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Assessment of Sustainable Building Material and the Benefits of Green-blue- grey Infrastructure for Feasible Urban Flood Risk Management

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Abstract- The green infrastructure has some other benefits besides flood risk reduction. Those benefits mainly covers conservation of water, energy, and improvement in air quality and much more. The materials used are the essential components of the green infrastructure. The proper design accompanied by the material properties provides the accountability of the mechanical strength of the infrastructure. Hence, the eco-friendly materials are given more priority for green infrastructure. The price is considered primarily when either selected or r4elated material is compared for the similar purpose. Except the social and environmental costs, the cost of the building element conveys only the cost of transportation and manufacturing. Therefore, the sustainable development of the nation relies on the proper choice of the construction materials having least burden on the environment. Moreover, the result of mixture of blue, green and grey infrastructure is likely the best adaptation strategy as these comply with each other. The grey infrastructure reduces the flooding risk while the green infrastructure has its own multiple benefits which is not offered by the grey infrastructure. The paper focusses on the contribution of the sustainable building material in order to reduce the impact of environmental degradation which could help in identification of the strategies that are highly effective in improving the urban flood risk management.

Index Terms- Sustainable material, decision making, urban flood risk management, Green-Blue-Grey infrastructure.

I. INTRODUCTION

Currently, the mass increase in the urban population is expected in the future (United Nations,2014). For a proper enhancement of sustainability and liveability in urban areas and ensure safety in urban and attractive living and working spaces. But the change in the. Climatic condition along with the urbanisation expose this at risk with issues such as increase in the risk of flooding, heat stress, scarcity of water and the environmental pollution (IPCC, 2012). Green-blue infrastructure endeavours the multifunctional approach for the reduction of vulnerability and rise of resilience against the different threats (European Commission, 2012a). The use of almost 40% of resources extracted from nature along with 70% virtual consumption of electricity, 12% of potable water and production of 45%-65% of waste disposed in the landfill leads to the tremendous impact of building on the environment in the industrialized nation. There is an additional responsibility of the building for the huge amount of emissions that have a harmful impact on the environment which accounts for 30% of the greenhouse gasses accompanied by the 18% of indirect induction due to exploitation of material and its transportation. From the environmental impact perspective, the building sector has momentous consequences on the environment due to the consumption of 40% of the raw stone, gravel and sand along with 25% of the raw timber used throughout the world annually. It is necessary to select the materials and the layout for the general sustainability. Different researches are carried out to find the alternative sustainable building material along with the minimal technology methods. The grey or traditional methods such as pipes mainly focussed on the flood management in olden days, but currently this method is least sustainable whereas the green-blue infrastructure has its own benefits (Vojinovic, 2015).

In a customary flood the board measure evaluation, just the essential advantages of the flood harm decrease are thought of. For this situation, the evaluation incorporates a few auxiliary advantages that is co-benefits, notwithstanding the flood harm decrease. For example, heat pressure decrease, air quality improvement and water reserve funds. These co-benefits are related with the utilization of green and blue measures. The outline of the entire methodological cycle is demonstrated as follows. The essential advantage, seen here as the advantage acquired structure flood harm decrease, is assessed by anticipated yearly harm (EAD). EAD is the probabilistic expected flood harm cost every year for all conceivable flooding occasions and is communicated in money related terms. The flood harm decrease is then determined as the contrast between EAD on account of the same old thing (without measures), and EAD after the use of flood decrease measures.

CBA requires the measurement, all things considered, and benefits in money related terms. This is accomplished here ascertaining the money related worth every time of each important co-advantage got from GBI application (other than the essential advantage. The expansion of EAD decrease and yearly co- benefits (ACB), both because of the utilization of a particular measure or measures blend, is the estimation of all out anticipated yearly advantages (EAB). In the interim, the figuring of costs considers speculation and upkeep expenses of each applied measure. When absolute advantages and expenses are assessed, both are changed over to the net present worth (NPV). This permits the examination of these figures, seen as present estimations of expenses and benefits, and to build up which is higher over the venture life expectancy.

