An Exploration of the Benefits, Drivers and Barriers that Affect the Adoption of Green Roofs in Urban Britain

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A thesis submitted as partial fulfilment of the requirements for the degree of Masters of Research Innovation and Improvement in Construction

THE SCHOOL OF CONSTRUCTION AND PROPERTY MANAGEMENT

UNIVERSITY OF SALFORD
UNITED KINGDOM

2006
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ABSTRACT

AN EXPLORATION OF THE BENEFITS, BARRIERS AND DRIVERS THAT AFFECT THE ADOPTION OF GREEN ROOFS IN URBAN BRITIAN

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In urban areas surfaces are sealed by stone, concrete, and tarmac and there is a limited network of green areas. Consequently urban areas have higher temperatures, lower atmospheric humidity, and higher air pollution. By adopting green roofs in sufficient numbers in cities the quality of the urban environment could be significantly improved by cooling and improving the moisture content of the air, by extracting CO₂ and pollutants and by attenuating rain water run-off. In Germany and Switzerland there is a well established and successful green roof industry that has developed steadily over many years. In contrast there are few green roofs in the UK. Yet the potential is huge, an estimated 20,000 hectares of existing urban roofs in the UK could be vegetated with little or no structural modification (Corus: 2001). Furthermore, roof gardens and terraces could offer an increasingly valued green space in cities where populations are growing and where it is becoming difficult to afford land on the ground.

This qualitative study aims to discover why recent existing urban green roofs were adopted and how this uptake was affected by the perceived benefits and barriers set out in the report. The study tests a possible research design, which could be used to explore the main research themes and questions. To explore these themes and potential designs the research uses the exploratory case study method. Three very different buildings with green roofs were used these are all situated in British cities and were all built between 1999 and 2004. The buildings include
Greenside Place in Edinburgh, BedZED in London and the National Wildflower Centre in Liverpool. The drivers for the adoption of each green roof match the theoretical drivers and benefits, as do the barriers. Where the green roofs have been adopted, no known, significant barriers exist. Although the roofs are not entirely problem free, for example, some plants on the roofs have suffered in the exposed conditions, on the whole, the studied roofs are well received and considered successful by stakeholder members.

Keywords

Case study, green roofs, innovation, qualitative, sustainable
ACKNOWLEDGMENTS

I am indebted to all those stakeholder members who contributed their time to this study and offered information and advice.

I would like to express my gratitude to my thesis supervisor John Hudson and course leader Dr David Eaton. Thanks also to Catherine Green, Mary Hamblett, David Dowdle and David Baldry.

I would like to thank Ali Waisy who accompanied me to London and Edinburgh and generally supported and encouraged. Thanks to Vicky Nutt who gave me valuable advice and Rina Shrabonian for sparking ideas.

Finally I would like to thank my family.
INTRODUCTION

Surfaces in urban areas throughout the world are sealed by impervious stone, concrete, and tarmac and in most cities there are insufficient networks of green areas. As a result cities suffer from higher temperatures, lower atmospheric humidity, and higher air pollution than the surrounding country areas. During flash storms, the city is vulnerable to flooding as rainwater runs straight off sealed surfaces into the sewage infrastructure, which sometimes cannot accommodate the increased burden of water. One way of compensating this concrete landscape is to use the extensive available area of space on the roofs of urban buildings, turning this space into green areas. Roofs covered by a layer of vegetation are known as green roofs (English Nature: 2003, more extensive definitions are explored in the literature review).

Green roofs could improve the quality of the urban environment by neutralising the Carbon dioxide effects of the building, by cooling and adding moisture to the air and by attenuating rainwater run-off. In built up areas such as London where the cost of land on the ground is at a premium and there is increasing pressure to build in high densities, green roofs offer an increasingly important landscaped area in a country well known for its love of gardens.

Many of these benefits could only be felt if the green roofs were adopted in sufficient numbers, throughout individual cities. Currently green roofs in the United Kingdom are not being adopted at a significant rate, though there is evidence to suggest that the pace of adoption is accelerating. In contrast green roofs have proved a great success in Germany and Switzerland where there is now an established multimillion-dollar green roof industry. Success in these countries has partly been attributed to the quantity of research devoted to green roofs and an evolving tradition of roof greening since the end of the 19th century. Some German green roof companies have been established for over thirty years, ZinCo and Ericso Bauder for example. Over this time they have produced highly evolved and engineered green roof solutions. These companies now supply their products through British companies such as Corus building systems (www.corus.co.uk: 2004) and Alumasc.

The successful green roof industry in Germany and Switzerland is to a large extent founded on comprehensive scientific research and development. Such research has focused and proved the benefits of green roofs. Kohler states that:
“Positive effects for indoor climate, micro climate and material durability are proven. The retention of rain water for the avoidance of inundations is not questioned any more”

(Kohler et al: 2002).

Government incentives and an historical legacy of green roofs have also been important factors in the success of green roofs in these countries.

Research devoted to green roofs in the United Kingdom is more limited. However, this is beginning to change as more British researchers are becoming increasingly aware of the benefits of green roofs. This research is strongly influenced by the work carried out by German and Swiss researchers.

A handful of government and private organizations as well as universities are currently involved in green roof research in the UK. Those who are involved long term in the research are encouraged by the increasing awareness that has come about over the past five years. This trend is particularly evident in London and surrounding areas where researchers are especially interested in the benefits to biodiversity offered by green roofs. These researchers tend to be attached to an organization that has a commitment to the improvement of biodiversity. Research here is part of a broader spectrum of activity in the South East where various organizations are actively engaged in using green roofs to improve biodiversity. One such group is The London Biodiversity Partnership’s Black Redstart Action Plan. These themes are explored in greater depth in the literature review.

This study explores the benefits, drivers and barriers effecting the adoption of green roofs, using exploratory case studies of existing green roofs. At this stage in the research a qualitative method is seen as an appropriate method to explore the central questions of the research. Though there are some problems and considerations with this methodology that could be rectified prior to a further study.
Chapter 1

REVIEW OF THE LITERATURE

From the reviewed literature it became apparent that the scope of research devoted to green roofs in the UK is very limited, though gradually interest does appear to be growing and devoted green roof research has increased in recent years. At the vanguard of UK green roof research, is work carried out in the South East of England. Research carried out in London, in particular, where the benefits of green roofs on biodiversity are being explored.

Definitions

A green roof can be defined as a roof that has been planted or one that has for one reason or another been allowed to colonize naturally (English Nature Report: 2003).

Green roofs may be categorised into the following types:

Intensive Green Roofs

Commonly referred to as roof-gardens (English Nature: 2003), this type of roof will need irrigation in the dryer months and more intensive maintenance (Johnston and Newton: 1993). The substrate depth is deeper than extensive green roofs, 200mm or more (Johnson & Newton: 1993). A wide variety of plants can be supported, including trees, shrubs and lawns, much the same as you would find in equivalent gardens and parks on the ground (English Nature: 2003). This type of green roof will normally require the building roof to be reinforced, so that the roof can safely support the weight of the substrate, plants and perhaps the ‘live’ weight (for example people and machinery). This type of roof is normally accessible and can therefore be used as an amenity.

Extensive Green Roofs

Extensive green roofs are low maintenance and should not require irrigation. Some roofs may only need one annual check to clear dead vegetation and drainage points (ZinCo: 2000). This type of roof offers a more limited scope for supporting plants and is really only suitable for drought tolerant grasses and succulents, such as stonecrop and sedum (ZinCo: 2000). The main advantage over the intensive green roof is that as the substrate depth is shallower as little as 10mm, it is a far cheaper
method of roof greening than the intensive method. Thanks to the shallow substrate depth and smaller plants, the burden of load on the building structure is considerably less than that of an intensive green roof. Kohler et al (2002) describe extensive green roofs as a “climatic skin”, due to their contemporary and historical role as a buffer against the extremes of the external temperatures.

Fig. 1 Sedum (source, ZinCo: 2000)

Semi Extensive Green Roofs

Like the extensive systems, semi extensive roofs use the same lightweight materials. There is a similar low cost and maintenance philosophy behind this type of roof. Though the substrate depth is a little deeper than the extensive method, which increases the loading on the roof, and there will be a need for some basic maintenance. The main advantage of this type of roof over the extensive method is that the substrate depth allows for a considerably improved range of plant types to be grown, while the costs, loading and maintenance is less than the intensive method (Dunnett: 2004).

Roof gardens

Roof gardens may be landscaped in much the same way as parks and gardens at ground level. An impressive example of this type of garden is the roof of the former Derry and Tom’s department store on Kensington High Street, central London, which supports a grade II listed garden. The roof is landscaped with trees and ponds and is home to a flock of flamingos (Peck et al: 1999).

Earth-sheltered buildings

The roof forms a continuous layer with the surrounding landscape. This is not technically considered a green roof, since there is no distance
between the ground and the roof. Residential earth-sheltered buildings boast superior energy efficiency of approximately 40%-70% (Collins: 2003).

Covered underground car parks

This includes Jacobs Island in London, a 6000m² landscaped underground garage, which has been landscaped with trees and shrubs and includes a large duck pond with fountain (ZinCo: 2000).

Brown roofs

Brown field sites can provide rich habitats supporting a diversity of flora and fauna. However these sites are now under threat in the drive to provide the land for the much needed housing stock, whilst at the same time safeguarding the countryside. The aim of brown roofs is to compensate for this loss, by mimicking brown field land, allowing ruderal vegetation (vegetation associated with disturbed sites) to colonise low fertility substrates, mimicking the rubble of demolished buildings on derelict land (English Nature: 2003). This type of roof has been highly influential in the improved rate of uptake of green roofs in London and the surrounding area.

Flat green roofs

With a few exceptions (The Hanging Gardens of Babylon for one) this is a relatively modern technique, which was adopted during the first part of the 20th Century. An example is London’s Cannon Street Station on the banks of the Thames, which has a vast roof, covered by lawn and shrubs (Collins: 2003).
Pitched green roofs

This is a traditional method of roofing used, for example for residential buildings in Iceland and for wine warehouses in Hungary. Simple grass roofs were used to buffer the core of the building from the external temperatures (Kohler et al: 2002). This type of roof has been adapted to modern use. Examples can be seen on the ‘Chase’ community centre in St Ann’s Nottingham and on traditional buildings in the Faeroe Islands.

Suspended green roofs

There is only one known example of this type of roof in Lyons, France, where a suspended membrane supports a turf roof (Collins: 2003).

The Benefits of Green Roofs

The benefits afforded by green roofs are repeated in many reports (Scrivens: 1994, English Nature Report: 2003, Kohler et al: 2002). British based research to prove the benefits of green roofs is limited, however, the benefits have been well proven in Germany (Kohler et al: 2002).

Currently a handful of researchers are investigating the benefits of green roofs to wildlife populations in and around the capital.

These groups include:

- English Nature
- The London Biodiversity Campaign
- The Creekside Ecology team
- And the Peabody Trust
The perceived benefits include:

- The Reduction of the Urban Heat Island Effect
- Increased Lifespan of the Roof
- Attenuation of Rainwater run-off
- Biodiversity
- Improved Air Quality
- Insulation
- Reduced Noise Levels
- Aesthetic benefit
- Amenity/ Recreational
- Economic benefit

The Reduction of the Urban Heat Island Effect

The urban temperature can be as much as 7°C higher than the surrounding countryside (Arnold: 1999). In urban areas where the vegetation has been replaced, the sun's energy is absorbed by concrete, tarmac and buildings. These are better conductors of heat than vegetation. The result is that the ambient temperature of urban areas is increased (Arnold: 1999). The higher ambient temperatures can increase ground level ozone or smog in the city (The www.enviroliteracy.org: 2004). Vegetation on green roofs can reduce this problem, by reducing the roof surface temperature and in some cases providing shade (Kohler et al: 2002). In rural areas solar energy absorbed near the ground is used to evaporate water from the vegetation and soil (Arnold: 1999). In the same way evaporative cooling compensated by vegetation in urban areas to some extent compensates for the heat gain on the ground (Arnold: 1999).

Stiger (2002, cited in www.enviroliteracy.org: 2004) found in a study within 300km of Houston, Texas, that the urban heat island effect, together with the high levels of air pollution from Houston's many oil refineries, increased the incidence of lightening in the city. A knock on effect of this phenomenon could be the disruption of rainfall patterns in the city, because of the increased rainfall that accompanies thunderstorms. Stiger's research is supported by a report carried out by Quattrochi and Luvall (www.science.nasa.gov: 2004) in the city of
Atlanta, which also concluded that thunderstorms are more frequent due to the urban heat island effect.

Lifespan of the Roof

The green roof provides a buffer for the roof membrane, protecting it from external temperature extremes, which cause the expansion and contraction of the membrane layer (English Nature: 2003). Ultraviolet light is also blocked by the green roof layers, preventing the degradation of the roof. The roof garden of the ‘Derry and Toms’ building, in London, is a good example, where the mastic asphalt membrane is in almost perfect condition after more than 60 years (Peck et al: 1999).

