

Article

Retrofitting Sustainable Urban Drainage Systems (SuDS): A Cost-Benefit Analysis Appraisal

Oluwayemi Oladunjoye ^{1,*} , David Proverbs ²  and Hong Xiao ³¹ School of Architecture, Building and Civil Engineering, Loughborough University, Loughborough LE11 3TU, UK² Faculty of Science and Engineering, University of Wolverhampton, Wolverhampton WV1 1LY, UK³ School of Engineering and the Built Environment, Birmingham City University, Birmingham B4 7XG, UK

* Correspondence: yemmyola2@gmail.com

Abstract: Sustainable Urban Drainage Systems (SuDS) are known to help mitigate flooding whilst simultaneously delivering other positive outcomes, such as the provision of environmental, economic, educational, and business benefits. Despite this, there has been a relatively low uptake of SuDS in new developments and even less of an uptake in the opportunities for retrofitting SuDS in existing buildings. A major barrier to uptake has been a lack of understanding regarding the value of the benefits provided by SuDS. This study presents an appraisal of the costs and benefits derived from the retrofitting of SuDS in existing buildings and reveals some of the key decision-making considerations during the design and installation of such schemes. A qualitative research approach that included a number of case studies of successfully retrofitted SuDS schemes within public buildings was conducted. A novel feature of the research was the use of the Willingness to Pay (WTP) approach to value the tangible and intangible benefits provided by the various schemes from the perspectives of the property owners. The findings revealed that the retrofit provided a net value to the client of over £100,000 over 10 years, a mean CBA ratio of 5.3/10, and a return on investment (ROI) that would be achieved in less than 3 years. The importance of stakeholder engagement during the decision-making process was highlighted in helping to overcome many of the design, installation, and maintenance challenges. The findings demonstrate a significant ROI for these SuDS retrofit schemes and highlight useful approaches to overcoming the barriers in valuing the importance of the intangible benefits. In supporting the uptake of the retrofitting of SuDS, it is recommended that these benefits are given full consideration by property owners, urban planners, and architects during the design of retrofit schemes and throughout the decision-making stage.

Keywords: flooding; cost-benefit analysis; Willingness to Pay; return on investment

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1. Introduction

SuDS, or sustainable urban drainage systems, is a catch-all term for a number of strategies used to manage surface water runoff and its impact on the environment [1]. Many people consider SuDS to be a crucial component of urban climate change adaptation [2]. They can increase the localised infiltration, attenuation, and detention of stormwater [3,4] and can thus make a significant contribution to flood alleviation capacity in any community [5,6]. Swales, water gardens, and green roofs are examples of vegetation-based interventions used in SuDS that replicate the natural drainage processes of an area. By lowering runoff volume and attenuating peak flows, sustainable urban drainage systems (SuDS) can lower the danger of floods by imitating natural infiltration patterns. SuDS, according to Kirby [7], are more environmentally sustainable than traditional drainage techniques because they are intended to control flow rates, preserve or improve the quality of the water, and be considerate of the surrounding environment and the requirements of the neighbourhood. In order to do this, they either deal with runoff near where the rain falls or attenuate flows and manage downstream releases.

The most used and well-known examples of SuDS are soakaways, green roofs, swales, rainwater beds, permeable surfaces, rainwater harvesting systems (RWHS), open drainage waterways, and reservoirs for excess rainwater [2]. These examples are either combined or used independently. All these solutions aim to absorb, evaporate, and channel rainwater so it does not end up in the sewage system. Notwithstanding this, the uptake of SuDS and the retrofitting of SuDS have been restricted by a number of issues including a lack of experience and trust in such schemes and a lack of an understanding of their wider benefits and how to incorporate this into the delivery of a typical SuDS scheme [4,8–10]. There has been limited research on the retrofitting of SuDS, and there are no well-established procedures for evaluating their feasibility, value, or cost-effectiveness. This study presents an appraisal of the costs and benefits involved in the retrofitting of SuDS in public buildings and reveals some of the key decision-making considerations during the design of such schemes.

2. Retrofitting of Sustainable Urban Drainage Systems

The retrofitting of SuDS is regarded as a stormwater management technique used to solve issues with urban water quality and floods [11]. When SuDS are suggested to replace or improve an existing drainage system, the term “retrofit” is employed [12]. In general, the United Kingdom has little experience retrofitting SuDS, and there are few defined methods for determining if they would be worthwhile or cost-effective [5,13]. However, the projection of this technology continues to be of increasing interest [14], and stakeholders and researchers have sought to establish strategies for raising the relevance and acceptance of SuDS in the UK [15]. Installing green roofs, using garden soakaways, and directing road runoff into ponds via roadside swales are a few examples of retrofitting SuDS [16]. These represent alternative ways of improving the quality of water downstream, thereby providing a more effective, resilient, and sustainable approach.