Calculation of Benefits

The initial step to assess co-benefits is the recognizable proof of locally pertinent advantages and material measures to accomplish these advantages. In this work, this is cultivated through a multi standards strategy for measures determination (Alves et al., 2018). This strategy depends on the inquiries with respect to neighbourhood qualities and favoured advantages. A positioning of green, blue and dark measure is manufactured utilizing the appropriate responses given by the chiefs to these inquiries. From this positioning, various blends of measures are chosen for additional examination. After the choice of measures, and the ID of advantages from them gave, the subsequent stage is the financial worth estimation of these advantages. This is accomplished understanding the connection between impacts on the earth and the ensuing human government assistance. A decent portrayal of these associations is given through the idea of effect pathways.

The demand for building material has its own form in different ways. As mentioned, the observation of grey energy & emissions must be done along with usage of high value energy as compared with building operation during the production of material. The by-products of the materials that are used has various environmental issues. Every building material used, has its own limitation for the extraction of resources. As a solution for the complicated reduced resources, corrosion, pollution, durability, lifespan and much more, the different technological methods are used. Firstly, more sustainability should be kept in mind at the time of constructing a new building that will not only help in reducing negative aspects with its operation and instead improves the life of the building which is mainly done when the design feature that outdates it rapidly are removed. The necessary factors that are required with the least lifespan are to be designed in such a way that it could easily be recycled or recovered in the form of raw material. The complexity of the building is broken into components to achieve a complete sustainable solution. Finally, at the time the lifespan of the building ends, the processing of the materials should be done in an extremely careful way. The composites that are not easy to handle are minimised and considered carefully during the design stage of the building. The materials that are used should have the ability to get recycled immediately so that the re-manufacturing of those materials is not required. Some materials are easy get recovered in the form of raw material if they are unable to get reused immediately. For the same material to be reused, it should be used in the similar quantity which results in the reduced waste.

II. MATERIAL SELECTION

The main ingredient of the high-performance building effort are the building materials that are environmentally responsible, stable and attractive. The occupant's wellbeing and connection felt with the natural world is due to the use of healthy and natural materials. Considerable environmental effects are seen in some building material due to the pollutant release, destruction in habitat and natural resource depletion. These things mainly take place at the time of extraction, procurement of raw material, the process through which the raw material is processed and produced along with transportation. When the building occupants and workers are exposed to toxic hazardous chemical which may result in harming their health. For reduction or prevention from environmental and health impacts, the building phase should be considered for selection and identification of materials to be environmentally preferred. Through the process of resource conservation and selecting the materials that are non-toxic helps in selection of materials that are environmentally attractive and with minimal impact on environment. During the process of manufacturing of the construction material, the resources used are responsible to affect the environment by diminishing the natural resources. For feasibility on the building procurement decision, the process is known as the environmental life cycle assessment. There is possibility for application of lifecycle thinking for evaluation of known environmental performance of materials.

III. LIFECYCLE OF THE SUSTAINABLE BUILDING MATERIAL

A better perception on the long-term cost of material is found when the raw material is collected till, they are disposed. The cost is paid by the owner, occupant and the environment. The building materials are selected due to the proper guidelines offered by the principles of the lifecycle design. The environmental impact inspection is done for every phase of the process of manufacturing starting from the gathering of

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the raw materials manufacturing, distribution and installation till disposal or recycle (Jong-Jin Kim et al., 2006). The cost benefit analysis is enabled by the assessment of environmental impact of material.

Pre-Building Phase

The pre-building phase shows the production and delivery process of the material except point of installation. This includes, gathering raw material in nature and transportation to a building site after extraction and packaging. The building materials are selected wisely when the environmental impacts of the pre-building phase are known. The environmental implications consist of procurement method of raw material, process of manufacturing and distance between manufacturing location to the building site (Jong- Jin Kim et al., 2006).