Attenuation of Rainwater run-off

Flooding in Britain’s cities is an increasing problem. 75-100% of urban surfaces are impervious and the rainwater quickly runs off into drains (Scholtz-Barth: 2001). In fact 75% of rainwater falling onto urban areas becomes rainwater run-off (Scholtz-Barth: 2001). Increases in rainfall can push urban sewage systems beyond capacity. The remaining water evaporates into the air (15%) through vegetation or permeates through to underlying aquifers (5%) (Scholtz-Barth: 2001). In contrast, when rain falls on the natural landscape there is virtually no rain water run-off, 30% of rainfall ends up in shallow aquifers, 30% permeates to deep aquifers and 40% is returned to the atmosphere through plant evaporation and transpiration (Scholtz-Barth: 2001). To accommodate rain-water run-off in urban areas expensive sewage systems are built (Scholtz-Barth).

“While costly storm water collection, storage and treatment systems deal with the impacts of sealed surfaces, they fail to address the source of the problem. In many cases, runoff is directly drained – untreated into open water bodies and receiving streams.”
Scholtz-Barth (2001)

In London for instance, after a moderate storm, storm sewage overflow runs into the Thames, causing oxygen depletion in the river (Ingleby: 2002). When this occurs, two barges are sent into the river by the Environment agency to pump oxygen directly into the river (Ingleby: 2002).

Green roofs can reduce the building’s rainwater run-off by 10-90%, taking the pressure off urban sewage systems (ZinCo: 2000). There is no rainwater runoff from the green roof of the Potsdamer Platz in central Berlin, as water is either evaporated on the roof or is collected and used by the building below (Kohler et al.: 2002). The measure of rain-water runoff on green roofs is effected by the depth of substrate and type of
vegetation, for instance a 2.5 cm deep moss and sedum layer over 4 cm gravel bed retains about 59% of rain-water (Scholtz-Barth: 2001). Reduced rain-water runoff can reduce construction costs on the building itself, as fewer down pipes, drains and so on are needed (Scrivens: 1980). In some cases the cost of the green roof may be offset by these savings (ZinCo: 2000).

Biodiversity

Green roofs can benefit the diversity of urban wildlife and plants (English Nature: 2003). Green roofs provide a ‘dropping off point’ for birds and insects, facilitating the movement and dispersal of wildlife. They provide habitats in areas where wildlife habitats are lacking. Roofs can be specially designed to suit the requirements of specific species (English Nature: 2003). Grasslands, tall herbs, succulents and mosses are likely to improve biodiversity on the roof, roof gardens containing ornamental plants and lawns on the other hand, are unlikely to provide a habitat for birds and insects (English Nature: 2003).

In London large areas of Green roofs in Canary Warf and at Deptford Creek, S.E. London, have been established to improve biodiversity and compensate for lost brownfield sites, which have been earmarked for development (Frith and Gedge: 2000).

The Black Redstart (Phoenicurus ochruros) is a rare protected bird in Britain, which is found in urban areas on rough rubble ground including brownfield sites (Gedge: 2003). The London Biodiversity Partnership has simulated the Black Redstarts’ habitat on London’s rooftops (Gedge:}
2003). Such projects are heavily influenced by the work of Stephan Brenneissen of Basel, Switzerland who pioneered work on Biodiversity and green roofs in 2000 (Gedge: 2003). In one study Brenneissen (2001) found 172 species of beetles, 60 species of spiders and 25 species of birds, including the Black Redstart (Gedge: 2003). Gedge (2003) states that

"The establishment of a thorough scientific investigation into how they (green roofs) can be used to protect rare species will hopefully inform design and lead to an expansion in the application of green roofs in the London area."

The Newcastle BAP identifies man-made structures as being important to some species (English Nature: 2003). Included in the plan are kittiwake, kestrels, starlings, and the black headed gull, Birmingham and Hull Biodiversity Action plans also include green roofs in their objectives (English Nature: 2003).

Improved Air Quality

Air quality in British cities still fails to meet minimum standards believed to be vital for the good health of the occupying population (English Nature: 2003). An estimated 24,000 people die prematurely each year from the effects of air pollution (GLA 2001). To improve air quality, vegetated areas should be increased. As there is limited space in cities, the significant available space on roofs present a significant opportunity. Vegetation on green roofs filter out particulates and absorb gaseous pollutants (English Nature: 2003).

Insulation

The vegetation and soil may insulate the building against extremes of hot and cold. Turf roofs have been built traditionally, to insulate the underlying building, for example in Hungary as wine warehouses and in Iceland and the Scottish Islands as residential buildings (Kohler et al: 2002).

Savings in fuel heating costs have been estimated at 2 litres of fuel oil/m²/year for a typical roof in Germany (ZinCo: 2000). Some modern green roofs, provided by companies such as ZinCo and Ericso Bauder, have certificates to guarantee that they will provide insulation (ZinCo: 2000).
Reduced Noise Levels

English Nature cites research by the European Commission (1996), which estimates that up to 20% of the European Union’s population are subjected to levels of noise, believed to be in excess of acceptable limits for health. A ‘Kalzip Nature Roof’ can reduce sound by 41dB when dry and 51 dB when wet (English Nature: 2003). ZinCo (2000) found that reflective sounds are reduced by up to 3dB and sound insulation is improved by up to 8dB.

Aesthetic

‘I always think that it is somewhat tragic that when you contemplate the view of any city from a high-rise building that the possibility of recreating the ground level site at the top of a building is generally squandered.’ Sir Norman Foster
(Johnston and Newton: 1993, p. 66)

A green roof could provide a more pleasant aspect than a flat asphalt roof. The visual appeal of vegetation, colourful flowers and visiting wildlife may also have a positive physiological effect on city residents and workers (Johnston and Newton: 1993). However, green roofs are perhaps not to everyone’s tastes, they may be perceived as unorthodox, scruffy and if the plants do not respond favourably to the harsher elements on the roof they could become brown in patches.

Amenity / Recreation

There is great scope for roof top gardens to provide an area, in which to enjoy recreational activities in a city where space on the ground for such activities may be scarce and costly (ZinCo: 2000). For instance, office workers in the Willis, Faber and Dumas building in Ipswich (Scrivens: 1980 pp 569-573) can relax during their lunch break on the roof top garden. There could be an economic advantage to such an amenity space. Scrivens (1980) noted that the staff turnover rate at the Willis, Faber and Dumas building was perhaps reduced by the pleasant working environment, which included the roof garden adjoining the café area. German green roof specialists ZinCo (2000) have built roofs, which have recreational areas designed into the roof, including children’s play areas and even a golfing green.
Economic

The initial cost of the green roof may well be a disincentive. However, over time this cost can be offset. The roof could potentially save money by for example reducing heating and cooling costs, by buffering the building against hot and cold and by prolonging the life span of the roof (Kohler et al: 2002).

The Savings offered to the building by green roofs are discussed by Scholtz-Barth (2001):

A developer in northern Germany considered a green roof for a single storey shopping mall purely motivated by economic reasons. He wanted to save the costs for a central air system. In this case, a 6-inch thick extensive green roof was sufficient to maintain comfortable temperature levels throughout the single-story building interior without central air. The added cost benefit to this developer, even without his initial consideration, is the extended life expectancy for the roofing system. He will save the costs for an otherwise needed new roof every 15 years.
These benefits are considered to be the main drivers for the uptake of green roofs and where green roofs are adopted it is because of one or more of these benefits. The ideal would be for many green roofs to be adopted over urban areas and that these roofs would provide as many of the listed benefits as possible.

There may be other factors linked with the perceived benefits that affect the adoption of the green roofs. For example the Ismaili centre in central London was adopted for its amenity and aesthetic benefits. The garden provides a religious space for spiritual reflection right in the centre of London. There is an important symbolism of the garden in the Islamic tradition. Professor Azim Nanji, director of The Institute of Islamic Studies, which is housed in the Ismaili centre, likened the experience in the garden as a ‘spiritual balm for the soul.’ (www.iis.ac.uk/news_events: 2004). When asked why the garden was built in an interview for the BBC World Service “when the building was erected you could have easily dispensed with this. This is in a sense a luxury. Why did you decide to build it?” (www.iis.ac.uk/news_events: 2004), Professor Nanji replied:

“I think it would have been a tragic omission because the garden is so central to Islamic thought and to Muslim culture and particularly because of its very important symbolism in the Qu’ran. I think it is necessary primarily because it enables the space to be understood in the context of the spiritual life of the Muslim.”
History and Background

This study presents green roofs as an innovation. However, green roofs are nothing new (and this does not contradict the theory of innovation which is discussed later in this chapter). There is a steady documentation of green roofs over the course of time since the first known architectural structure of a temple in Mesopotamia, was built to support plants in circa 500 B.C (Scrivens: 1994). An engaging history of roof gardens can be found in 'Roof Gardens: history, design and construction' by T. Osmundson (1999).

'Probably the most famous roof gardens of all time, the fabled Hanging Gardens of Babylon were one of the Seven Wonders of the World. The gardens probably constructed during the rebuilding of Babylon by Nebuchadnezzar II were purportedly built by that king to console his wife, Amytis, who missed the greenery of her homeland, Media.'

(Osmundson: 1999).

In Italy rooftop gardens have been built since Roman times. Roof gardens have been found in the ruins of Roman Herculaneum, which were buried during the eruption of Mount Vesuvius in AD 79 (Osmundson: 1999). During the Renaissance roof gardens were patronised by the Medici and Gonzaga families and by Pope Pius II (Osmundson: 1999).

In Iceland, Hungary and Norway sod roofs were used to buffer the interior against the extremes of the external climate, in some areas the custom is still practiced today (Kohler et al: 2002, Osmundson: 1999).

Turf roofs were also common on buildings in Ireland and the Scottish Islands since the time of the Vikings. These are typified by the crofters’ cottages, still seen today (Browlie: 1990).

By the end of the 19th Century, roof gardens had become a distinctive feature in Berlin (English Nature: 2003). A German roofer in 1900 adapted the traditional Hungarian turf roofed buildings, for use on contemporary residential buildings (Kohler et al: 2002). These were used in many German cities as a form of fire protection (Kohler et al: 2002). Le Corbusier and Roberto Burle Marx were modernist exponents of the roof garden and exhibited a building with a green roof in the Hanover Expo of 1930 (Kohler et al: 2002). By the 1960s a few offices blocks in Switzerland included roof gardens (English Nature: 2003). From these early examples, green roofs in Germany and Switzerland developed on a basis of research and development (Kohler et al: 2002).
Success in Germany and Switzerland

By 2001 14% of all new flat roofs and an increasing amount of sloping roofs in Germany were greened (Schundler Company: 2004). There is now a multi-million dollar industry dedicated to green roofs in Germany. This industry has been established since the 1950s and many of the manufacturers have been operating for at least 30 years (Schundler: 2004) Most of these manufacturers give their green roofs a warranty of 30 years (Kohler et al: 2002).

Roof greening is well supported by German policy with 43% of German cities now offering financial incentives for roof greening (DDV: 2001) and 29 German cities offering 25-100% off the installation costs of green roofs (Osmundson: 1999). In Switzerland a new building must now relocate the vegetation lost to the buildings’ footprint (Osmundson: 1999). It wasn’t until the 1990s that companies started to immerse in the rest of Europe and North America (English Nature: 2003). There are a number of successful high-tech specialist German green roof companies including ZinCo and Ericso Bauder who now supply their products in Britain through companies such as Corus building systems (www.corus.co.uk: 2004) and Alumasc.
Design, Construction, Costs and Maintenance

From bottom to top most green roofs are made up of the following layers; a waterproof membrane, an insulation layer, protective layers, a drainage layer, a filter mat and a substrate. A drainage layer may not be necessary for an extensive green roof and an insulation layer could be an additional consideration for any type of roof (Johnston and Newton: 1993: p 56).

Waterproof membrane

ZinCo (2000) recommends bituminous membranes and state that ‘a fully bonded system is recommended as this will prevent water tracking beneath the waterproofing in the event of damage to the membrane.’ Alternative materials such as PVC, liquid plastics and synthetic rubbers are also suggested (Scrivens: 1982, ZinCo: 2000). Mastic asphalt is not only waterproof, but it is flexible, strong and it can withstand root pressure (Scrivens: 1982).

Insulation

An optional watertight insulation layer could be added. This will help keep the roof warm and dry (Johnston and Newton: 1993). Suitable materials are glass reinforced concrete, extruded polystyrene board and foamed glass (Johnston and Newton: 1993).