Retrofitting SuDS can be seen as a good opportunity to address flooding whilst also creating better urban communities that are welcoming and environmentally friendly, and it can help to improve the quality of life in a community [17,18]. While new developments offer an opportunity to manage surface water better than what has been done traditionally, this requires the early consideration of drainage and SuDS in the development planning process [16]. New developments form only a small part of the existing urban area, while the refurbishment and adaptation of existing developments and properties represent the dominant feature of the built environment [19]. If the retrofitting of SuDS can be incorporated into existing developed areas, then the opportunities for delivering sustainable solutions that offer multiple benefits will be much greater [20].

The benefits of retrofitting SuDS are various, ranging from improvements in people's lives to improvements in their dwellings. Malulu [8] discovered that a typical SuDS intervention programme, which is one of the primary benefits of SuDS, comprises the construction of works on rivers to boost their ability to transport flood flows. Friberg et al. [21] demonstrated how channel maintenance or widening the channel cross-section enhanced surface water flow by extending the broader capacity. The reduction in the heat island effect and noise, the enhancement of air and water quality, and the provision of recreational or urban facilities are all ways in which SuDS retrofitting may help to preserve the environment [16,22,23].

The reduction in infrastructure costs through the use of green infrastructure is one of the additional advantages of SuDS retrofitting. In contrast, Ellis [16] contends that an extended strategy based on the integration of SuDS, such as micro- and meso-vegetative SuDS systems, into a larger green infrastructure (GI) framework can successfully address on-site and catchment urban surface water issues. Conventional drainage systems, he claims, cannot provide the expected solution to any flood mitigation process.

Health improvements from the use of SuDS are also considered important benefits. Lamond et al. [24] emphasised the necessity of enhanced flood risk management in controlling the increased burden of flooding events on community health and well-being. Greenough et al. [25] studied the health implications of floods, which are commonly connected with

disasters and include direct effects such as morbidity and death, as well as secondary or indirect health effects. Flooding has a direct influence on public health infrastructure, access to health care services, and psychological and social implications. Flooding has an indirect influence on ecological systems, causing damage to land covers and altering the amount and distribution of disease-carrying insects, rodents, and other vectors [26]. The retrofitting of SuDS will help to address many of these issues and lead to improved health systems.

Economic growth can also be stimulated by SuDS retrofitting by improving an area's attractiveness to new businesses, creating jobs through SuDS installation and maintenance, and improving worker productivity when the environment is positively impacted by aesthetics, improved health conditions, improved air quality, and many other factors [27,28]. Carpenter [29] discovered that SuDS visually enhanced landscapes and leisure, attracting more tourists and other visitors from various regions, both locally and worldwide. Green infrastructure has been linked to increased employment growth in the United Kingdom [30]. In addition, research conducted in the United States discovered that the presence of green structures caused consumers and business visitors to stay longer [31].

In projecting the costs and benefits of installing a SuDS retrofit and the future effect on a community, a value-oriented structure involving a conducive whole life costing (WLC) approach is required [9]. This involves a whole life costing approach as a methodology that gives a systematic economic consideration of all the costs and benefits associated with SuDS retrofitting. Considering this methodology, factors such as finance, business costs, income from the land sale, and user costs need to be considered. All these factors are essential when gauging the economic implication in terms of the cost-effectiveness of SuDS retrofitting in a community in order to deliver the best value for the money. However, despite the increased flooding events in the UK, the uptake of SuDS retrofitting as a flood risk management measure is still mainly being ignored [4]. A lack of experience and trust in some of the approaches is a significant setback for implementing SuDS retrofitting [32]. Convincing stakeholders about such new approaches is not straight forward, especially when consideration is given to failed flood risk management schemes [33].

The fear of high maintenance costs for SuDS schemes has also proven to be a barrier to their adoption [34]. Because of the intricacy of monetisation and the assessment of their wider benefits, SuDS are frequently underestimated by the major stakeholders involved. Agwuele [35] relates this to the avoidance of the potentially significant financial consequences and the control of future implementation expenses. Due to the generally fragmented structure of systems, evaluating the retrofit proposal in terms of several aspects makes appreciating the entire benefits challenging [36]. Due to the reluctance in the uptake of SuDS retrofitting in the United Kingdom, direct and indirect incentives are low; therefore, the number of private investors prepared to invest in these schemes is limited.

The BeST (Benefits Estimation Tool) tool was developed by the Construction Industry Research and Information Association (CIRIA) [37] to guide blue-green infrastructure valuation, including SuDS. It is said that by using the tool, blue-green infrastructure is more easily assessed without requiring economic inputs of any kind. The BeST tool was initially developed in 2015 and has gone through three stages of updates, with the latest update in 2019. In the current version, the tool consists of a simple screen and qualitative assessment to quickly identify and evaluate the benefits. The latest version has now been updated to allow the benefits of Natural Flood Management (NFM) to be considered; however, the absence of any consideration of the intangible benefits suggests that this tool is undervaluing the overall benefits of such schemes.