Building Phase

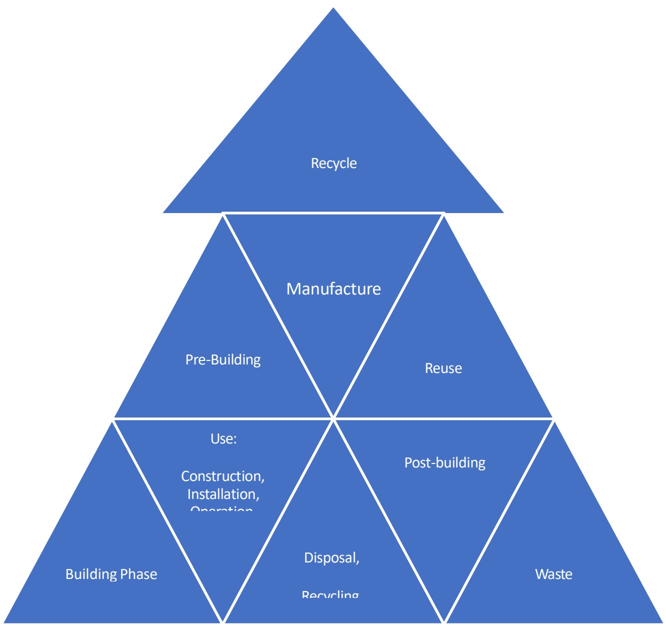
This Phase mainly refers to the useful life of the materials used in the building. The point at which the materials are assembled to be used in the structure including the maintenance and repairing the material combined together to commence the building phase. The overall health of the building's occupants could be harmed if some of the building materials are exposed for a long time. A little focus is given at the time of selection of the materials so that only materials with potential of the materials that could outgas the harmful chemicals with a demand of regular maintenance of such chemicals or where the replacement is required due to the perpetuation of exposure cycle.

Post- Building Phase

This Phase refers to the stage at which the performance of the materials used in the building runs out. Basically, there are three possibilities mainly: If the materials could be recycled, some of the elements or few of them could be reused or the last possibility is the material to be thrown. Perhaps the minimum measured and least known step of the building life-cycle occurs from the perspective of the builder when the useful life of the building material has been exhausted. A major environmental expense is the demolition of the building and clearance of the resulting waste. Degradable materials can alone or even in mixture with many other materials produce harmful waste. Gradually, a very less landfill space is utilized by the inert materials. The energy that goes inside the materials in the construction gets sustained when the present structure gets recycled. Due to the ineffective utilization of the resources will waste the energy that exhibits the construction of the materials along with the manufacturing of the materials.

Development of Green Building

A new building philosophy that is emerging as the application of environmentally friendly material, consumption of lower waste as a strategy for conservation of resources mitigating the effects of the buildings along the life-cycle. This also leads towards few benefits such as financial, economic, environmental and social. High efficiency illumination and insulation system along with the planned material selection process according to the potential of the material can help in saving the cost of maintenance and operational costs in the green buildings. The reflection of the daylight roof is the best example of this benefit. Some more advantages of the green building could be mentioned as reducing the health costs and the level anticipation of satisfaction of employees towards the area of work escalates the productivity. Besides these, the Philanthropy of the builder and the building and the anticipated added value should also be taken into consideration for the proper guidance of the decisions of investors and the future owners. In spite of the benefits that are shown green buildings are yet to be regarded as projects that are attractive as most of the time expensive technologies are related to the green features that automatically increases the cost. The selection of material in a comprehensive manner and design process done carefully apart from investment elevated in terms of technology this sometimes acts sufficiently so that ideal objectives for the environment could be accomplished easily. It is observed that insufficient difference between the average investment cost per square feet for some green buildings is supported by some of the researches. A better dividend for a long run is provided by the green buildings that recovers up to 10 times the green premium after the anticipated benefits are realized. The quality and the effectiveness of the green systems installed is considered to be an achievement. Hence, a common approach is demanded so that green building and traditional building could be differentiated with the use of current standard ensuring the achievement of green building requirements at a minimum.



Phases of the life of the sustainable building materials

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IV. COMPONENTS OF SUSTAINABLE BUILDING MATERIALS

Usually, cost is considered as primary at the time of assessment of the related material or the materials selected for the purpose of same function. Mainly, three tier criteria is finalised in accordance with the life cycle of the material mainly used to consider whether the building material is environmentally sustainable. Some of the components of the building material that are present do not stops it from becoming environmentally sustainable. The sustainable building material has few components that are well known and mentioned in the table:

Components of the Sustainable Green materials

Design principle of Sustainable building

The various principles of the sustainable building design are:

Robust Interior Environment

Different necessary steps and measure should be adopted to make sure that building systems and the materials are not emitting any toxic gasses or substances into the interior atmosphere. Additional measures are also adopted for the proper cleaning of interior air with the planting and filtration.