Protective layers

Johnston and Newton (1993) state that the waterproofing of the roof will almost certainly need to be covered by a protective layer. ZinCo (2000) recommend an optional protection layer if no root resistant waterproofing is used. The protective layer will guard the underlying surfaces from root damage, temperature changes, structural movement and gardening mishaps (i.e. digging) (Johnston and Newton: 1993). ZinCo (2000) recommend an oil and bitumen-resistant layer of PVC with a thickness of about 0.8mm.

A common negative perception regarding green roofs is that the roots from plants, particularly trees will penetrate the roof. Scrivens states that roots will only penetrate a membrane that is already split and will not perforate a continuous layer (Scrivens: 1982). Scrivens (1982) also comments that ‘a single sheet of polythene buried in the soil is impervious to normal root activity, so a roofing membrane backed by a concrete slab should be infallible.’ Scrivens (1982) also states that studies have revealed that almost all roots develop horizontally, ‘which is to be expected since few natural top soils are more than 500mm thick.’
Drainage layer

A roof with an angle of 10-15° may not require a drainage layer as the water can drain naturally off the roof (Scrivens: 1982). Green roof manufacturers have developed a range of high-tech solutions, to suit varying situations, to control the moisture level of the substrate. ZinCo’s Floradrian FD 60 system (ZinCo: 2000) is a drain damming system that allows 40mm of water to be stored on the roof directly beneath the vegetation. This is incorporated into the drainage layer, where pockets are filled with recycled clay bricks. This particular system is only suitable for a flat roof (ZinCo: 2000). The Floradrain FD 60 system can be linked to an automated irrigator, which will ensure a constant supply of water, this is controlled electronically, and ZinCo can supply a solar powered system (ZinCo: 2000).

Filter mat

Glass fibre mats, polypropylene or polyethylene fibre mats prevent the soil from entering the drainage layer (Johnston and Newton: 1993).

Substrate

Soil depths on green roofs vary from as little as 10mm to as much as 2000mm (English Nature: 2003). Soil depths for extensive green roofs vary between 10-200mm, lawns or turf will require a soil depth of 150-200mm, a sedum roof may need a soil depth of 50mm (Scrivens: 1980). An intensive green roof has a substrate, which is over 200mm deep (Johnson and Newton: 1993). Shrubs will need 500-600mm, and larger trees 800-1300mm of soil. Birch trees grow in soils as shallow as 600mm (English Nature: 2003). The soil should have good permeability for air and water, be able to hold moisture, and should be able to withstand erosion (Johnston and Newton: 1993). Clay bricks and compost may also be added to the soil to improve drainage and Ph levels (ZinCo: 2000).

Loading

Loading on the green roofs varies dramatically according to the type of roof, how the roof is to be used, the weight of substrate and the weight of plants used. A specialist supplied extensive green roof system could weigh just 25kg per m² (Johnston and Newton: 1993). The load of an intensive green roof with a depth of 600mm and including trees could be up to 1 tonne/m² (Scrivens: 1980). ZinCo’s’ (2000) intensive green roofs use highly developed technology and weigh between 150kg/m² to 900 kg/m². Additional allowances are needed to ensure the live weight, that is the mobile weight of traffic including people above the roof, is safely
supported (Scrivens: 1980). A heavy steel or reinforced concrete structure will be required to support this weight (English Nature: 2003). English Nature (2003) states that ‘although these structures are expensive, they are usually several storeys in height and little if any, extra strength would be added to support a green roof’. Buildings like Willis, Faber and Dumas where there are likely to be crowds on the roof garden will require a higher loading of up to 5kN/m² over all walkways (Scrivens: 1980). Despite this structural demand, the roof garden at the Willis, Faber and Dumas building has been built at no extra cost (Scrivens: 1980). An intensive green roof on a lightweight low-rise building on the other hand will be expensive requiring extra structural reinforcement and may therefore be unrealistic, a light-weight extensive green roof would be a better solution (English Nature: 2003).

**Exposure**

Wind speeds on the roof can be twice the speed of winds on the ground (Scrivens: 1982). Scrivens (1982) suggests that perimeter trees or a perimeter wall could reduce the exposure on the roof. A perimeter wall could also make an important safety barrier, not just as a precaution to prevent people from falling but to stop children pushing things off the edge, if ball games are considered the area may need to be entirely enclosed by a cage (Scrivens: 1982). Scrivens (1982) defines this enclosed area as an ‘introvert’ roof where the emphasis is not on the view but the enclosed tranquil space. However, the perimeter wall of Gaudi’s “La Pedrera” demonstrates that a solid enclosing wall does not mean that the view has to be compromised.

![Fig 5 the roof garden of No.1 Poultry Road in London (source, ZinCo: 2000)](image)
Planting

As previously discussed extensive green roofs provide a very limited habitat for plants, whereas intensive green roofs can support a succession of levels of diversity depending on how deep the soil is and how great the burden of load that may be supported by the roof. Another important issue to consider is the harsher conditions on the roof, where the plants are more exposed to wind (if there is no perimeter wall), temperatures are a few degrees higher than on the ground and the soils are more arid.

Johnston and Newton (1993) comment that:

'To flourish on a roof, many plants will have to cope with harsher living conditions than those encountered on the ground. For some plants conditions will be intolerable. Others may find life on the roof amenable and they will grow quite happily. Lower concentrations of some pollutants and reduced disturbance from people are positive factors. The conditions in individual situations vary enormously and depend on combinations of local factors. The most common variables that need to be considered are wind, temperature and moisture regime.'

Plants Suitable for Extensive Green Roofs

Johnston and Newton provide comprehensive tables detailing plants that are suitable for extensive green roofs (1993, p.p. 86-88), where growing conditions are limited, especially because of the thin soil (200mm or less) and the absence of irrigation systems. Particularly important is the low growing succulent 'sedum', which is drought tolerant, hardy and (significantly) low maintenance (English Nature: 2003).

Nigel Dunnett of the University of Sheffield has lead research into the investigation of suitable plants for green roofs in the British climate. (www.landscape.co.uk: 2004). The research shows that where the soil depth is 6cm or lower, the substrate is prone to drying out and plants must therefore be extremely drought tolerant (Dunnett: 2004).

Plants suitable for Semi-Extensive Green Roofs

Dunnett (2004) suggests that a substrate depth of 15cm will offer greater planting opportunities than an extensive green roof and will be less dependent on irrigation than an intensive green roof. Trials carried out at Sheffield University (Dunnett: 2002) tested the success of a range of
plants on a semi-extensive green roof. The research found that most species that grow in free-draining and sunny positions may be used in this situation. These plants include: herbaceous species such as Origanum laevigatum, Salvia nemorosa, alpines and creeping plants, such as Dianthus deltoids and Gypsophila repens, additionally a range of clump forming grasses will perform well in these conditions. Johnston and Newton (1993) similarly recommend herbaceous plants and shrubs that are found in arid free-draining landscapes such as heaths and dry grasslands: buddleia, and herbs such as rosebay willow herb and evening primrose and alpines. Dunnett (2002) also suggests aesthetic considerations in the landscaping of this type of roof, for example he suggests many of the suitable plants tend to have grey or silver foliage and blue, white or pink flowers, so that they make for a harmonious scheme.

Plants suitable for Intensive Green roofs

Intensive green roofs can support most plants that you would find in an ordinary park or garden, trees, shrubs, flowerbeds, lawns and meadows and even ponds (Johnston and Newton: 1993). The 15th century Benettoni tower in Lucca, Italy, supports large oak trees 40 metres above the ground (English Nature: 2003). To reduce the gardens dependence on irrigation, plants that normally tolerate arid conditions, such as succulents, herbaceous plants, grasses and meadow varieties can be used (Dunnett: 2004). As discussed earlier in this chapter, ornamental plants and lawns do not provide a habitat for urban wildlife. Plants that are a good source of nectar, that produce edible nuts, seeds, or berries and provide some areas of dense cover will improve the chances of attracting wildlife to the roof (Johnston and Newton: 1993). Trees and shrubs could be of particular value (Johnston and Newton: 1993). There may also be potential to conserve Britain’s native plants (English Nature: 2003).

British Publications and Research

Compared to the quantity of information available in German and Swiss texts there is very little written about green roofs by British authors. However, interest in Britain, especially London, is developing among researchers. In September 2003, Sheffield University hosted the first green roof seminar, ‘Green roofs for Healthy Cities,’ and a second seminar was hosted in April 2004 at the Royal Institute of British Architects in London. Contemporary research activity in this country is especially prevalent in and around London, where the potential benefits to urban biodiversity, offered by green roofs are being explored by a handful of dedicated individuals.
Steven Scrivens

Scrivens is a pioneer of British research, writing on the subject of roof gardens, he is also a Landscape architect. Many of his reports were published in the Architects Journal during the 1980s and discuss the design and construction of green roofs. Scrivens was very much a lone voice at this time and it was not until the onset of the new millennium, that publications devoted to green roofs became more common.

Scrivens publications include 'Roof Gardens: Construction' (27 February, 1980), 'Irrigation' (12 March, 1980), and a 'Design Guide' (17 March 1982). Scrivens' reports are comprehensive technical guides which use case studies of British green roofs to demonstrate the design and construction issues associated with green roofs. Potential problems and their solutions are discussed and related to actual case studies.

Scrivens published these case studies of British buildings with green roofs in the Architects Journal, they include, Gateway House, Basingstoke,' (26 March, 1980), 'Suffolk Hospital', (16 April 1980), 'Willis Faber and Dumas,' (17 September, 1980), 'Derry and Toms', (15 October 1980), 'Harvey’s Store, Guildford,' (24 February, 1982), 'Kingston Hospital' (24 February, 1982), and 'Landscape Revisit: Gateway House, Basingstoke,' (11 December, 1985).

Stephen Scrivens also designed the roof garden of Jacobs Island, London, built in 1997 by ZinCo (ZinCo: 2000). This is a landscaped area situated over a car park, which has a focal point of a large lake (see figure 2 ZinCo: 2000).

Johnston and Newton

'Building Green: A Guide to Using Plants on Roofs, Walls and Pavements,' published by the London Ecology Unit in 1993, is a particularly important book. Of this book Mathew Frith of the Peabody Trust says:

"...in retrospect it certainly established the first milestone in terms of capturing ideas and pointing a way forward"

www.greenroofs.com/skygardens: 2004

Chapter 8 'Green Roofs' is a general and concise guide to green roofs, their advantages, design and construction, it includes a guide to planting and a how to guide to encourage wildlife on the roof.
Contemporary Green Roof Research Activity

Currently the green roof research in the UK is largely centred in and around London. Since the late 1990s a movement in this area, has emerged. Largely this research focuses on the potential of green roofs to contribute to urban biodiversity. For example, a PhD project is currently being conducted (2003-6) by Kadas in Canary Warf and concerns populations of invertebrates on green roofs.

A useful guide to contemporary green roof research and development, in and around London, is provided by a report by Linda Velazquez who writes for the American website www.greenroofs.com (‘Skygardens’: January/February 2004).

Particularly useful is the guide to the ‘Current Movers and Shakers’ in the British green roof movement.

‘Several government and private organizations, universities, and a handful of designers and architects are actively involved in both London specifically and England in general regarding ecological issues that include green roof development or promotion. Many of the government bodies partner with each other for specific issues including green roof related research and dissemination’

www.greenroofs.com/skygardens: 2004

Velazquez describes the green roof development in Britain in terms of the ‘First, second and third waves of leaders.’

The first wave; according to Velazquez; are the so called pioneers of British Green roof research who instigated the promotion of green roofs during the early 1990s and include the London Ecology Unit and the Green roof companies Ericso-Bauder and Alumasc.

Velazquez (2004) describes the leaders of the second wave driving forward green roof issues from the late 1990’s to the present as primarily researchers, writers, architects and biodiversity champions.

Current work led by Nigel Dunnett, of the Department of Landscape, University of Sheffield, work by London biodiversity campaigners Dusty Gedge, Jill Goddard and Matthew Frith who have incorporated green roofs in their long term conservation strategies. To this so-called ‘second wave’ English Nature could be included, for their very important contributions, also concerning green roofs and biodiversity (English Nature: 2003).
The third wave according to Velazquez (2004) is yet to come, Mathew Frith (Velazquez: 2004), comments that “It will happen by hook or by crook; I suspect this ‘third wave’ of green roofs will break into significant action across the capital – one can sense the momentum that has gathered over the past 3-5 years (and that’s coming from an outside position). However, the need for a non-partisan, non-business-driven organisation to advocate the accurate multi-functional values of green roofs, prepare model policies, commission and collate research, and prepare the necessary guidance and specifications is now very urgent, and some of us are in the throes of doing this...... The key, in my opinion, is to ensure that the various benefits/disbenefits of the full spectrum of possible green roofs is made available, that the Sedum-focused industry adapts to the other needs within this area, and that we engage with the right drivers.”