3. Research Methods

In seeking to address these barriers, this research adopted a qualitative approach to investigate the Cost-Benefit Analysis (CBA) of SuDS retrofitting. A case study approach involving a process of the triangulation of evidence involving focus groups and interviews, documentary enquiry, and observations was employed [38]. Three case study public buildings that had successfully implemented SuDS retrofitting were purposively selected,

comprising a leisure centre, civic centre, and primary school. Interviews and focus groups with key stakeholders involved in the design and installation of the SuDS were undertaken at these properties. This enabled various information to be obtained, including the value of the intangible benefits of using a Willingness to Pay approach, as well insights into the decision-making process and the design, installation, and maintenance processes.

In terms of selling a product or service, the WTP process is defined as the maximum price a customer is willing to pay. [39]. In this case, the WTP was used to value the intangible benefits brought about by the retrofitting of SuDS from the viewpoint of key stakeholders. These intangible benefits are notoriously difficult to quantify and include aspects such as improved aesthetics, air quality, habitat, and education. These intangible benefits can be significant, and, therefore, ignoring these can lead to an incomplete understanding of the full benefits. This represents a major gap in previous studies on the retrofitting of SuDS and was hence given considerable focus in this study [40,41].

Stakeholder and SuDS Scheme Used

Various stakeholders were consulted on each property depending on their level of involvement, their relevance to the scheme, and their availability. Table 1 presents a summary of the stakeholders that were interviewed and also of the types of SuDS retrofit schemes installed within the properties. Further details about the different schemes can be found in Appendix A.

Table 1. Stakeholder and SuDS details.

Property	List of Stakeholders Consulted	SuDS Retrofit Scheme
Leisure Centre	Property Manager Landscape Architect Council Representative The Contractor	Raingardens, swales, permeable surfaces, roof channels, basket-controlled outlets, stainless steel architectural rain channels
Civic Centre	Project Manager Landscape Architect Senior Water Management Officer (SWMO)	Raingardens, swales, permeable surfaces, lower-level detention basins, voided stone layers, infiltration planters
Primary School	Landscape Architect Council Representative Property Manager	Swales, constructed wetlands, rainwater harvesters, detention basins

4. Results and Findings

This section discusses the factors that influenced the decision-making process including the costs of installing the scheme, the process of obtaining the funds, and the maintenance procedure of the different schemes. Particular emphasis is placed on explaining the perceived benefits and the value of these from the perspective of the key stakeholders.

4.1. Decision-Making Process

Focus groups and interviews were conducted across the different study sites. These involved at least three participants at each of the sites, which included some key stakeholders in the delivery of the schemes. Stakeholder involvement was identified as a major factor in the delivery of the schemes. For example, at the Leisure Centre, the property manager stated, “... Yes, we were all involved. We had meetings where we met quite frequently to discuss the project” (property manager at the leisure centre). This was considered very important because it confirmed the level of support that was needed to drive the acceptance and delivery of the scheme. This also helped to establish a strong team ethos among the stakeholders, and it also provided a means of selling the idea of a SuDS scheme to the council, who facilitated the funds that were secured for the scheme.

At the civic centre, many of those that were involved at the inception of the project had already moved to other jobs, which left the landscape architect and the project manager as the people who could give an account of the project. The landscape architect was able to give well-informed insight into the decision-making process and other information. One significant finding was the establishment of a strong link between the landscape architect and the management team at the council. This enabled the provision of sound technical expertise and experience to facilitate the design and advice on the cost of the scheme.

The landscape architect was well known to the team at the council and had worked with them on other projects, which helped to establish trust and rapport for the scheme “... They had responsibility for some projects, large schools, which I worked on, and we had got into the habit ... so that was a big advantage” (landscape architect). As such, bringing him on board for the redevelopment of the centre was considered a norm. This was an advantage particularly at the early stages of the design, as it allowed the SuDS to be identified very early on, especially at Parkside. “... So in the context of scheming in Bromsgrove, Parkside when they knew that they were going to have to build a new civic centre, they asked me to look at the site right at the beginning saying was SuDS appropriate there, of course, it is appropriate everywhere” (landscape architect).

4.2. Flood Risk

While the properties had no record of previous flooding, the risk of flooding and the proximity of the nearby water courses at the leisure centre and the primary school were clearly factors that influenced the decision to adopt SuDS. At the primary school, the nearby River Avon had caused significant flooding in 2007, which had not directly impacted the school but had clearly influenced the decision to install SuDS. “... in 2007, there was the flood event which led to the council advising the local properties should take up flood defense measures in case of future occurrences” (council representative).