Efficiency of Energy

It is made sure that energy used in the building is minimum by following all possible measures. The products that consume less energy and conserve the energy are to be used and more prioritized.

Eco-friendly Materials

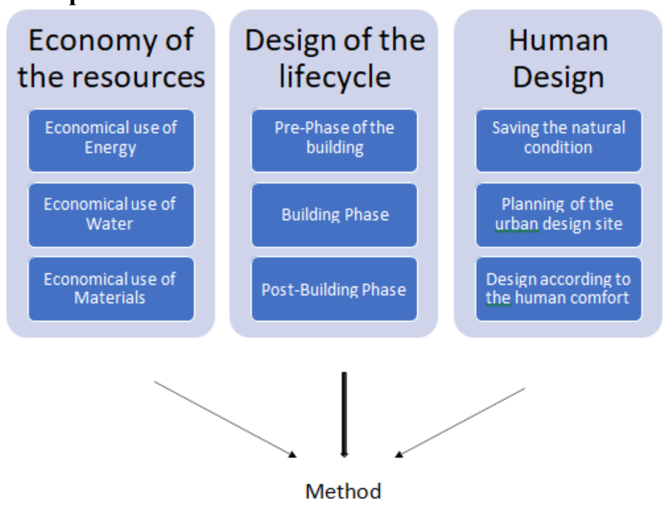
It is made sure that only the building materials that reduce the environmental destruction should be used by fo9llowing different possible measures.

Environmental Form

Different steps and measures are to be followed in order to relate the building form and nature with inhabitant in a peaceful way.

Conceptual framework for Sustainable design and pollution prevention

Principles



Concept of Blue-green Infrastructure

The main aim of the blue-green infrastructure is to create an artificial hydrological cycle while its contribution to the facilities of the area giving more priority to the water management and green infrastructure in a synchronised manner (Hoyer et al., 2011). Preserving and combining the ecological and hydrological values in the urban area at the time at which adaptive and resilient measures are provided at the time of which the flood events are dealt. The main function that are included are restoration of the natural drainage channels, improvisation in the water quality, imperviousness reduction, increase in infiltration, Surface storation and use of water retention plant (Novotny, V. Ahern & Brown, 2010). The blue infrastructure consists of the small water reservoirs such as ponds, flowing waterways, wet detention basins, wetlands existing between the network of drainage while the green infrastructure indicates towards the natural land and plant-based process of ecological treatment system. This consists of the open area, grounds, parks, garden and places undergoing wet/dry cycle because of the runoff flow such as trees along the road/street, green roofs. A wide range of services are generated by the blue-green infrastructure that consists of regulation of climate, supply of water, pollution control and hazard regulation and ability of adaptation and mitigating changes in the climatic condition (Maksimovic et al., 2013). The direct attribution of the benefits is often seen as absent when the surface water and flooding is managed using the traditional grey infrastructure. A network of the blue-green infrastructure is proposed with the connection and interaction of blue-green assets for treatment and management of the urban runoff and flooding with expansion of the benefits is the main concept of the blue-green infrastructure. The highly urbanised catchments with lack of space usually restricts, the incorporation and retrofitting of the blue-green infrastructure and this also introduces the role of the grey infrastructure in the concept of blue-green infrastructure especially of the events of high magnitude and the occurrence with low probability.

Various Benefits of the Blue-green Infrastructure

A group of environmental, ecological, socio-cultural and economic benefits could be generated by blue-green cities even though, the urban systems are in flood state or not. Primary goal of reducing the risk of surface water inundation during the occurrence of flood is fulfilled by the blue-green infrastructure that performs according to the design standards. Additionally, during the state of flood the quality of water could be improved when the water pollution is reduced due to the Blue-green Infrastructure which leads to the controlled water supply and the torrent of negative social impacts occurring after the flood could be prevented (Foster, Lowe & Winkelman, 2011). These mainly involve expensive repairing costs, displacement from homes, damage to health reduction in business and economy. It is also observed that the maintenance and construction of blue-green infrastructure is way cheaper than grey alternative in terms of reducing stormwater runoff and overflowing of combined sewer. There are various benefits such as reduced effect of urban heat island, improved air quality, reduced noise and much more are offered by the blue-green cities when the system in in non-flood state. The ability of cities is also expanded due to Blue-green Infrastructure so that it could easily adapt and mitigate towards the climatic change which is a very vital part of economic regeneration projects. Which helps in the improvement of liveability of urban environment (Newcastle & Gateshead City Council, 2013).