Adam Ingleby

Ingleby wrote; Green Roofs: A study of their benefits, and barriers to their installation in London (2002); for his MSc Thesis to fulfil the requirements for a postgraduate course in Environmental Management at Birkbeck College, London:

“This study is about Green Roofs, their benefits, the policy work that supports them and the barriers to their installation” (Ingleby: 2002)

Ingleby sent postal questionnaires to major stakeholder groups in construction, including architects, developers, engineers and planners. 280 professionals were contacted, 75 responded, of these 81% said they were aware of green roofs. The majority of respondents agreed with the theories concerning the benefits of green roofs, 80% said green roofs improve the aesthetics of the building and 92% agree that there are benefits to biodiversity. 50% disagreed that there are few constraints to the adoption of green roofs in London. The majority of respondents believed that a lack of awareness among developers was the strongest constraint, followed by a lack of awareness among architects. Further barriers, the respondents believed were the lack of public demand and the concerns of investors. Over 95% of architects and planners would like to see more publicity, particularly promotional literature and information circulated among stakeholder groups, this would facilitate the establishment of green roofs across London, they say. Many respondents believe that a flagship green roof project will improve the chances of the adoption of green roofs in London. Such promotions would also boost the profile of the green roof. The green roof could then be regarded as more mainstream and not as one respondent

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commented, “huts in wildlife reserves.” Planning permission was not seen as a constraint, although it was believed that planning conditions could prove a useful vehicle. However, Ingleby states that it is unlikely that the government will provide direct financial incentives for roof greening. Several respondents said that they were considering green roofs for future projects, Ingleby discusses how if these considerations are turned into action this will increase the number of green roofs across the capital.

*Ingleby’s Methodology*

The study was designed to establish how widely known are the benefits of green roofs, and to find out what barriers exist that prevent their establishment.

*The Stakeholder Groups*

Several stakeholder groups were identified, these included:

- Developers
- Architects
- Engineers
- Planners

The research looked for differences of opinions between the different groups.

*Data Collection*

Data was collected by questionnaire. Ingleby used a combined method, using open-ended and pre-coded questions. A total survey population of 280 people of the stakeholder groups was selected, using selection methods to avoid bias. 75 people responded to the study, or 27% of the consulted population. All respondents were given an overview of the study.

*Ingleby’s Recommendations for Future Research*

Ingleby concludes that there are inevitably, things that could have been done better and also opportunities which could be interesting to explore in future studies:
1. Further qualitative research could look at a wider range and larger sample of respondents from the stakeholder groups, the results, Ingleby comments, would then be more significant.

2. 40% of the architects questioned said they had experience of establishing green roofs. However, none of these claimed that their projects were “successful”. More in depth interviews with these architects could reveal why.

3. University College London is now running a PhD in Green Roofs, largely concerning green roofs and biodiversity. A study could be based on interviews with the owners of the studied green roofs, to discover the constraints and barriers that were overcome to establish the green roofs.

*English Nature*

English Nature is involved in ongoing research concerning green roofs and their associated positive effects on urban wildlife. English Nature was set up by the Environment Protection Act of 1990. It is the UK governments’ advisory body on green roofs and champions the conservation of wildlife, geology and wild places in England (www.english-nature.org.uk: 2004).

English Nature published: ‘Green roofs: their existing status and potential for conserving biodiversity in urban areas, report number 498’ (English Nature: 2003) this was a follow up to an earlier publication ‘Roof Gardens: a review from Urban Wildlife Now,’ published by English Natures’ predecessor, the Nature Conservancy Council in 1990.

The report discusses the background, history, design and construction of green roofs. It is a very useful overview of current British policy concerning the Urban built environment, and how this relates to green roofs.

‘Recent official guidance on urban design in the UK (see DETR/CABE 2000, DTLR 2001, and Levelly-Davies 2000) has overlooked the role and value of green roofs.’

(English Nature: 2003)

The research focuses on the role green roofs could play in supporting urban biodiversity. Such studies in this county are influenced by the work of Brenneissen (2001) who studied the birds, beetles and spiders on green roofs in Basel, Switzerland. The report concludes that further
work is needed to establish the significance of green roofs in supporting wildlife populations (English Nature: 2003). ‘Proposals are currently being progressed in a number of locations to design and create building-integrated habitat specifically for biodiversity conservation (e.g. the ‘brown’ roofs at Deptford Creek, S.E. London). These are in the vanguard of a movement to create similar features throughout the nation’s cities’ (English Nature: 2003). This report is also a useful source of locations, suppliers and designers of green roofs throughout Britain. These are listed at the back of the report along with a list of selected of green roof websites (English Nature: 2003).

**The British Council for Offices and the Corporation of London**


**Nigel Dunnett, Sheffield University**

Dunnett of Sheffield University leads research devoted to the study of plants that will successfully colonize green roofs in British climatic conditions (www.landscape.org.uk: 2004). In 2001 the University of Sheffield’s Flowering Green Roof Research Plots were installed (www.landscape.org.uk: 2004):

> “The aim of the trials is to investigate the range of plant material that is suitable for use on extensive and semi-extensive green roofs in the UK climate (generally cooler and wetter than central Europe where much previous green roof research has been undertaken). Plant mixtures are being grown on different substrate depths, with and without additional irrigation. Plants were chosen for the trials that had a known degree of drought-tolerance. In the trials, substrate depth has had less influence on plant survival and performance than the effect of periodic irrigation, even if this irrigation was minimal. However, irrigation and increased substrate depth was detrimental to carpeting species, such as many Sedums, which were out-competed by more vigorous species under favourable conditions. Further trials investigate plant establishment methods, particularly the use of seed mixtures to establish meadow-like communities of both native and non-native grasses and flowering plants”

www.greenroofs.com/skygardens: 2004
Dunnett’s book co-authored by Noel Kingsbury ‘Planting Green Roofs and Living Walls’ (2004) devoted specifically to extensive and semi-extensive green roofs. ‘It’s partly a practical how to do it book, but also a research work where we have tried to summarise available literature in German and in English on green roof benefits and performance’ (Dunnett, Personal correspondence: 2004).

Paul Collins, Nottingham Trent University

Collins, Head of Postgraduate studies at the School of Property and Construction at Nottingham Trent University leads the Universities very own ‘Green Roof Research Team.’ Information compiled by Collins and colleague Hannah is available online at http://construction.ntu.ac.uk/staffwebs/greenroofs (2004). An overview of green roofs is discussed and illustrated on the website. A general history of green roofs and a general set of definitions are included in this report. Posted on the website is the teams 2000 survey, a follow up investigation of a previous research project that investigate ‘the policy and implementation of two main areas of ‘green buildings’; namely ‘Green Roofs and Earth Sheltered Buildings’ (http://construction.ntu.ac.uk/staffwebs/greenroofs: 2004). ‘The 2000 survey broadens the field of the questionnaire by including flat roof contractors, case study buildings and separate questionnaires for forward planners and the development control departments in Local Authorities. In addition there is a sample survey of Local Authorities in some parts of Germany’ (http://construction.ntu.ac.uk/staffwebs/greenroofs: 2004).

The London Biodiversity Campaign, Gedge, Kadas and associated projects

Gedge of the London Biodiversity Campaign has contributed to projects in London to improve urban biodiversity by installing green roofs on the cities flat roofs. Most especially his work concerns the Black Redstart (Phoenicurus ochruros), a rare British bird whose population in London is threatened by the development of brownfield sites (Gedge: 2003).

‘This wonderful bird is found in London on old vacant lots and has a particular liking for rubble – certainly not everyone’s idea of pristine wilderness – yet in many ways such sites are more interesting for biodiversity than more pristine areas of the English countryside.’... ‘Pondering the dilemma of the bird and rubble verses swanking new apartment, an idea began: Why not transfer the rubble to the roofs?’
The response was to found The London Biodiversity Partnership's Black Redstart Action Plan, now more than 100,000m² of green roofs are planned or have already been built in the capital.

Gedge is also involved with green roof projects in Canary Warf and Deptford Creek (Gedge: 2003). Above the 86 acre Canary Warf estate is one of Britain's largest green roofed areas, covering an estimated 5,000-6,000m² (www.greenroofs.com/skygardens: 2004). The London Biodiversity Partnership and Royal Holloway University of London are currently funding green roof research based at Canary Warf. PhD student Kadas is involved in the Canary Warf project and in 2003 started a three year study of three extensive green roofs (2 sedum matted and 1 sedum on 7cm of crushed brick) and two brown roofs (rubble based roofs) located within the Canary Warf Estate (Gedge: 2003). Research work and laboratories will be maintained by The London Biodiversity Partnership and Royal Holloway University of London, who will establish further green roof laboratories in London 'to establish the important or essential design factors to provide mitigation for brownfield invertebrates on green roofs' says Gedge (Gedge: 2003).

Gedge and Kadas are also involved with a green roof project at Deptford Creek, in London. Deptford Creek a tidal tributary of the Thames; is haven for 100's of fresh and salt-water plants and animals (http://home.btconnect.com/creekside: 2004). Goddard, Ecological Regeneration Manager at the London Borough of Lewisham, runs the Creekside Environmental Programme at Deptford Creek, where she has been instrumental in the establishment of 'brown' roofs (www.greenroofs.com/skygardens: 2004). Again the brown roofs are intended to compensate for lost brownfield habitats on the ground, to encourage biodiversity (www.greenroofs.com/skygardens: 2004). Part of this development is The Laban Dance Centre, designed by Herzog and De Meuron the building won the 2002 RIBA 'building of the year award (www.greenroofs.com/skygardens: 2004). The Laban Dance Centre has a brown roof, which has been specially built to attract the Black Redstart. 400m² of crushed concrete covers the roof, to mimic brownfield habitat. A similar roof has been constructed in the same development on the 'Creekside Education Centre' and a further six are planned in this area. (www.greenroofs.com/skygardens: 2004). Work on this project has been catalysed thanks to the project's partnership with Stephan Brenneissen’s research in Basel Switzerland (www.greenroofs.com/skygardens: 2004).
The Peabody Trust and Frith

The Peabody Trust is one of London’s largest and oldest housing associations, founded in the nineteenth century by a wealthy American philanthropist, after whom the trust is named. It is now a charity and regeneration agency (www.peabody.org.uk; 2004). The Trust was involved in a joint venture with Bill Dunster Architects, Arup and the BioRegional Development Group on the innovative and award-winning project ‘BedZED’ (Beddington Zero Energy Development) built in the London Borough of Sutton and completed in 2002 (www.peabody.org.uk; 2004). This is a mixed use, high density development 82 residential homes (www.peabody.org.uk; 2004), where about 25 roof gardens are managed by residents (www.greenroofs.com/skygardens; 2004). Mathew Frith is the Landscape Regeneration Manager for the trust. Frith previously worked for English Nature, and commissioned the 2003 report, he has authored several green roof and biodiversity articles (www.greenroofs.com/skygardens; 2004).

Opportunities and Barriers

The rationale to support the widespread adoption of green roofs in British cities is considerable and the benefits or green roofs are well proven in German and Swiss research (Kohler et al: 2002). The potential for the adoption of green roofs is also significant. An estimated 20,000 hectares of existing urban roofs in the UK could be vegetated with little or no structural modification (Corus: 2001). Collins (2004) observes that ‘one has only to look at aerial photographs of cityscapes and wonder at the number of wasted flat roof areas that already exist.’ Collins goes on to remark that many of the flat roofs of industrial and commercial buildings built in the 1970s are nearing the end of their lifecycles, presenting a relatively convenient opportunity for roof greening. Unfortunately unless there is a widespread adoption of green roofs their positive environmental effects will not be felt (English Nature: 2003). There is an increasing demand for the development of urban green areas. Though they cannot compensate completely this loss of green space, green roofs could provide a substitute. Vegetation may only cover about one third of the land surface of urban areas as compared with 75%-95% in outer suburbs (Johnston and Newton: 1993). The required development of brown field sites will further reduce this area (DETR: 2000).
The Perceived Barriers

Government Policy

Incentives are offered on a local and national level by German and Swiss authorities, such incentives have played an important role in the success of green roofs in these countries (English Nature: 2003, Kohler et al: 2002).

According to English Nature (2003), recent official guidelines on urban design in the UK, such as those stipulated by the Commission on Architecture and the Built Environment (CABE: 2000, see also Llewellyn Davies: 2000), have overlooked the potential of green roofs to improve the urban environment. Currently there are only a few direct government policies concerning green roofs in Britain (Ingleby: 2002: 2004). In London the boroughs of Brent, Lewisham and Enfield, and the city of Westminster, have produced policies directly related to green roofs (Ingleby: 2002).

Though green roof government incentives have been successful in Germany and Switzerland, it is unlikely that government policy directly implementing financial incentives for green roofs in Britain (Ingleby 2002). However, Ingleby (2002) comments that, "it may be possible to implement another German policy; zoning. In 27 cities the installation of green roofs is mandatory on new developments with flat roofs".