One major reason for installing the scheme was to manage the overflow from the surrounding properties. “... The SuDS scheme we designed to protect that land from overland flow from the housing” (landscape architect). The swale runs down the boundary which protects the school site from the adjacent housing site and takes the flow to the brook. This swale helped to solve the problem of pumping the water from the playground and the overall property into the sewer, which was adding some costs to managing the drainage system within the property.

At the leisure centre, the close proximity of the river Mease, including the threat of surface water runoff, clearly influenced the decision to install SuDS: “... because of the rainfall from the roof because it was a concern ... there is a watercourse behind that it could slump in” (the consultant). The presence of the river and the potential risk in the neighbourhood could pose a future risk for the property, and this made the siting of the schemes a very important factor.

At the civic centre, it was important to the council that an infiltration site was constructed to prevent flooding downstream: “... the reason that SuDS was done there was to prevent flooding further downstream and there is flooding downstream” (landscape architect). However, the most important factor that influenced the need for the SuDS scheme was the need to have an infiltration site: “... the most important one was to decide that we were going to have an infiltrating site ... in this case, we had to store all the water because much of the site was hard surface” (landscape architect). The presence of the hard surface informed the need to introduce storage under the permeable surface to be stored for a short time, which can then soak into the ground or further into the Severn River, which is located some miles from the property.

4.3. Benefits from the SuDS Retrofit Installation

The uptake of the SuDS retrofit was found to provide benefits to different stakeholders, including the property owners and the wider community, across the three case study sites,

as summarised in Figure 1. This section discusses the perceived benefits and the value of these from the perspectives of the key stakeholders from the properties considered.

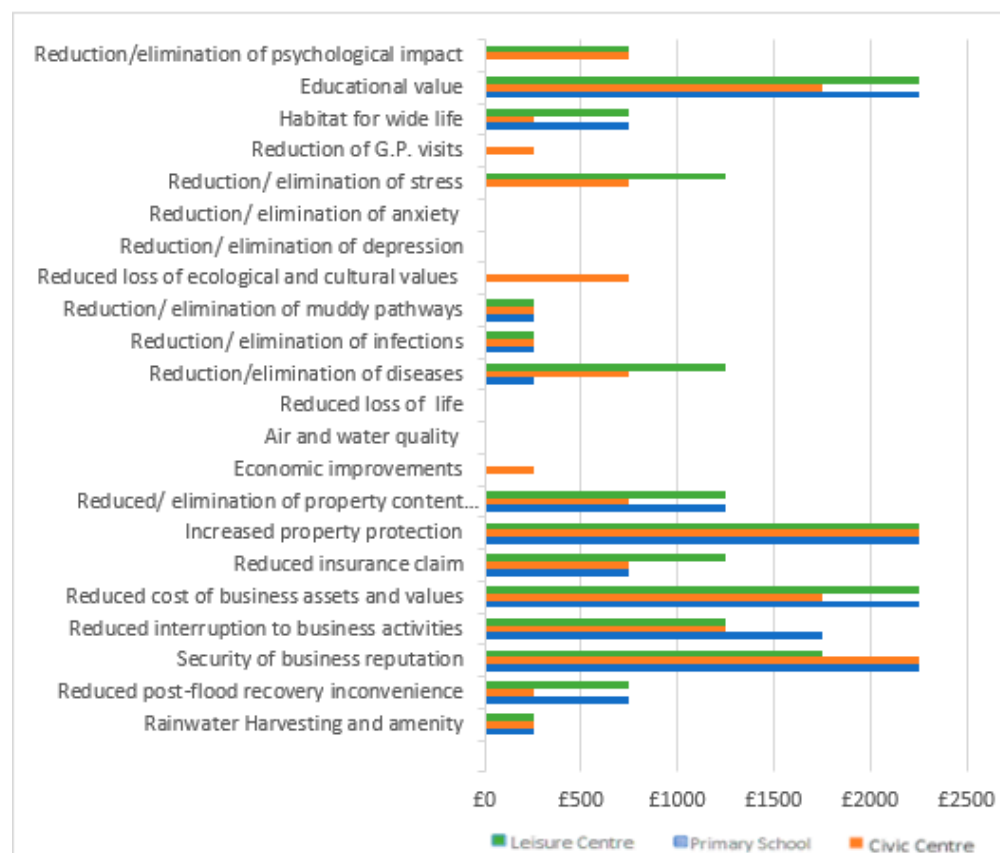


Figure 1. WTP Value of benefits across the cases.