Identification of the barriers for implementation of Blue-Green Infrastructure: Case Study

Newcastle is situated on the northwest bank of the Tyne, Tyne and Wear. In addition to being a statutory consultation for surface water management issues in planning applications, Newcastle city council is the lead local flood authority with responsibilities related to managing flood risk throughout the city. They work to manage flood risk from all sources in partnership with organisations such as the Northumbrian Water and Environment Agency and encourage residents to contribute to reducing their own flood risk. The objective of the joint Newcastle-Gateshead surface water management plan is to remove and reduce the amount of surface water entering the combined sewer system serving the Howdon sewerage treatment works to free up headroom from new development for foul water. SUDS is recognised as a viable approach that developers need to implement. Recent strategic planning frameworks, such as the core strategy and urban core plan for Gateshead and Newcastle upon Tyne 2010-2030, reiterate this point, stating that, given the multifunctional advantages of water quality, green space and habitat improvement, new developments are expected to prioritise SUDS for surface water management (Newcastle City Council and Gateshead Council 2015). Newcastle experienced a serious precipitation event in 2012, where 50 mm (the expected total for June) fell within a two-hour period, causing widespread flash flooding, mainly due to surface water runoff (Environment Agency -

Yorkshire & North East Region Hydrology 2012). This event was estimated to have a return period of 1:131 years and affected more than 1200 properties, resulting in internal flooding of over 500 (Newcastle City Council 2013). Met Office projections indicate that in future winters, such rainfall events in Newcastle will become more common, with high uncertainty surrounding future changes in summer rainfall (Slingo et al. 2014). Newcastle City Council has undertaken work to enhance the resilience of the city since the 2012 events and allocated £3 m for capital works in 2013/14 and 2014/15 (Newcastle City Council 2013). As such, Newcastle is a city that while enabling economic improvement and new development, recognises the challenges of achieving sustainable urban water management. Many stakeholders (as subsequently discussed) aspire to greater BGI implementation and a change in attitudes and behaviours. Some significant successes have been made (e.g, SUDS ponds in Newcastle Great Park, Melbury, and Warkworth Woods), but challenges and barriers hinder greater progress.

V. METHOD

Nineteen professionals from a variety of Newcastle organisations were selected for interview, including the following professional fields: owner/manager of land/facilities (5), investment and development (4), flood risk and water management (2), project management (2), planning (2), communities and households (1), policy and communications (1), environmental consultancy (1) and urban traffic management (1). As most respondents worked within the Newcastle administrative area, the study had a small geographical range (the exception being Northumbrian Water which covers the wider NE region). (the exception being Northumbrian Water which covers the wider NE region). (the exception being Northumbrian Water which covers the wider NE region). Respondents were selected on the basis of their knowledge and participation in water and flood management, urban planning, land and environmental management, and/or other interdependent urban water infrastructure systems, such as transport, communications and development. A wide range of perspectives on BGI were provided by the diverse professional remits of the respondents, but they can be seen as operating within a set of common local and national stresses. Most also showed an interest in the Newcastle Learning and Action Alliance to develop a Blue-Green vision for Newcastle (Lawson 2015). Between 19 March and 13 May 2015, interviews lasting 24-67 minutes were conducted, either face

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to face (N = 5) or by telephone (N = 14). The interviews were semi-structured, enabling respondents to discuss a series of open-ended questions aimed at raising awareness of their views on urban flood and water management and BGI.

Barriers Identified
If the respondents used words such as 'challenge',' barrier',' restriction',' issue',' concern',' trepidation',' lack of',' risk' and 'problem', statements were regarded as pertaining to obstacles. It was easy for respondents to identify a string of challenges they and others could face in trying to support and implement BGI. 184 barrier-sensing references were identified, classified into 17 categories and defined as socio-political, biophysical or both (Figure 1). Socio-political barriers are the five most prevalent. 89% of respondents (accounting for 30 references) indicated that they believe there is a reluctance to promote novel/new approaches to flood and water management and to change practises, typically from traditional grey hard-engineering solutions to more sustainable blue green strategies.

