widespread implementation of GI than the technical challenges in both countries. The most prevalent socio-political barriers were the lack of knowledge, perceptions, attitudes, mind-set, fear and other intangible factors that make policy-makers, landowners and water resource managers reluctant to change and install GI –an issue that was highlighted by 9 out of the 12 respondents.

Despite being regarded as an underpinning element of urban sustainability, the slow adoption process of GI is mainly blamed on socio-institutional and cognitive barriers (Brown and Farrelly, 2009; O'Donnell et al., 2017). Other barriers including resources and policy barriers are essentially the result of these two barriers. Social acceptance is arguably the most decisive driver of technologies, which can be facilitated by enhancing education and knowledge of GI. Increased social acceptance could help formulate other pro-GI policies and programs more easily and encourage lawmakers to make favorable policy decisions.

China adopted a top-down policy for initiating SCPs directly, but a less organised civil society and less cooperation among different institutions in China have shown that there are greater challenges for GI in relation to the public engagement in the early stages in these projects. In China, public participation is limited and carried out at very late stages for real inclusion in decision-making and the limited public survey, has barely influenced the final decisions of administration in fact as in China the process is rather more top-down and centralised, headed by the administration from central government and moving to provincial to municipal and then local government (Zhou, 2015; Neo and Pow, 2015). China could learn more about public engagement and behavior change from GI projects in the UK. The implementation of SUDS in the UK is different to the SCP approach in China. It is more a piecemeal and bottom-up process, mainly dependent on support from local “SuDS Champions”, rather than by legislation (Lashford et al., 2019), meaning that it is easier to involve the public at the early stage. The UK seemingly has more open and transparent planning systems than China in procedural terms, with regular meetings with multiple stakeholders developed under a carefully planned and chaired programme (Llausàs and Roe, 2012). The conditions for the successful initiation and implementation of pilot schemes is the continuous participation of local communities and stakeholders in the planning, design and maintenance phases (Di Giovanni and Zevenbergen, 2017).

The use of public involvement, education, clean-ups and outreach programmes can involve the public in the early stages of GI, which is more likely to lead to successful final decisions and outcomes. China could draw on the experience of GI projects from the UK through these activities and schemes that in tandem with local authorities, local communities and water companies. For example, the Thames Water Company in the UK participated in schemes with local authorities and local communities such as ‘Twenty 4 Twenty’ and ‘Thames21’, which included education, training and campaigning to help people take over ownership of GI projects in their communities in order to create initiatives and a lasting legacy for their communities (Thames Water, 2019). For example, one such scheme at the Queen Caroline’s Estate in London where several sustainable drainage measures were adopted, now drains 1.2 million litres of rainwater every year thanks to the removal of impermeable surfaces (Thames Water, 2018).

In both countries, insufficient evidence of cost and performance due to the absence of monitoring data has resulted in industry professionals doubting the reliability of GI (Porse, 2013; Copeland, 2014) giving rise to liability concerns over the implementation of the technology (Olorunkiya et al., 2012). This barrier is often cited in other studies such as (Copeland, 2014; O'Donnell et al., 2017; Dhakal and Chevalier, 2017) making GI appear risky to the policy-makers, municipal staffs and the general public, discouraging them from adopting GI (LaBadie, 2011). The absence of historical data, of higher costs and lower performance levels of GI, as well as misconceptions, combined with risk-aversions attitudes, are the most often-highly cited reasons for the reluctance to adopt GI (Dhakal and Chevalier, 2017; Clune and Braden, 2006; Van de Meene et al., 2011). In addition, the limited opportunities for formal coursework, research in university and college, and on-the-job training cause a shortage of trained professionals in GI design and installation (US EPA, 2014; Clune and Braden, 2006; Tian, 2011). Therefore, both countries would benefit from long-term monitoring and evaluation of GI and from a two-way knowledge exchange between researchers, developers and decision-makers both within and between the two countries.

5. Conclusion

This study has found that despite the political, cultural and social difference between China and the UK there are many similarities in the enablers and barriers to the implementation of GI. This suggests that both countries share research priorities and there are opportunities for knowledge exchange.

In both countries, multiple benefits were seen as the primary enablers of GI rather than grey infrastructure. Stormwater runoff reduction and flood control were the main functions, and the social effects and microclimate adaptation benefits that GI can provide were also highlighted as important enablers. It is important that the synergies between benefits provided by GI are well demonstrated and communicated in both countries so that they are appreciated and not overlooked by decision-makers.

This study also found that the most important barrier to increase the implementation of GI was related to finance, both in upfront costs and maintenance. While the central Chinese government has ensured funding for GI, implementation is reliant on public funding which may not be sustainable and could be holding back the delivery of a number of SCPs. In the UK most funding must be found at local levels which prevents large scale adoption of GI. Therefore, research into the monetisation of the benefits of GI and identification of additional finance streams for GI implementation is critical for both countries, and a shared research is also essential.

In both countries, barriers to GI and sustainable water management span the financial, biophysical and socio-political spheres. The most prevalent socio-political barriers were lack of awareness, knowledge, and education, with other barriers including resources and policy barriers resulting from these two barriers. Long-term monitoring and demonstration of the benefits of GI could help overcome these, along with knowledge exchange between researchers, developers and policy and practice decision makers. The roles of stakeholders also should be clarified in implementing and delivering of GI.

We recommend that both countries share information and learn from each other, as well as from other countries, to further improve the GI implementation and practices. China should follow the UK's lead and increase public participation in GI projects through education, outreach, clean-up and other voluntary programmes, while the UK could adopt alternative, innovative financial mechanisms that have been applied in China, such as PPP. The UK and China are becoming increasingly interested in developing joint research priorities (with GI and SCP) thereby ensuring multiple benefits from GI projects, new finance streams to support their wider adoption, showing their value to both public and private developers, and increasing awareness at the government and community level for higher buy-in to schemes.

Finally, there have been many successful case studies and best practices about GI in urban development. Thus, it is essential that international knowledge-sharing and cooperation is increased through personnel training, technical consultation, expert guidance to enhance more effective and wide-reaching joint partnerships.

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Appendices

A. Related stakeholders and beneficiaries of GI projects from interview analysis

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