Some benefits were considered at the preliminary stage of each of the SuDS retrofit schemes; however, many of these benefits were not quantified. The stakeholders at the leisure centre explained that they never considered quantifying these benefits, as it did not seem to them to be a necessary procedure. Similarly, this was also the case with the civic centre and primary school. It is interesting to discover, however, that the stakeholders were keen on the available ways to quantify the benefits; however, they were very naïve about any process that will aid the procedure and the advantage of quantifying these benefits. Research has shown that a breakdown of the costs related to the benefits in terms of monetary value has the potential to help inform a business case for the use of SuDS retrofitting [42,43]. However, the only available procedure is the BeST tool [37]. It was observed that there were limitations and shortcomings with the tool, such as the benefits listed not being comprehensive and that it was mainly designed for new schemes rather than for retrofits.

At the leisure centre, some benefits were more useful to the wider community. The stakeholders acknowledged the fact that the community had been very responsive to the scheme as a result of some of these benefits, such as aesthetic value, health, tourist attractions, the ecosystem, and educational value. This had encouraged the presence of volunteers in contributing to the maintenance of the scheme and resulted in little or no concern about maintenance on the part of the stakeholders: “... and we have the local gardening club come to look after the plants that you know, part of their social prescribing, through the doctors, GP referrals and things like that. So as part of their health and social benefits, that’s what they do” (council representative). While at the civic centre, the benefits were influential at the design stage, driving the steps that were taken for implementation. Aesthetic value, educational, and flood management benefits were the main considerations. The school was

a Victorian building and had some ancient features, and the aesthetic value brought about by the installation of SuDS was a key influence. The educational and flood management benefits were also essential to the implementation of the scheme. In the case of the primary school, benefits such as education and FRM were among the factors that influenced the decision to install the SuDS within the property.

The lack of clarity of the value of the benefits represents one of the barriers to the uptake of SuDS, which has been reported in previous research [4,15]. This suggests that the main concern of the stakeholders was towards managing the flood risk within the site, and these wider benefits were not fully considered. “... So how can you quantify beauty? How can you quantify well-being? You can quantify quality or quantity ... Can you quantify clean water as opposed to dirty water? ... maybe you want to ask the water agency how they do it but it won't be money” ... I can't put a figure on amenity. All I can tell you is that this is used by the public and they like the space” (project manager).

Another factor that was found to have influenced these views was based on the confidence the stakeholders had in the professionals involved. Where the parties had established good working relationships, this led to them to develop confidence in the proposals and to build trust with, for example, the landscape architect. However, in some instances, the landscape architect opined that, in order to convince the clients or the wider community, it would be useful to be able to quantify these benefits at the design stage so that they could appreciate the opportunities that are derived from the uptake of SuDS retrofitting. As the benefits derived from the scheme were not well understood by some of the clients, a reliable means of establishing these in a robust method based on evidence, facts, and figures was very appealing. Many of these benefits and the opportunities brought about by them had not been considered by these clients or by the wider community.

5. Discussions

When considering the installation of a SuDS retrofit scheme, the consumer is faced with the decision about what and how much to pay for it [5]. These are basic assumptions that drive the Willingness to Pay concept and are perceived as the costs and benefits of installing a SuDS retrofit scheme. They are also related to one's needs or wants concerning the scheme. WTP is quite hypothetical and may not be a full substitute in this context; however, it has been useful in solving similar problems in other research [44]. Since consumers are usually faced with the need to solve a major flooding event that may have invaded their property, it is usually a huge commitment to decide on the implications of investing in a scheme or other available alternatives to mitigate the effect of flooding events. This process is largely characterised by extended problem solving and CBA considerations, which have been expressed in the details of earlier research conducted by the authors [45].

Figure 1 demonstrates the perception of the benefits derived from the installation of the SuDS retrofit scheme within the properties based on the views of the key property stakeholders. However, many of the stakeholders had little or no understanding of how to quantify these wider benefits and had failed to consider these when designing the scheme. Zalejska-Jonsson et al. [44] argued that users/purchasers of properties are willing pay a premium to either buy or use the properties with good GI. However, there is little research about the process in consumers' minds leading to such a premium. This research sought to provide insight into that process. The purpose of the Willingness to Pay procedure was to quantify and value the benefits and to establish the importance of these values towards a full appreciation of the advantage the scheme brought to the stakeholders.

Across the cases, this procedure revealed how the stakeholders perceived these benefits, particularly intangible benefits such as educational value and habitat within their property. Research has shown that intangible benefits, by their subjective nature, are difficult to quantify [10]. The dialogue with the stakeholders revealed the difficulty they had in agreeing to put a value on some of these benefits.

CBA of the SuDS Retrofit Scheme

A CBA approach was used to undertake an economic appraisal of the monetary and non-monetary benefits of the uptake of SuDS retrofitting across the three cases (see Table 2). The CBA process was undertaken by calculating the net present value (NPV) of the SuDS retrofit scheme across the cases, assuming investment returns within 10 years. Using the average of the upper and lower benefit intervals provided by the stakeholders, the total value of the benefit in the present year and the total benefit in 10 years were derived. The installation costs were obtained from the stakeholders, and this was then subtracted from the total value of the benefit accrued over 10 years [46,47]. Importantly, no maintenance costs were included in the analysis, reflecting the use of the workers and volunteers at the different properties.