More than half of respondents commented that BGI's lack of knowledge, education and awareness is a key barrier to local authorities and the public gaining support. Securing funding (including funding for ongoing maintenance) was also mentioned by more than half of respondents as a significant barrier.

These three obstacles were most frequently referred to and classified as 'major barriers by the majority of respondents (Appendix Figure 1). 'Minor barriers' refer to those rarely mentioned by few respondents and censored by negative past experiences, competing priorities, future land use and climate. Three biophysical barriers (uncertainties in physical science/engineering, lack of available space, and future land use and climate) were identified: In contrast to the socio-political barriers, they received fewer total references and were mentioned by fewer respondents. Two barriers (maintenance and adoption, and the identification and quantification (monetisation) of multiple advantages) that include 6th and 7th ranked biophysical and socio-political factors.

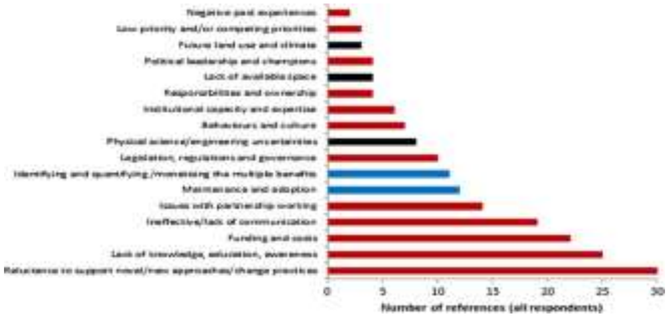

Figure 1 Barriers to the implementation of Blue-Green Infrastructure in Newcastle.

Red= Socio-political barrier Black= Biophysical barrier
Blue= barriers that are both socio-political and biophysical

Overcoming the Barriers
During the interviews, all respondents were asked to outline their thoughts on how to potentially overcome specific challenges to the implementation of the BGI. Statements reflecting strategies to overcome obstacles have often described 'a need and the desire for change ('it just needs',' I think they need',' needs to change'). In this category, other statements included words such as 'suggest',' think about',' make sure',' ensure that',' we/ they could/should and statements discussing the positive impact of following a new course of action. Respondents found it easy to identify general strategies, such as raising awareness and improving education, to overcome the barriers to BGI. Further categorization of obstacle management approaches reveals subsets that are either specifically related to BGI projects or applicable to general water and environmental infrastructure projects (Appendix Figure 3). Interestingly, 70 percent of the strategies specifically relate to BGI projects within the 'promoting multifunctional space and multiple benefits' sub-node. On the other hand, thoughts on improving education, awareness raising, community engagement and communication, another important approach, are more generic and apply to all infrastructure projects that change the local environment. This suggests that particular BGI barriers relating to lack of knowledge and understanding can be addressed by general improvements in education and outreach. This strategy places emphasis on action by decision-makers and communities.

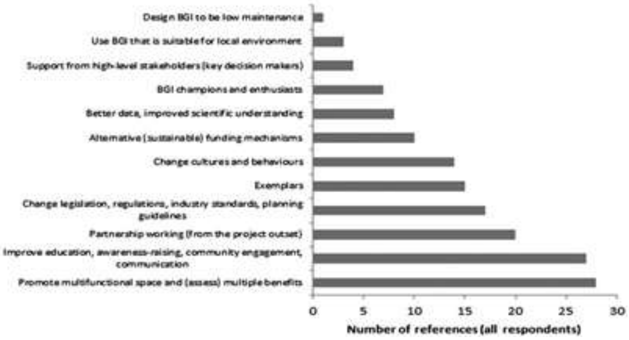

Figure 2 Strategies to overcome barriers to the implementation of Blue-Green Infrastructure in Newcastle.