Collins (2004) cites research by his department that found that there was little evidence to suggest that English Planning Authorities have positive attitudes to green roofs. However, the research found that London boroughs were the exception with a more positive attitude to green roofs and greater experience of green roof building in practice. Collins (2004) argues that 'as the sustainability issue moves up the political agenda,' in the near future green roof policies may form a part of local planning policy. Scholtz-Barth (2001) suggests that incentives offered by local government could be connected to the savings offered by green roofs on urban sewage systems, thanks to reduced rainwater runoff.

Existing policy could also be adapted to promote green roofs. The British Governments’ Urban White Paper (DETR 2000) promotes the use of brown field sites for new construction projects. It also states the importance of good urban design and the correlations of people and places, nature and the built environment. Green roofs could play an important role to achieve some of the requirements of this government

**Initial Costs**

The initial and maintaining costs of the green roof could be a major disincentive (Collins: 2004). However, the cost of a basic green roof is not excessively high. Pete Massini of English Nature (www.bbc.co.uk: 2003) estimates the current cost of converting an existing flat roof to a green roof to be around £15 to £30 per m², he expects this price to drop as the green roof becomes more popular. The cost of green roofs in Germany has been reduced in recent years thanks to the competitive and developed green roof industry (English Nature: 2003). Extensive green roofs offer a particularly cheap solution. German manufacturers can now offer a complete extensive roof system at 20-40 Euros per m², excluding labour (English Nature: 2003). Furthermore a green roof can reduce the overall costs of a building in the long term, through savings in heating and air conditioning and by increasing the lifespan of the roof (Peck: 1999, Scrivens: 1982). Wong et al. (2002) in a life cycle cost analysis of rooftop gardens in Singapore found that despite the initial cost of the extensive green roofs included in the study, the life cycle cost was lower than buildings with exposed flat roofs.

The Willis, Faber and Dumas building, in Ipswich, was designed in 1971 by Fosters Associates. On the summit of the building is a roof garden, which was included at no extra cost. The roof garden is accessed through the doors of the roof top restaurant and provides a recreational area for the office workers from the building. The addition of the green roof permitted the removal of expansion joints and the removal of adjustable joints to mechanical elements, ceilings and floors. This saving was offset by the cost of the structural strengthening needed to support the roof and its’ soil load. The roof garden also benefits the buildings through savings in heating and through its’ amenity value which may help to lower the staff turnover rate (Scrivens: 1980).

**Maintenance, costs and labour**

The time and money spent on the maintenance of green roofs varies considerably depending on the type of roof chosen. An extensive green roof, such as a low maintenance sedum roof may be the best solution for a roof, if there are limited resources available for maintenance. Intensive green roofs will be more costly in terms of time and money. Collins (2003) of Nottingham Trent University suggests that ‘The time and money spent on the maintenance of roof gardens and grass roofs can be compared to gardens, parks and lawns on the ground’.
Careful planning during the design stage of the roof can minimize and control the long-term costs. High-tech systems provided by German manufacturers such as Ericso Bauder and ZinCo mean that the time and money allocated for the maintenance of the roof can be tightly controlled during the planning stage of either the building or the roof. After the initial planting of a ZinCo extensive green roof it will be necessary to irrigate to establish plant growth (ZinCo: 2000). After this period ZinCo (2000) recommend that their extensive roof is inspected 1-2 times per year, particularly to check for debris obstructing drains. ZinCo (2000) state that the 'supply of water and nutrients is mostly by natural processes.'

Semi-extensive and intensive green roofs will depend on irrigation, which can be automated or computer controlled (ZinCo: 2000). Dependence on irrigation may be minimised by modifying the moisture retentive qualities of the substrate on semi-intensive and intensive green roofs, for instance, by adding clay brick to the soil (ZinCo: 2000) to retain moisture or by adding a layer of pea gravel to improve drainage (Scrivens: 1982). Complete cover of the soil by vegetation (Scrivens: 1982) will also reduce the amount of water lost and drought tolerant plants will reduce the dependence on water (Dunnett: 2004).

Another consideration is discussed by Scrivens (1982) who describes a design fault on the roof garden of Gateway House in Basingstoke where considerable time and effort would have been saved had provision for storage of equipment and disposal of rubbish on the roof been supplied.

Negative Perceptions and Lack of Awareness

General perceptions of rugged grassed roofs may well be negative. English Nature cites research that found that people consider natural green spaces in an urban environment to be discordant (Rohde and Kendle: 1994). Furthermore according to English Nature (2003) natural meadows and rough looking grasses on sloping roofs that may brown during warmer months do not appeal to the majority of people.

Ingleby (2002) found that a general lack of awareness regarding green roofs and their important benefits among, architects, planners, local government and the public, was a significant barrier to the adoption of green roofs. If the stakeholders are aware of the modern green roofs they may be reluctant to include a green roof in a new venture if they feel the design may not receive support from the client (Ingleby: 2002). Furthermore the construction industry has to guarantee sale and resale of a building, Ingleby (2002) comments that:
“If one then starts to consider difficulties in gaining planning permission, which can be rigorous, especially in inner city areas, many of which have Conservation Areas then, one can see that these barriers begin to accumulate.”

However, Ingleby (2002) found that 81%, of a sample of 280 professionals; architects, developers, planners and engineers were aware of green roofs, and of these, most were aware of the associated benefits of green roofs.

Many people believe that green roofs are impractical, expensive and high maintenance and some are anxious that the roots of plants will penetrate the roof. Gedge (cited in Velazquez: 2004) asserts that the ‘myths’ of green roofs need to be exposed if the green roof movement is to progress. One such myth is that all buildings that support green roofs will need major reinforcement to support the load of the green roof. Roof gardens will in many cases require the supporting building to be re-enforced. Extensive green roofs, on the other hand, tend to be very light weight and do not require that the roof be reinforced. An ordinary flat roof is designed to take the loading of up to 150kg per m² (Dunnett: 2004). Lightweight substrates such as expanded clay granules weigh up to 30kg per m² for a 10cm layer and commercial green roofs have a loading of up to 50kg per m² (Dunnett: 2004). In many cases this means that no structural re-enforcement is required to support an extensive green roof.

Extensive green roofs present no problems when it comes to the intrusion of roots through the roof. Root barriers are used for intensive green roofs, for example a bituminous membrane flanked by a polyethylene layer, a barrier offered by ZinCo, means that root penetration is virtually impossible (ZinCo: 2000).

Opportunities

There are an estimated 20,000 hectares (200 million m²) of flat roof space in the UK that could be vegetated with little or no structural modification (Velazquez: 2004).

As shown in Germany, research and development by, researchers and government entities can improve awareness and positively influence the widespread adoption of green roofs (Velazquez: 2004). According to English Nature (2003) research specific to the UK and government guidance are urgently required.
Biodiversity is emerging, particularly in London as a major driver in the adoption of green roofs. Work by organisations such as The London Biodiversity Campaign has been responsible for considerable areas of flat roofs in the Capital being turned over to brown roofs, to compensate for loss of the Brownfield habitats on the ground. In Canary Warf approximately 5,000 to 6,000 m² has been converted to brown field habitat for the study and promotion of biodiversity. The part that green roofs can play to support biodiversity is re-enforced by the Lord Majors Biodiversity strategy, which states that; “Where wasteland habitats are lost to development, mitigation and compensation should concentrate on provision of similar habitats.” The report directly implicates green roofs “such as creating wasteland habitats on roofs” (GLA: 2002).

Ingleby (2002) discovered that many respondents in a survey of construction professionals held the view that a series of major flagship, high profile, green roof projects need to be developed so that green roof benefits and possibilities can be more widely known. By raising the profile of green roofs one significant barrier could be removed. Recently there has been some discussion about green roofs, especially roof gardens, in the mainstream media. For example, one report in the self-build magazine ‘Grand Designs’ states that

‘Roof terraces are on the up. Rarely has the demand for high-rise horticulture been more intense, particularly in London’ (Sept: 2004).

A report in the Guardian online (August 25, 2004) discusses the merits of roof gardens to ameliorate the problems caused by hard, impervious surfaces in cities, linking recent flash floods in London, where the sewage infrastructure of the city was pushed beyond capacity, leading to sewage being dumped in the Thames. Westminster council (Ingleby’s current employers) sponsored ‘The Reflective Garden’ at the Chelsea flower show, which promoted the councils objectives to encourage roof gardens to improve the London environment (www.rhs.org: 2004). Increasingly the benefits of green roofs are being talked about and promoted in mainstream arenas.

**Innovation**

An innovation is an idea, practice, or object that is perceived as new by an individual or other unit of adoption, whether or not an idea is “objectively” new as measured by the lapse of time since its first use or discovery (Schumpeter: 1939). In a business context Schumpeter describes innovation as “a process of cumulative growth initiators, which
introduces the innovation into the market (after it’s exposure by entrepreneurs) with expectations of high profits” (Schumpeter: 1939). Fairclough (2001) comments that: “innovation is profitable change, affecting the bottom line.” Holmon et al state that “there is little dispute that technological innovation is important for the prosperity of firms, industries and society.”

Most theorists agree that innovation is a social phenomenon. Rogers (1983) stresses the importance of interpersonal networks in the adoption and rejection of innovations. Holmon et al (2003) talk about the importance of ‘interorganisational’ relationships in the construction industry, amongst architects, engineers, contractors and so on. Rogers (1983) argues that the rate of innovation is likely to be improved if adopted by influential individuals or groups. Whereas the uptake of an innovation and the rate, at which the innovation spreads throughout the population, may be adversely affected if adopted by those without influence (Rogers: 1983).

Innovation in Construction

The construction industry is generally considered to be conservative and adverse to change. Fairclough (2001) goes, as far as to say that the construction industry is perceived as ‘dirty, dangerous and old fashioned.’ For many years the industry has stuck rigidly to traditional ways and is characterised as being slow to adopt new innovations, in many European countries there is now a discussion among industry professionals, government bodies and academics as to how the level of innovation may be increased (Holmon et al: 2003).

According to Holmon et al (2003) the construction industry is characterised by adversarial relationships and this lack of interpersonal cooperation has been a significant factor in the low uptake of innovations in the industry. Holmon et al (2003) argue that organizational innovation is a prerequisite for technological innovation.

According to Winch (2002) there is now a strong appetite for change in the United Kingdoms construction industry. Old methods are being re-examined. Innovation and experimentation are now positively encouraged (Winch: 2002). Innovation in construction is now seen as vital to the success of the industry. Until the perception of the industry as dirty and antiquated is corrected; Fairclough (2001) fears that young people will not be encouraged to enter the industry and the existing skills crisis will continue.
The development of intellectual knowledge in construction has been called for by a number of theorists. The importance of investment in Research and Development is discussed in Sir John Fairclough's (2001) report 'Rethinking Construction, Innovation and Research,' which states that R&D is not given the same priority as in other industries. Fairclough argues that there is a need for a strategic framework to be set out. This would outline the issues facing the construction industry. From this framework, focused, long term research planning could be derived. Fairclough (2001) argues that the government should play an important role in encouraging R&D, informing the framework for research and providing funding for some projects, but he states that the government should not control research.

In 1998 the Deputy Prime Minister’s Construction Taskforce set out an agenda for change entitled ‘Rethinking construction’ also known as the Egan report. The report was commissioned to identify opportunities to improve the efficiency and output of the construction industry. The report stresses the importance of industry ownership in the change process. The taskforce identified five key drivers of change, these are: committed leadership, a focus on the customer, integrated processes and teams, a quality driven agenda and commitment to people. Like Fairclough the Taskforce discusses the urgent importance of knowledge development and the part that the public sector could play in implementing sustainable change. The report invites the public sector bodies to seek improvements in efficiency and quality.

**Rogers Diffusion of Innovation (1983)**

Much research has been devoted to the theory of innovation to understand the process and to understand how to influence the rate at which innovations are adopted.

Rogers' (1983) describes the diffusion of an innovation as the process by which knowledge of an innovation spreads throughout a population, eventually to be adopted or rejected by a decision-making unit in the organisation.

According to Rogers (1983) the diffusion of innovation is broken down into four main elements:

"(1) An innovation (2) is communicated through certain channels (3) over time (4) among the members of a social system." Finally the adoption is the decision to make full use of an innovation as the best course of action available.
The Innovation-Decision Process

Rogers' defines this as the process through which an individual or decision making unit passes from

"(1) the knowledge of the innovation, (2) to forming an attitude toward the innovation, (3) to a decision to adopt or reject, (4) to the implementation of the idea or confirmation of this decision."

This process consists of a series of actions and choices over time through which an individual or organization evaluates a new idea. This process may be influenced by a change agent, an individual responsible for influencing the clients' innovation decisions in a direction deemed desirable, in most cases the change agent seeks to secure the adoption of new ideas.