Below is a calculation for the net value (NV) of the entire project in 10 years:

Net cost (NC) = Present cost (PC) of installation + maintenance cost (MC)

Net benefit (NB) in 10 years = total benefit/annum \times 10

Hence

Net value in 10 years = Net benefit in 10 years – Net Cost

The NPV provides the property owner with an indication of the interval of time between when the investment is made and the cash flow. Drawing inferences from the case study sites, it can be concluded that the SuDS retrofit schemes were cost-effective and that the benefits outweighed the costs. The return on investment (ROI) for each of the SuDS retrofit schemes was forecast to be achieved in just three years. ROI is an important consideration in the decision-making process and when, for example, considering the uptake between different FRM schemes in terms of their cost-effectiveness and asset utilisation [48].

Table 2. CBA value of the SuDS retrofit scheme.

Property Type	Cost of Installation	Net Cost (10 yrs)	Net Benefits (10 yrs)	Net Benefit (10 yrs) Minus Net Cost	Return Investment Ratio
Leisure Centre	39,000	39,000	152,565	113,565	7:10
Civic Centre	106,105	106,105	183,000	76,895	4:10
Primary School	93,015	93,015	177,575	84,560	5:10
Average	79,373	79,373	171,047	91,673	5.3:10

A closer look at the CBA outcomes shows that there is a level of difference in the net benefits (NB) across each of the cases. This is due to the value of the benefits as seen by the stakeholders and as a function of the nature of the property. Zalejska-Jonsson et al. [44] found out that dense areas give high value to green urban spaces, whereas in less dense areas (suburban), the value is lower. This is a factor that may have affected the perceived value from the stakeholders, as indicated in the WTP process.

When considering the location of the case study sites, it can be observed that the leisure centre and the primary school sites are in suburban areas, while the civic centre is located within an urban area. For a stakeholder who decides to allocate a certain value or SuDS retrofit scheme, an overestimation of value will likely appear in urban spaces due to the relatively low accessibility and the absence of existing SuDS in comparison to suburban or rural areas. On the other hand, in lower-density areas, WTP is most likely to be underestimated, since the general saturation level is higher than that in a dense urban area.

The ROI for each property shows the investments to be positive and worthwhile. Calculating the ROI ratio helps property owners to evaluate the performance or even the potential return on their investment in SuDS retrofitting. This ratio also allows other stakeholders to efficiently evaluate their investment in SuDS retrofitting and to understand how it has impacted their organisation. The higher the return-on-investment ratio is, the more efficiently the schemes are being used to meet their purpose. In Table 1, it is clear

that the ROI ratio is high and at different levels. This also confirms the efficiency of these schemes in terms of investment by the stakeholders.

6. Funding and Costs of Installation

Concerns over the cost of maintaining and implementing SuDS by stakeholders are among the major barriers to their uptake [4,35,49]. This has been attributed to fear of the high cost of maintaining SuDS retrofit schemes and clarity in the value of the monetary and non-monetary values of the scheme. In the case studies considered in this research, the stakeholders were determined to find ways by which the retrofit schemes could be funded. At the civic centre, funds were already available from the local council to execute the scheme as part of other construction processes that were to be implemented on-site. However, in other cases, it was clear there was a lack of understanding about the availability of funds, including a lack of a clear funding procedure by the government to support SuDS retrofit schemes. This fragmentation of the systems of funding resulted in the assessment of proposals from varying angles and contributed to the difficulties encountered in securing funding for the schemes.

In practice, there are different sources of funding for SuDS, and it is difficult for property owners to navigate the funding process. Often, these funding opportunities were not known to the property stakeholders, meaning that, in the cases of the leisure centre and the primary school, funding posed a major challenge in implementing the SuDS retrofit scheme within their properties. Stakeholders had to strategise on how to raise funds to actualise the project, while funding the scheme at the primary school had to be included in the overall renovation process for it to receive the required attention. Funding is an essential aspect of any project, as it can either aid the speedy delivery of a project or stop the execution of any project [50]. Funding this sort of retrofit is usually not part of the standard maintenance budget, so this represented a challenge. Many establishments or organisations may be faced with challenges of this nature, which will act as a setback for them towards the uptake of SuDS retrofitting.

The cases addressed these issues in different ways. At the leisure centre, the council representative was able to submit the required documents to the Regional Flooding and Coastal Committee to seek funding through the Environment Agency. In the case of the primary school, the opportunity to include the costs as part of an extensive renovation process was taken up to achieve their goal. It would be useful to provide specialised guidance and support at the level of the government or specialised bodies, which will be helpful for other organisations to ease the process of obtaining funds for future SuDS retrofit schemes.