VI. DISCUSSION

The obstacles in this study provide fresh insight into the challenges and constraints surrounding BGI implementation in cities in the UK. There was a great deal of consistency in the responses; no cases were noted where a barrier was repeatedly mentioned by only one respondent as an expression of a strong personal opinion. Of the 17 obstacles, 12 were classified as socio-political, supporting earlier literature and the predominance of social, institutional and economic obstacles (Niemczynowicz 1999; Brown and Farrelly 2009; Bastien 2013; Carlet 2015; Thorne et al. 2015). In general, the obstacles are consistent with those in previous studies, but two potentially new obstacles have been recognised. The first refers to how negative past experiences with sustainable water management, or with project partners, could have a strong negative impact on BGI's future support. This barrier is highly personal and was only mentioned by two responses to specific projects. For several reasons, such as the lack of questions and questions, this barrier may not have been identified in previous research. The second barrier (e.g, Ashley et al. 2015; Simmons 2015) that has not been extensively mentioned in the literature until recently refers to difficulties in identifying and quantifying (and monetising) the multiple benefits of BGI, especially with regard to the benefits that accrue during the non-flood state (e.g, carbon sequestration, habitat and amenity improvements). This may be due to earlier studies investigating the barriers to sustainable drainage systems with a particular focus on water quality and quantity management, or because of the professional responsibilities of interview participants, e.g, Cettner et al. (2013) interviewed only water professionals, while a group of multidisciplinary stakeholders was selected in this study. Compared to previous research e.g, Lee 1999; Niemczynowicz 1999; Thorne et al. 2015), the lack of biophysical barriers identified in this interview information set is also noteworthy. This might be related to the respondents' highly knowledgeable and experienced profile. Ten respondents currently work or have a background in water engineering in flood and water management, and five of the nine remaining respondents are part of the BGI's Newcastle Learning and Action Alliance. As observed in other interviews with water management professionals, respondents may be comfortable with the level of certainty that current hydrological and engineering science provides based on trusted design guidance, their own engineering expertise and personal experience of successful schemes (Cettner et al. 2013; Simmons 2015). Respondents repeatedly cited reluctance to support new approaches and change practises as a barrier to BGI. This suggests that the largest obstacles are institutional inertia and a preference for conventional approaches. BGI and SUDS are still regarded as 'novelty' and absent from standard practise, despite an abundance of international research and case studies. While BGI may not be considered novel by the interview respondents themselves, many feel that communities and decision makers perceive that BGI has not been proven in practise. This relates to the second most prominent obstacle: the lack of BGI knowledge, education and awareness. In two ways, this barrier can be interpreted. First many respondents felt that communities and professionals working outside the profession of flood and water management were unaware of how BGI could reduce the risk of floods and manage surface water. In reality, because of its primary functionality, BGI may not necessarily be appreciated and the other advantages may be valued more highly. For example, aesthetic improvements and increased greening of urban areas were key benefits of Portland bioswales, but knowledge of the hydrological functioning of bioswales was less widely understood (Everett et al. 2015). Second, professionals in water management may feel that they lack knowledge and information about future plans for SUDS and BGI adoption and maintenance. The main problem is not the physical maintenance schemes needed to maintain optimum functionality, but the identification of responsibilities and funding. This relates to the 'legislation, regulation and governance' barrier. The 2010 Flood and Water Management Act (FWMA 2010) aimed to address ownership and maintenance issues by local authority SUDS Approval Bodies (SABs).

Recommendations: Further perspective

Several recommendations are now presented for practitioners involved in implementing BGI that draw on the original findings from the interviews with Newcastle and knowledge synthesised from the broader literature. First of all, we recommend recognising the multifunctionality of the BGI at the institutional level. As a concept that benefits multiple stakeholders and meets multiple policy and strategic objectives, BGI should be promoted outside the flood risk and water management discipline, such as Local Authority departmental targets for urban regeneration, adaptation to climate change, water quality, recreation and public amenities, health and well-being, open space improvements and biodiversity. Typically, the flood risk management literature does not focus on how BGI/SUDS could be identified other than flood risk management systems, but the multifunctionality must be identified, supported with scientific evidence, and championed by stakeholders who will be benefit for actual implementation. In order to generate greater public support for BGI, it is recommended, first of all to identify the types of benefits that could accrue to the various recipients and to use this as a basis for public participation and consultation. The values placed on costs and benefits depend on the social and environmental context, so engaging with communities can help to develop a shared understanding of BGI's various benefits and a negotiated set of values. This may contribute to recipient communications that are more likely to promote the implementation and take ownership of BGI. This is challenging in practise, as these benefits are rarely monetarily valued and are difficult to include in cost-benefit analyses and business cases. We concur with Ashley et al. (2015) in their suggestion that a business case is invaluable in order to take into account the wider value of SUDS and BGI without strict regulation and legislation.