Knowledge Stage

The individual or group is exposed to the innovations' existence and gains understanding of the innovation. According to Rogers (1983) we consciously or unconsciously avoid messages that are in conflict with our predispositions, Rogers' terms this 'Selective Exposure'. Even if this innovation is registered by the individual or group, it may not be perceived as relevant to the needs, or consistent with the attitudes and beliefs of the party, this is termed 'Selective Perception.' A need could be defined as a state of dissatisfaction or frustration with the current situation, for instance a need to improve city air quality or the need to reduce the cost of heating or air-conditioning, in a building. Some change agents create needs among their clients by suggesting the need for new ideas. The need may be preceded or followed by the knowledge of an innovation.

Persuasion

In this stage the individual or group forms a favourable or un-favourable attitude towards the innovation. A certain amount of uncertainty regarding the innovation is inevitable at this stage therefore information about the new idea is actively sought. In this way the individual or group will seek to evaluate the innovation, in order to reduce uncertainty. Once the initial evaluation is completed, the outcome of the persuasion stage is a favourable or unfavourable attitude to the innovation.
Decision Stage

For most it is necessary to engage in a trial of the innovation in order to cope with the uncertainty that may be a problem at this stage. A substitute trial could be “trial by others” an evaluation of an innovation already adopted by an equivalent peer. Change agents often speed up the innovation-process by sponsoring demonstrations of an innovation in a social system. During this probationary period the usefulness of the innovation is determined, a decision can then be made as to whether or not the innovation is adopted. The stages so far do not necessarily fall in a linear order, for instance the sequence could be knowledge, decision, persuasion.

Implementation Stage

It is one thing to decide to adopt and quite another to put the innovation into practice. Uncertainty is still a potential hurdle at this late stage, despite the decision having already been made. It is likely that practical and technical problems are queried and so information is actively sought once more during this stage. The change agent will often provide technical assistance to the client during the early stages of the operation of the innovation.

Summary

A green roof is a roof that has been planted or sown or one that has self established (Johnston and Newton: 1993). Green roofs have the potential to improve the quality of urban areas, by improving air and water quality (Johnston and Newton: 1993). Green roofs are by no means a new concept. One of the earliest examples of a green roof is the Hanging Gardens of Babylon, built by Nebuchadnezzar at a time believed to be between the eighth and sixth centuries BC in Mesopotamia (Scrivens: 1994).

At present British research devoted to green roofs is limited. At the vanguard of UK contemporary green roof research and development is the research carried out in and around London, largely influenced by the environmental benefits, especially to urban biodiversity (Velazquez: 2004).

This report is concerned with the drivers and barriers that affect the adoption of green roofs. The drivers are believed to be the same as the perceived benefits of green roofs and include; the increased lifespan of the roof, the attenuation of rainwater run-off, biodiversity, improved air
quality, insulation, reduced noise levels, aesthetic, economic and amenity benefits. The perceived barriers include, government policy, initial costs, the cost of maintenance, negative perceptions and lack of awareness.

According to Rogers’ (1983), knowledge is the first stage in the process he terms ‘diffusion of innovation’ the process whereby innovations are adopted, over time. Ingleby (2002) found that lack of knowledge amongst stakeholder groups was regarded as the greatest constraint to the adoption of green roofs in London. Research and Development in construction is currently supported by government backed reports (Fairclough: 2001) as an important driver in the radical modernisation of the formerly traditional and conservative British Construction industry.
Chapter 2

AIMS AND OBJECTIVES

The aim of this research is to explore the drivers and barriers to the adoption of green roofs in urban Britain.

The main objectives of the research are as follows:

- to identify why the green roofs were built
- to discover if the uptake of the green roof was influenced by any of the perceived benefits/drivers
- to identify barriers that affected the uptake of the green roof and any problems that affected the green roof once constructed
- to explore the diffusion of innovation as cited by Rogers (1983). That is to explore how awareness of the green roof came to be and how this knowledge is transformed into forming an attitude toward the innovation and to a decision to adopt or reject, to the implementation of the idea or confirmation of this decision.

The Boundaries of the Research

The limits of this research do not make it possible to explore methods to improve the frequency of green roofs in Britain. This research will be based only in British cities, where the frequency of green roofs are affected by the British environment, this includes; government policy, planning regulations, the British climate and growing conditions. This research will not compare green roofs in Britain with those in Germany and Switzerland; this would make a separate study. However, these differences will be analysed in the literature review.
Chapter 3

METHODOLOGY

The research is a qualitative study, which uses the exploratory case study method, to explore the phenomenon of green roofs in the context of the subject buildings and their surroundings. It was originally intended to rely solely on interviews to collect the data. However, this proved unsatisfactory. To decrease bias, this research uses multiple lines of enquiry to collect the data from each case. During the research process the research method was adjusted and refined.

Together with the lists of benefits and barriers to the adoption of green roofs, the pilot questions set out by the objectives form the theoretical propositions of the study. To link the data with the theoretical propositions the pattern matching logic was used.

Qualitative research is often used in exploratory studies, where very little is known (Silverman: 2000). Using this method the researcher can identify themes. The research can focus on just a few case study subjects, so that the study can be kept at a manageable cost in terms of time and money. A qualitative methodology is also seen as suitable in this study, where there is a limited sample of potential buildings with green roofs available. This methodology can deal with individual vagaries and context and can identify the existence of a phenomenon in its context. The quantitative methodology is not seen as an appropriate method for this exploratory study; however, it could be used in a subsequent study once the initial themes have been explored (Hakim: 2000). As the quantitative methodology relies on a considerable sample population, the sample population used in any near future studies could not be based in the green roof population of British cities. One alternative could be to use a large sample of stakeholder members. Unfortunately, a problem with this type of study is that it is difficult to find cooperative stakeholder members to engage in the research (Ingleby: 2002).

Robson (1998) defines the case study method as an empirical inquiry that can be used to investigate a contemporary phenomenon within its real-life context. It is especially important when the boundaries between phenomenon and context are ambiguous. A particular benefit of the case study method is that it can accommodate multiple sources of evidence, where data can converge to achieve triangulation (Mason:
1996 25). The case study will benefit from previous development of theory and questions, which will guide the data collection and analysis (Mason: 1996).

The case study is one method that could be used. Other methods include surveys, experiments, and histories. The research methodology for this project concerns a phenomenon within its context. To assess this, an experiment would not be suitable, as the nature of an experiment is that it deliberately divorces the phenomenon and its context. This is a contemporary study and therefore a history, though it can deal with phenomenon and context, would also not be suitable. The survey method could be used but it is considered a poor method of assessing context (Mason: 1996). The case study method is an appropriate method, where the purpose of the research, is to analyse a phenomenon within its context (Mason: 1996). Furthermore, the case study is particularly important in studies of contemporary events where documents, interviews and observations can be suitably explored (Hakim: 2002).

A disadvantage of the case study method is that there is very limited information available to the case study researcher. There are no prescribed strategies for this type of study (Yin: 2003). In contrast there are numerous texts outlining successful frameworks for other approaches, the survey method for example, where there are many books, which contain prescribed ‘recipes’ for the researcher to follow. Without such a framework it is difficult to conduct the research in a systematic manner, therefore the rigor of the research is jeopardised (Yin: 2003). A useful source of information for the case study methodology is provided by Yin (2003) who has developed rigorous rules and procedures.

There are three primary types of case study; these are explanatory, descriptive and exploratory.

*Explanatory*: this method tends to be used for historical events though it can deal with contemporary studies.

*Descriptive*: this method is used to give a complete description of a phenomenon and its context, this may be a useful method for further study but the object of this research is not to provide a full account of the phenomenon.

*Exploratory*: This is considered an appropriate method to answer the questions on a subject, which is relatively novel and where little is known. ‘Fieldwork and data collection are undertaken prior to the final
definition of study questions and hypotheses….the result is usually a report that will lead to further research.’
(Yin: 2003)

For this research the exploratory case study method was used.

The Theoretical Propositions

The theoretical propositions are based on previous research discussed in the literature review, most notably, Ingleby’s’ 2002 study of barriers and drivers affecting the adoption of green roofs in London. Ingleby concluded that there is a limited frequency of green roofs because of the lack of awareness of the viability, potential and benefits of this type of roof. Additionally the initial and maintaining costs of constructing a green roof are a disincentive to the adoption of the innovation. Architects in Ingleby’s’ report commented that flagship buildings could play a part in the uptake of the innovation by raising awareness among architects. The barriers and benefits that directly affect the adoption of green roofs have been discussed in many reports (Scrivens: 1994, English Nature Report: 2003, Kohler et al: 2002, 2004), there is also a discussion of the barriers and drivers in the literature review of this report. Frith (2004) discusses the emerging phenomenon of biodiversity as an important driver in the London area and discusses the role that local and national government and social housing could play in the future.

According to Toffler (1970) by developing the knowledge concerned with the adoption of an innovation, change and ultimately improved uptake of the innovation may occur (Toffler: 1970).

Defining the Sample Population

The individual cases in this report will be used to test the questions of this research. Each case study is identified using the following constraints. The green roof must have been built on a building within five years of the completion of this report, and must lie within a British city. The research concerns the lifecycle of the development, from the inception of the green roof to the present day.
Unit of Analysis

To investigate the research questions in sufficient depth, this study uses a multiple case study design to explore the problem. Hakim (2000) argues that multiple case studies are more robust and more compelling than a single case study. At this stage it cannot be assumed that the drivers and barriers for each case will be the same.

Recent green roofs constructed since 1997 were located using a list of selected green roofs compiled by English Nature (2003), and by referring to the company literature of green roof providers including Alumasc (ZinCo) and Blackdown Horticultural Consultants (www.greenroof.co.uk: 2004). More green roofs were identified whilst studying the literature and running Internet searches. In this way twenty green roofs, fulfilling the criteria, were identified. These are recorded in Appendix 1 of this document.

The sample population was limited as there are so few green roofs to study. The sample was defined as the total number of buildings with green roofs, whose stakeholder members were willing to contribute to the study. Unfortunately, the response from the emails was very limited. As stated in the proposal, it was the initial intention of this research to focus on the interviews to answer the research questions. However, because of the poor response rate from prospective interviewees, and to improve the studies rigor, it was considered appropriate to use a multiple case study enquiry, using documentation, archives, interviews, direct observations, and physical artefacts to explore the questions (Yin: 2003).

By applying the sampling definition the list of green roofs (as listed in Appendix 1) was narrowed to Greenside Place in Edinburgh, the National Wildflower Centre in Liverpool and BedZED in London.

Methods of Enquiry

A case study may incorporate multiple methods of enquiry (Yin: 2003). Suitable methods of enquiry for this study could be:

1. Documentation
2. Archival Records
3. Interviews
4. Direct Observation
5. Physical Artefacts
1. Documentation

Many of the potential stakeholder organisations included in this study, can be seen as ‘self documenting’ (Atkinson and Coffey: 1997). That is to say that the culture of the included organisations, are involved in the ‘production and consumption of written records and other kinds of documents’ (Atkinson and Coffey: 1997). The analysed documents included council minutes, websites, newspaper articles, journal articles, financial accounts, prospectuses and various reports and plans given by the associated stakeholder members. Some of the reports given by the stakeholders were written in response to a request for their comments regarding an overview of the research. The respondents directly discussed the uptake of the green roofs, detailing the drivers and barriers.

Atkinson and Coffey (1997) comment that; ‘We should not use documentary sources as surrogates for other kinds of data’ and that; ‘we cannot treat records – however ‘official’ – as firm evidence of what they report.’ However, Atkinson and Coffey do argue that this method should still be treated very seriously:

‘Documentary methods should be regarded as data in their own right. They have their own conventions that inform their production and circulation. They are associated with distinct social occasions and organised activities – it is vital to give documentary data due weight and proper attention.’
Atkinson and Coffey: 1997

2. Archives

Archives of the case study could include, organisational records, maps and charts, lists survey data and personal records (Yin: 2003) (in this study lists could include lists of stakeholder members or ‘credit’ lists as they appear in architecture journals and personal records may include telephone listings). Analysis of this information was highly useful for locating potential respondents and defining the contextual surroundings of the building through maps.

3. Interviews

Important stakeholder members were contacted by email and their cooperation was politely requested. Stakeholders included individuals who were actively complicit in the idea to adopt the green roof. Those stakeholders included architects, the building owner(s) and developers, as relevant to each case. It was also seen appropriate to talk to members of the local council who were connected to the planning
process and to occupants of the buildings where available. Consent must be obtained from interviewees. It is unethical to collect information from the interviewees without their knowledge or permission (Booth, Colomb & Williams: 2003). With the request for cooperation an overview of the research project was attached so that the prospective interviewees could have a general understanding of the research, and what would be required of them. Unfortunately it was difficult to generate data in this way, as it was hard to find willing interviewees. Those who did respond were interviewed using a semi structured interview technique. Each interview was carried out using open ended questions. The respondents were all extremely helpful and were also able to supply relevant documents.