O'Donnell [51] opined that it can be challenging to obtain funding for green SuDS schemes from local organisations that are likely to benefit the most from them. This may be because most people and organisations do not know what SuDS are or the benefits they can offer. Because of this, many SuDS schemes remain funded by the local government and their agencies. Raising awareness of SuDS retrofit schemes and active engagement with communities to help break down socio-institutional barriers related to a lack of knowledge and understanding is strongly advised. This goes beyond passive engagement, as active engagement holds a greater potential for a behavioural and cultural change compared with solely relying on public observation [52]. This will also raise more public interest and increase the number of interested organisations willing to invest in these schemes.

7. Conclusions

The adoption of SuDS as a retrofit solution for mitigating flooding to existing buildings has thus far received very little uptake in practice, and there has been a dearth of research in this area. One of the main barriers to uptake has been a lack of appreciation of the benefits provided by such schemes, particularly the various intangible benefits such as biodiversity and improved air quality. In response to these gaps, this research has developed a CBA appraisal of the retrofitting of SuDS, drawing on a series of case study buildings and

adopting the use of the WTP approach to value these tangible and intangible benefits from the viewpoint of property owners.

Three different case buildings were considered: a leisure centre, a civic centre, and a primary school. Each case had a different range and combination of SuDS, including swales, rain gardens, and impermeable surfacing, all professionally designed and installed at an average cost of GBP 79,373. The results highlighted the value of the benefits brought about by these retrofit schemes, with an average ROI ratio of 5.3:10. This represents a significant outcome of the research and highlights the importance of the intangible benefits. Property owners are recommended to consider these intangible benefits in the decision-making process and when assessing different flood alleviation schemes and options.

The WTP approach highlighted a number of important findings. All three properties viewed the increased property protection from flooding as a major benefit. Reflecting the character and purpose of the facilities, the value and type of benefits varied across the three buildings. For example, the primary school emphasised the importance of the educational value, the reduction in business assets, and the improved business reputation brought about by the scheme. The improved habitat, the elimination of infections, and the swifter recovery were also highlighted. For the leisure centre, the educational value and the reduced cost of business assets were of high value. For the civic centre, the security of the business reputation and the educational value were of particular value, with intangible benefits such as the reduced ecological impacts and economic improvements also noted.

There are a number of limitations of this study which need to be acknowledged. First, the research utilised a small number of cases, and, hence, these findings are best described as illustrative of the kind of benefits these schemes can bring about. The WTP method has been shown to provide a useful means of valuing the benefits, albeit this was done with the benefit of hindsight by the property stakeholders. Further research is needed to test whether this WTP would equate to a commitment to investing at the design or decision-making stages of a project.

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Appendix A

Appendix A.1. The Leisure Centre

The leisure centre (see Figure A1) was built as a community project to offer a range of facilities including a sports hall, a fitness suite, fitness classes, and sports pitches. A SuDS retrofit scheme was installed on the site in 2016 to help to manage flooding events whilst also providing educational, aesthetic, social, and health benefits for the property and the community.



Figure A1. Front view of the Leisure Centre.

The SuDS design comprised four different components: rain gardens, lined swale basins, basket-controlled outlets, and stainless-steel architectural rain channels. This project used landscaping to reduce flood risk and pollution by delivering a controlled flow of clean water into the river. The rationale for SuDS was developed by analysing natural flow paths and dividing landscape zones broadly. The entrance to the leisure centre was enhanced by the inclusion of two large rain gardens, replacing previously underperforming tree pits and adding year-round aesthetics. The rain gardens received rainwater from an area of 675 m², including adjacent hard standing and half of the parapet roof. They provided the storage of 16.8 m³ water, accommodating for up to the 1 in a 10-year storm event. The planting choice was such that a simple maintenance routine (annual cutting of perennials and grasses in February) could be implemented.

The rainwater goods on the building are integrated with stainless steel rills designed to channel rainwater from the roof into the building's rainwater channels. Water can be collected from four downpipes via the rills, which are only slightly raised from the ground. At the centre of each rill, rainwater drains into a blockwork channel. There are two large rain gardens that can be accessed through these channels, which are shallow enough to allow pedestrians to pass through them. To store and treat the rainwater from the south-facing element of this parapet roof, two downpipes were diverted towards the rain gardens at the entrance. This rearrangement of downpipes extends the catchment area by 190 m².

An additional component was the swale, which received water via four downpipes to the building's western side, positively draining 365 m² of the roof catchment. A control orifice, housed in a gabion basket, drains the swale at no more than 5 L/second/ha. In the front, rain gardens would provide amenity benefits, while in the rear, a lined wetland swale would provide biodiversity benefits by linking to adjacent habitats.