With the development of new instruments, including the CIRIA Benefits of SUDS Tool , multiple benefit assessment is gaining greater traction within academia and industry, allowing cost-benefit analysis through a structured evaluation to help quantify and monetise each benefit (CIRIA 2015). The

Blue-Green Cities Multiple Benefit GIS Toolbox can create benefit maps and profiles to provide context-specific assessments of the spatial scope and intensity of benefits, providing insight into the recipients (Hoang et al. 2016, Morgan and Fenner in review). When designing BGI projects and discussing with institutional and industry recipients. It is recommended that Investing in improving education, raising awareness of BGI and engaging with communities to help break down socio-institutional barriers associated with lack of understanding and knowledge. This should go beyond passive engagement (e.g, notices explaining the functions of BGI assets) as active engagement has higher behavioural and cultural change potential compared to relying solely on BGI public observation (Johannessen and Hahn 2013; Shandas 2015). Holding training activities and technology demonstrations on exemplary BGI assets could also help build confidence and trust in efficiency and technical feasibility (Brown and Farrelly 2008; Carlet 2015). Local terminology may also help to raise awareness and credibility of the new schemes when discussing BGI (Fletcher et al. 2015). Finally, I recommend investing resources from departments and organisations in improving collaborative working and promoting partnerships to deliver BGI. There is a need for leadership from individuals within organisations who are able to span borders and build trust and relationships for successful partnership work (Margerum and Robinson 2015). Developing shared practises that foster collaboration would help address the risk of interagency fragmentation and ineffective communication. These partnerships should include a wider range of city actors, in addition to flood and water management professionals, such as developers, social housing corporations and other landowners who are responsible for large parts of the city's estates, in order to support a transition towards sustainable water management. Partnership working can also facilitate social learning, which in turn can help manage the risk perceptions that different stakeholders hold regarding future implementation of sustainable urban water infrastructure (Dobbie and Brown 2014).

VII. CONCLUSION

Biophysical and socio-political areas are spanned by barriers to BGI and sustainable water management. In order to facilitate a change in how the UK manages urban water and flood risk towards an approach focused on 'living with and making room for water,' specific strategies are needed to overcome these challenges, generate acceptance and support and promote the delivery of BGI. Newcastle's professional stakeholders generally perceive the socio-political barriers to exert a more significant negative influence than the biophysical barriers on the widespread implementation of BGI. The reluctance to promote perceived novel approaches and changing practises and the lack of knowledge, education and awareness were the most prevalent among the socio-political obstacles (of publics and decision makers). Many of these barriers were specific to BGI in the context of the interviews. While general strategies such as improving education and raising awareness are essential to improving BGI comprehension, the lack of specificity indicates that they are of limited use in practise for water management professionals. Barriers are inter-dependent and so strategies should not be mutually exclusive to overcome them. Decision makers, professionals, practitioners and communities all have a role to play. We identify several specific strategies to overcome the obstacles, notably promoting multifunctional space, evaluating and quantifying (and monetising) the multiple benefits of BGI, and working to deliver such projects in a more efficient (and wider reaching) partnership. The potential impact of BGI on urban infrastructure is currently unknown and therefore the impacts of policy discussions that try to link BGI with quantifiable measures required for decision-making processes are valued in Germany. In addition to providing a flood and water management function, we recommend that BGI be promoted as a concept that can meet numerous policy and strategic objectives of various organisations and departments. BGI's benefits and beneficiaries go beyond flood risk management and can therefore contribute to other urban initiatives, such as adaptation to climate change, urban regeneration and health and well-being. In combination with collaborative, inter-agency working and sustainable co- funding mechanisms, strong business cases supported by proof of the benefits could help advance the implementation of BGI. There is also a need for long-term strategic thinking; it is not enough to just construct a system because active involvement with residents and decision-makers is needed to change behaviours and increase acceptance. In order to build a scientifically sound infrastructure that is accepted and supported by city stakeholders, we also suggest that a concerted effort should be made to reduce some of the bio-physical uncertainties and obstacles through better data and improved scientific understanding.

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