*Semi Structured Interview*

During the semi-structured interview the interviewer guides the discussion, allowing the respondents enough freedom to steer the conversation to potential ‘tangential matters’ (Hakim: 2000).

Mason (1996) argues the importance of developing interviewing skills so as to make on the spot decisions when conducting interviews, rather than a list of questions, forming a structured interview. Mason (1996) goes on to suggest that interview training should be available to the researcher. The researcher should develop a style and substance so that the interview is conducted in a strategic and considered manner, rather than becoming an ad-hoc and chaotic discussion (Mason: 1996).

The interviews conducted in this research therefore, although they are not rigidly structured as in questionnaire surveys, do have a basic structure. In order to construct contextual knowledge, Mason (1996) states that it is useful to concentrate on the specific characteristics in each case. By using semi structured interviews it is expected that the interviewees’ views regarding the developments are meaningful representations of the phenomenon of green roofs.

Unfortunately bias is inherent in interviews and data is seldom reliable as no two interviews could generate the same data and therefore the findings cannot be generalised (Hall & Hall, 1996:44). Another criticism is that interviews rely on the respondents’ accounts of their actions and may therefore be inaccurate (May: 1997). For example the respondent may offer the interviewer the response they believe the interviewer wants to hear (May: 1997). There may also be circumstances or events of which the interviewee has no knowledge (May: 1997). Finally, bias may occur if questions are poorly constructed. However open-ended questions within interviews although not guaranteeing reliability, do increase validity (Hall & Hall, 1996:98). When using open-ended
questions during interview the candidate is asked about the facts of a matter as well as their own opinions (Hall & Hall, 1996:98). All interviews were conducted using open-ended questions; this allows a certain amount of flexibility, where the interviewee can suggest additional information. In this way the interviewee acts more as an informant rather than a respondent (Yin: 2003).

Defining the stakeholder groups

For the purpose of this research a ‘stakeholder’ can be defined as one who holds a share or interest in the enterprise of the building.

Ingleby (2002) has discussed relevant stakeholder members for his research ‘Green roofs: A study of their benefits, and barriers to their installation, in London’. After consulting some green roof experts Ingleby (2002) decided that the stakeholders would be ‘those who had the biggest influence on urban development, namely, developers, architects, engineers, and planners,’ and therefore the most relevant respondents for his research project. For the purpose of this research relevant stakeholder members are believed to be those responsible for the uptake of the green roofs, these could include architects, owners and developers. Local councils responsible for planning permission may give a further insight into the existence or absence of barriers and drivers.

Architects

The architect uses a brief set out by the client. The client may be a developer, local authority, individual or a company. The brief may allow for innovation or may be restrictive. The architects are usually involved from the early planning stage through to the end of construction. The architects must liaise with other stakeholder members (quantity surveyors, engineers and so on) throughout the project. Once construction has begun the architects’ role is to inspect the work as it progresses, ensuring that the project runs smoothly. According to Ingleby (2002) architects are seen as well placed in bringing green roofs onto the agenda.

Developers

The developer usually provides the initial funding for the project and is involved from the identification of the site to completion. Before the construction phase the developer is first involved in researching the market and acquiring land for development. During the construction process their role is in essence, one of project management. The usual perception of a developer tends to be that they put profit above all other
considerations. However, developers may include, for example, housing associations, who may be motivated by social priorities.

Owners

The owner(s) of the development could be from a variety of backgrounds, commercial or otherwise and may have bought the building before or after the green roof was planned and built.

Planners and local councillors

Planning permission is required under the Town and Country Planning Act for ‘development’. The planning department of the local council is responsible for granting permission for a construction project. The green roof itself will almost certainly need planning permission. Planning conditions vary from location to location.

The Interviews

Two interviews were held in Edinburgh concerning the Greenside Place development. Dougie Kerr a member of Edinburgh city council who is responsible for the ward of Calton was interviewed on June 30th 2004 at the Council Chambers. Gillian McLaren of Allan Murray Architects, the practice responsible for the master design of Greenside Place, for the adoption of the green roofs and for overseeing the development of Calton Square from start to finish (Ms McLaren was involved throughout) was interviewed on the July 1st 2004. Ms McLaren also conducted a tour of Greenside Place. The owner/director of Landlife and the National Wildlife Centre, Grant Luscombe was interviewed by telephone on the August 6th 2004. Naomi Martin a resident at BedZED was interviewed on November 22nd 2004. No members of Dunster Architects, the practice responsible for the adoption of green roofs at BedZED, agreed to be interviewed. The councils relevant to BedZED and the National Wildflower Centre were both contacted for interview but did not respond.

All interviews were recorded in note form. This was considered a more suitable method than tape recording. The tape recorder would have provided a complete record of the interviews especially if this had then been transcribed to a written document. However, tape recorders can make the interviewee feel uncomfortable and self conscious (May: 1997). A tape recorder would also have been a cumbersome method during the interview at Greenside Place, where the interview took place during a tour. It is also not suitable for telephone interviews. Another problem with tape recording is that the interviewer may be tempted to rely entirely on the tape recorder and therefore not take notes. The
interviewer may also be tempted to assume that once the data is collected the work is done this is not the case (May: 1997).

4. Direct Observations

A visit to Greenside Place was arranged by a member of Allan Murray architects, who kindly gave a tour of the building. The building and its surroundings including the adjacent Calton hill were visited on July 1st 2004. The context of the surroundings of this building, its immediate surroundings and Edinburgh itself, was an important factor for this research. The National Wildflower Centre in Knowsley, Liverpool was visited on September 6th 2004. The roof was also assessed in the context of its surroundings, particularly its immediate surroundings in the park and in the context of the function of the building as an educational facility. BedZED in Sutton, London, was visited on December 4th 2004.

5. Physical Artifacts

The actual fabric of the roofs was observed, particularly the plants on the roof, their condition and the substrate that supports them.

Secondary Analysis

The studies carried out by Frith (2003, 2004) on the green roofs at BedZED will also be incorporated into this research. Frith's research provides an essential insight into a case, which has been otherwise difficult to gain access to. Furthermore Frith's case study is a highly relevant report of a green roof development.

Triangulation

The most important advantage of using multiple sources of evidence, argues Yin (2003) is the development of 'converging lines of enquiry.'

'An important clue is to ask the same question of different sources of evidence; if all sources point to the same answer, you have successfully triangulated your data.'

Yin: 1993, p. 69

Hakim (2000) also states that multiple sources of enquiry can be combined so that the particular strengths offered by each will achieve triangulation. Denscombe (2000) states that 'one of the strengths of the case study approach is that it allows the researcher to use a variety of sources, a variety of types of data and a variety of research methods as
part of the investigation. It not only allows this, it actually invites and encourages the researcher to do so.’

Four types of triangulation for evaluating evidence are discussed by Hakim (p.p. 173-174: 2000).

1. Methodological Triangulation
By using multiple sources of evidence (Documentation, Archival Records, Interviews, Direct Observation, and Physical Artefacts) validity and rigor are strengthened.

2. Data Triangulation
Issues of construct validity may be addressed by using multiple sources of data because the multiple sources of evidence provide multiple measures of the same phenomenon.

3. Investigator Triangulation
This research is conducted by one sole researcher. Yin (2003) argues that if possible it would be better to use a group of researchers to eliminate the chance of bias brought about by a single researcher. However, a group of researchers could bring about variable biases to the research process, whereas a single researcher will tend to be consistent throughout the process in his or her bias.

4. Theoretical Triangulation
Different perspectives to the same data set, improves the theoretical triangulation. For this research Ingleby (2002) and Frith (2004) provide prior theory about green roofs.

Maintaining a Case Study Database

Retaining an organised library of notes from interviews, observations and document analysis and complete documents can increase the reliability of the study. This is particularly important where further study is considered (Yin: 2003).

Analysing the Data

Data was collected using the five sources of enquiry (documentation, archival records, interviews, direct observation, and physical artefacts) and collected as notes (which were typed up immediately), maps, emails, architectural drawings, project reports, photographs and brochures.
The research questions and the theoretical propositions form the basis of this research and the data was analysed accordingly. This information was then used to build a narrative of the drivers and barriers apparent during the process of the building, from its inception to the present day.

Pattern Matching

According to Yin (2004) the pattern matching approach is one of the most advantageous techniques available for the case study investigator:

"...such a logic compares the empirically based logic with a predicted one."

In this research the perceived drivers and barriers are compared with the drivers and barriers that were identified during the research process. If these patterns coincide the results of such a case study can strengthen its internal validity (Yin: 2004). This technique offers a fairly straightforward framework in which to analyse the data.

In order to present a compelling study it is considered appropriate to build a narrative concerning each case. The ‘Explanation Building’ logic could be used to do this. This uses a similar logic to pattern matching, but differs as the theoretical propositions are questioned and then revised in order to provide a new perspective. This is not considered an appropriate methodology for this exploratory research. It was never the intention of this research to re-evaluate the theoretical propositions. When employing this logic, it is also easy to veer away from the studies propositions (Yin: 2003).

Other data analysis methods that may be used are; Time-series analysis, Logic models and Cross-case synthesis. Pattern matching is seen as the most appropriate method, as it is the most direct and simple method to answer the research questions and provoke new questions and ideas, as the perceived barriers and drivers may be directly matched with the actual barriers and drivers in each case.

Summary

This research uses a qualitative methodology and an exploratory case study approach, to explore the phenomenon of green roofs in the context of the subject building and its surroundings. The initial intention, as stated in the research proposal, was to use a single line of enquiry to collect the data from each case. This framework was adjusted and the research now uses multiple lines of enquiry to collect the data from each
case. The research process was adjusted and refined during the process of the study.

Together with the lists of benefits and barriers to the adoption of green roofs, the pilot questions set out by the objectives form the theoretical propositions of the study. To link the data with the theoretical propositions the pattern matching logic will be used.
Chapter 4

RESULTS

Introduction

The results section is organised into the three separate case studies, these are Greenside Place, BedZED and the National Wildflower Centre. In each case the context and background of the building and its green roof is established. The collected data was used to answer the questions of the research as set out in the aims and objectives section. Briefly these are to identify why the green roofs were built, discover if the uptake of the green roof was influenced by any of the perceived benefits, drivers and barriers outlined in the literature review, to gauge the success of the green roofs and to explore the diffusion of innovation using Rogers (1983) framework. The data was collected using the five lines of enquiry as set out in the methodology chapter. These are; documentation, archival records, interviews, direct observation and physical artefacts.

The green roofs were adopted for reasons that tallied with the theory of the research and the collected data confirmed the perceived benefits and drivers of the research. No dramatic barriers came to light in the research, though all the studied green roofs were subject to problems. One problem that affected all the roofs was that plants on the roof suffered some damage, due in part to the harsher climatic conditions on the exposed roofs. That being said, overall the green roofs were considered successful. Using the methodology of the research it was difficult to thoroughly explore the diffusion of innovation (Rogers: 1983) as discussed in the literature review such a long time after the decision to adopt the green roofs had been made.
Case Study 1

Greenside Place, Edinburgh

Construction completed in 2002

Greenside Place is a vast, commercial, development built within the world heritage site of Edinburgh New Town. It encompasses a 200,000 sq ft leisure complex ('Omni') and a 150,000 sq ft flagship office building ('Calton Square'). The architects considered the roofscapes of both buildings very important throughout the development process. Especially because the roof is highly visible from Calton Hill which overlooks the development. The hill is a popular tourist attraction and historical site. Eight separate green roofs have been constructed on the roofs of the development including an expansive rooftop garden for a luxury hotel (Alumasc: 2003).

The development is highly commercial, costing £73 million and includes office space, bars, restaurants, a comedy club, a five-star hotel, a health club and a 12-screen cinema. The roof terraces were built as eight stepped, terraced roofs on the Calton Square office building and as a courtyard garden on the Omni Building. Green roof specialists Alumasc were contracted to build the green roofs. According to Alumasc the £200,000 green roof package comprises Hydrotech waterproofing membrane, root barriers, drainage layers, Topfoam insulation and Zincolit soil. Scottish Roofing Services, Alumasc’s approved contractor, installed system (Alumasc: 2004). Alumasc comment that a particular
consideration was that the waterproofing needed to be very robust to enable following trades to work on it (Alumasc: 2004).

Fig 7 A roof garden in Edinburgh (source, Johnson and Newton: 1993)
**Edinburgh**

Edinburgh has been the capital of Scotland since the 15th century. It is well known for its stunning architecture and rich history, attracting tourists in their droves year after year. These visitors make an important contribution to the city's economy.