Appendix A.2. The Civic Centre

The civic centre (see Figure A2) is a grade 2 listed old school building located in Bromsgrove, West Midlands, within walking distance of the main pedestrianised high street that connects the town's main shopping area. The building was opened in 1910; so, before redevelopment could take place, certain conditions had to be met, such as retaining the facade and landscape frontage.



Figure A2. The Courtyard at the Civic Centre.

The centre comprises five sub-catchments, each with a different character and therefore with different SuDS components. The first sub-catchment is the frontage of the civic centre, with a soakaway and sewer connection retained in front in a bid to reduce costs during the installation of the SuDS scheme. Rain gardens were initially proposed to capture roof water as a protection measure to the existing combined sewer but were not constructed due to a change in the plan by the property owner.

The second sub-catchment is located in the car park to the north of the health centre access road. Throughout the site, sandy soil overlies sandstone and allows for infiltration.

This location where the car park was located had significant levels of Polycyclic Aromatic Hydrocarbon pollution (PAH). Several lined permeable block double parking bays were constructed with impermeable access surfaces from the road. A final chamber directs clean water under the access road into an infiltrating swale basin in the main part of the site from each double bay's control structure. Water that does not infiltrate is conveyed down the western boundary in solid pipes when it is close to the building or in perforated pipes when it passes through an under-drained basin, overflowing into storm sewers if necessary.

The third sub-catchment is a small access area with access pathways and parking behind the main central area. Because the tarmac surface has been used previously, manipulating this area has only partially enabled the collection of runoffs. This is accomplished by two bio-retention features that collect and clean first flush volumes on a daily basis, occasionally overflowing during heavier storms into the existing combined sewer.

The site's major area, the fourth sub-catchment, was planned as a civic square in the style of 20th-century gardens. The Georgian school elevation, an existing school hall, and the library with Local Authority services are all integrated within the square. A modest parking lot is located near the square's entrance. The periphery path is made of both permeable block and slab paving since the entire core space was viewed as an infiltration surface. The middle green area serves as a detention basin during really heavy rain since it infiltrates water and is somewhat lower than the surrounding paving. Another small soakage area is formed using permeable block parking. A small patch of impervious tarmac drops to a swale basin with an underdrain that connects to a controlled flow overflow and the exceedance route.

The only surface specifically designed for the SuDS in the central area is the swale basin. A large portion of the new structure features a green roof, which reduces flows and cleans runoff before it infiltrates through low planters or permeable surfaces to the ground level.

The extremely small entry area, which also serves as a gathering path for some runoff from green roofs, makes up the fifth sub-catchment. Small planters that connect directly to the path sub-base are used to gather this. Daily rainfall is ensured to penetrate by a raised control structure, although larger quantities may discharge to the storm sewer if necessary.

Appendix A.3. The Primary School

Figure A3 shows the main entrance to the primary school, which was located in the West Midlands region of the UK within a residential community. The primary school was first established in September 2001 with the intention of providing primary education to the local community. A directive from the local council for schools to install SuDS within their properties to meet the 1-in-100-years flood return period in line with the new policy was introduced. However, the primary reason the SuDS scheme was installed in 2003 was to replace the existing conventional drainage system, which was becoming too expensive to manage and inadequate in attending to the property's water management needs based on the council's requirements.



Figure A3. Entrance to the primary school.

The SuDS retrofit scheme was made up of four different types, incorporating a swale, detention basins, a constructed wetland, and rainwater harvesters. The SuDS scheme follows the contours of the site and drains downhill to the nearby brook. This removes the annual charge for the sewer connection. The scheme begins with two storage/detention basins referred to as the main drive collection basin and the car park storage basin. These detention basins were designed to hold back storm runoff for a few hours to allow solid components from the runoff to settle before further flowing through the swale. They were also expected to reduce peak flows and the risk of flooding within the entire property. The inlet serves as a channel for the purification and channelling of water through the swale to its eventual destination in the brook. This component helps to provide clean and healthy water to reduce pollution and contributes to the health benefits provided to the community.

The swales collect overland flows from an adjacent site across the main road in front of the property and the runoff from the car park and playground, providing source control. By providing source control, the volume of water and the potential amount of contamination are lower and, therefore, require smaller SuDS components further downstream. The main driveway is then drained to an extended detention basin. These systems are connected to a built-in wetland that receives runoff straight from the roof, offers amenities, and houses practical instructional materials. According to the council's policy, the system was built to handle storms with a 1-in-100-year return time, and overland flow pathways were created for storms with a greater return duration. The playground is located next to the main car park and was designed alongside the SuDS scheme as a component to control the flow of runoff within the property. Flower beds were included as components to add some aesthetics to the property, which brightens the playground for the pupils yet serves to

manage runoff. The beds infiltrate water and control water movement just around the playground. Any excess water then flows to the swale that surrounds the playground and is then thereby transported to the brook.

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