![A roof garden in Edinburgh](image)

**Tourism**

In fact tourism is one of Edinburgh’s key industries, supporting around 25,000 jobs, roughly 8% of the cities workforce (Edinburgh World Heritage Trust: 2003). The Hogmanay (New Year) celebrations and Edinburgh Festival are popular times for visits, though tourism is prevalent year round. Visitors to Edinburgh spent £904 million in the 1998/99 financial year (Edinburgh World Heritage Trust: 2003). The Edinburgh World Heritage Trust (2003) stresses the importance of the well preserved building stock to tourism and to the economy of Edinburgh.
Table 1. What most influenced decision to visit Edinburgh

<table>
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<tr>
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<th>British Visitors</th>
<th>Overseas Visitors</th>
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<tr>
<td>Historic Town</td>
<td>39%</td>
<td>52%</td>
</tr>
<tr>
<td>Friends and relatives in City</td>
<td>29%</td>
<td>19%</td>
</tr>
<tr>
<td>Specific attraction(s)</td>
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<td>19%</td>
</tr>
<tr>
<td>Capital of Scotland</td>
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<td>Festival(s)</td>
<td>12%</td>
<td>13%</td>
</tr>
<tr>
<td>Buildings/Architecture</td>
<td>11%</td>
<td>14%</td>
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</tbody>
</table>

Source, Edinburgh World Heritage Trust: 2003

Table 2. What most impressed visitors

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<th>British Visitors</th>
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<td>Castle</td>
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<tr>
<td>Atmosphere</td>
<td>29%</td>
<td>27%</td>
</tr>
<tr>
<td>Friendly/Helpful people</td>
<td>24%</td>
<td>29%</td>
</tr>
</tbody>
</table>

Source, Edinburgh World Heritage Trust: 2003

The Old and New Towns World Heritage Sites


"Edinburgh has two distinct areas: the Old Town, dominated by a medieval fortress; and the neoclassical New Town, whose development from the 18th century onwards had a far-reaching influence on European urban planning. The harmonious juxtaposition of these two contrasting historic areas, each with many important buildings, is what gives the city its unique character."

Edinburgh World Heritage Trust: 2003

The ‘Edinburgh World Heritage Site, Monitoring Report 2002-2003’ was the first ever annual report concerning Edinburgh’s status as a World Heritage site and its conservation. Greenside Place is directly affected by the issues in the UNESCO planning report.
"There are concerns about the appropriateness of new developments, especially in relation to the mass and height of new development and the intrusion of the roofscape of the site.............Inappropriate redevelopment poses one of the greatest threats to the 'Outstanding Universal Value' of the Site."

(whc.unesco.org: 2004)

The report goes on to stress the importance of the retail and office core, which make an important contribution to the site and have recently staved off the threat of decline. It states that the city’s public administrative and office and retail based businesses and the numerous tourist attractions provide employment for over 50,000 workers. Together these activities are vital to the economy of the region.

To preserve the unique character of the city The Edinburgh Heritage report discusses the need for clear guidance. New proposals must fit into the overall roofscape and pattern of the site and should not have ‘unwarranted prominence’.

Fig 9 the roof of Scottish Widows Headquarters by Arthur’s seat

Calton Hill

Adjacent to and directly overlooking the Greenside Place Development is Calton Hill. Calton Hill is a highly symbolic and historic site containing a number of outstanding monuments, making it one of the most popular tourist attractions in the city. Edinburgh Council’s website
(www.edinburgh.gov.uk; 2004) describes the hill as a 'focus of architectural, academic and artistic endeavour; a place of science.'

The hill also provides an excellent vantage of breathtaking views over the city and beyond. From here the importance and prominence of Edinburgh's rooftops can be appreciated. Incidentally the hill is also unusual because it supports a semi natural wilderness in the heart of a capital city.

![Fig 10 Map of Calton Hill, showing the location of Greenside Place (source Bartholomew Edinburgh Street Finder, 1995).](image)

**Greenside Place**

Greenside Place is located at the bottom of Calton Hill. The site of the current development, the last 'gap' site in Edinburgh's East End, it had lain dormant for over 30 years. The site had been the subject of a number of aborted proposals, including a BBC building. None were successful, until, in 1998, Allan Murray Architects won an international competition, a call for architects to design a leisure complex and flagship office building. Alan Murray Architects were involved in the project from 1998-2002, the master architects for the whole site. They were also involved as architects in the construction of Calton Square from start to finish.
The architect submitted a 'Supporting Information Document,' which was given to Edinburgh Council to back up the Planning Application. It states that:

"The building is within a World Heritage Site and the quality of the architecture and urban design must reflect that unique position. The scale and massing of the building must compliment and reinforce Edinburgh's unique landscape and topography.

Edinburgh and its citizens must benefit not only by participating in the building's activities but also in the building's contribution to the streetscape and public spaces.

The Greenside site should, however, be seen within the greater urban context of Picardy Place and Calton Hill, where our key considerations encompass the following:"

World Heritage Site status.

Significant interchange within the city, and key link space between Leith Walk and Princes Street.

Part of Edinburgh's commercial, retail and entertainment epicentre.

Large expanse of open space for over 30 years increases sensitivity of site. Views towards the West of Calton Hill are only a recent phenomenon.

Site accommodates complex level changes typical of Edinburgh's topography.

Roofscape is exceptionally important, particularly when viewed from the elevated position of Calton Hill.

(pers coress, McLaren: 2004)

The support document also contained a section relating specifically to the "Roofscape":

‘Our proposal for the roofscape (a fifth elevation) is shaped by the elevated view from Calton Hill. The roof elements help reinforce the principal east/west edge to the site on Picardy Place and the secondary perpendicular north/south (feu pattern) roofs to Calton Hill. The provision of an extensive landscaped garden on top of the leisure building will be flanked by a "crust" of roofs similar in scale to the surrounding tenements. The roof garden will create a visual link with the heavily foliaged north slope of Calton Hill.’

(pers coress, McLaren: 2004)

The roofscape was primarily adopted because of the aesthetic benefit it could offer the buildings, influenced by the planning demands for the height and mass of new developments to fit with the Georgian terraced buildings prevalent in the New Town area. The idea of the green roofs originated from Allan Murray himself who saw the highly visible ‘roof profile’ or ‘fifth elevation’ of Greenside Place was a significant element in the overall aesthetics of the development. A walk up and around Calton Hill makes sense of why the grassy terraces were seen as important as they do indeed reflect the surrounding landscape. The architects intended the aesthetic benefit of the green roof to work from the vantage point of the roofs themselves and from Calton Hill and although the roof terraces are well manicured they blend well with the rugged slopes of Calton Hill, from both aspects.

The overall aesthetics of the building were very significant for example, abseil points for window cleaners were designed, instead of the usual cradles which the architects saw as unsightly. The urban design of the building was also important. For example, locals expressed their concerns about the possible loss of views from Princess and Leith streets to the Hill, having benefited from a clear view of the hill from these vantages for over 30 years. The civic square between Omni and Calton Square buildings allows views of Calton Hill and breaks up the mass of the building.

According to the architect green roofs were accepted with enthusiasm early on in the project, by all the stakeholders, who saw the roof gardens as an exiting part of the development. The green roof project is seen as very successful by AMA and they intend to build more buildings with green roofs. The architect commented that the AMA practice values strongly the principles of innovation and creativity as important factors in the delivery of quality.
A second important driver for the green roofs is the amenity benefit offered. The roof gardens provide small spaces for office workers to enjoy on top of the Calton Square building and a luxurious and expansive garden for the Glasshouse Hotel a 65 bedroom ‘boutique’ hotel owned by the Eton Group (www.theetoncollection.com: 2004), this is housed in the Omni building.

Fig 11 The Glasshouse Garden as seen from Calton Hill

The Glasshouse Hotel garden is flanked by the three external walls of the hotel and by the bank of the hill. This has the effect of screening the noise from the streets below in an otherwise busy area of the capital. Some of the guest rooms on the roof open directly onto the garden. There have been favourable reviews regarding the hotel some refer to the roof gardens as one of the distinguishing attractions of the hotel:

‘The unexpected two-acre roof garden with arched timber pergola, raised beds of porcupine heather plants, lawns framed by ash trees, conveniently-glued shingle and view on to the more chaotic forestry of Calton Hill is a superb nerve-soothing coup de theatre.’

Guardian Travel: 28.06.2003
Not only do the guests enjoy views of the hill but also of the city. Eventually the hotel hopes to increase the amenity value of the roof by using it as a venue for special events including wedding receptions (pers coress).

When the site was visited most of the offices in Calton Square were unoccupied and it was difficult to observe the amenity value of the roof terraces, which serve the offices and their workers. However, a security guard did comment how she enjoyed spending time in the evenings on one of the upper gardens enjoying the peaceful vistas above the busy city and the Firth of Forth. Gillian McLaren commented that the amenity
value of the green roofs could potentially be a major selling point for prospective tenants of the offices and the hotel.

Other Drivers

Any other benefits of the green roofs were incidental and were not seen as drivers. No offset was made for the insulation and the build up from layers of green roof was in addition to the generous insulation of the building. McLaren (pers coress: 2004) commented that perhaps the building was over insulated. She went onto state that new building regulations require greater insulation than before. Rainwater Attenuation was not seen as a driver by the architects and no offset of the drainage infrastructure on the roof was made. McLaren (pers coress: 2004) commented that the experience of the practice (including knowledge of the increased rainwater levels) has been such that the practice tends to err on the side of caution when it comes to drainage from the roof. Though the economic benefits of the green roof were not seen as a driver it is possible that they will improve lease rates, thanks to their amenity and aesthetic value (Pers coress, McLaren: 2004).

Barriers

Similarly there do not seem to be any major barriers to the roof. Perceptions regarding the green roofs were always positive and stakeholders were enthusiastic about the roofs during meetings. According to Councillor Dougie Kerr the green roofs did not play any strong role either for or against in the decision to grant planning permission for the development. Though the local council is aware of the benefits of green roofs, in fact a new council headquarters building is being constructed, with a green roof to attenuate rainwater runoff. Only a modest amount of time and money is necessary to maintain the roof gardens at Greenside Place and so maintenance is not seen as a barrier. No increased loading was required on the roofs. McLaren commented that the green roofs are level with adjacent floors of the building and are already very strong. Only the ground level courtyard above the three story underground car park has a massive loading, beneath this courtyard is a three story car park. Strict fire regulations limited the size of the office roof gardens, which were carefully planned accordingly.
Fig 14 Terraced roof garden on Calton Square
Case Study 2

BedZED, Sutton, London

Construction completed in 2002

BedZED (Beddington Zero Emission Development) also known as ‘Telly tubby land’ by locals, thanks to its surreal green roofed landscape, is a revolutionary and highly experimental development located in the London borough of Sutton. The Peabody Trust, Bill Dunster Architects, The BioRegional Development Group and Arup joined in partnership to design and construct a sustainable mix of housing and workspace (Frith: 2004). Though the many innovations employed by the development, have caused some controversy, BedZED is now seen as a model for practical and sustainable living.

Fig 15 BedZED’s distinctive roofs with their wind cowls, sedum roofs and ‘sky gardens’ (source, www.bedzed.org.uk: 2004)

Sustainable design

‘ZED’ (Zero Fossil Energy Development) is a concept developed by Bill Dunster Architects:

‘Our definition of Zero-fossil Energy Development (ZED) is an excellent passive building envelope that reduces the demand for heat and power to the point where it becomes economically viable to use energy from renewable resources......At BedZED, ZED has meant generating enough renewable energy over the course of the year to meet the whole of the community’s annual heat and power demands.’

(Dunster: 2003)
BedZED is the largest sustainable development of its kind in the UK (Hawkes and Forster: 2002). One important aim of BedZED was to show that sustainable living is achievable, it is not necessarily expensive or high maintenance, the design of the buildings do not have to be compromised and quality of life on the development is high (BedZED: 2004). According to BedZED’s glossy brochure (2004), ‘BedZED is a long way from the hair and shirt image that bedevils green living.’

Among the themes of Lord Rogers report ‘Towards an Urban Renaissance’ (1999) were the problems of poor waste management and increases in traffic (Hawkes and Forster: 2002). BedZED aims to address some of the issues discussed in the report, its strategy for sustainable living encompasses health, safety, water-use efficiency, recycling, waste minimization and green transport (Hawkes and Forster: 2002). For example the provision of work space and housing in the same area cuts down on commuting and helps boost the local economy. A mix of homes for sale and rent, which are both affordable and in accordance with the market will attract high and low incomes, thereby facilitating a socially inclusive community. BedZED is built on a brownfield site, which had previously been a sewage plant (Hawkes and Forster: 2002). Now 82 homes and 1,600m square (17,220ft square) of work space have been accommodated on a 1.4ha (3.5 acre) site, along with a football pitch, sports club, nursery, organic-food shop, and a health centre (Hawkes and Forster: 2002).

The Peabody Trust

The Peabody Trust is the oldest social housing trust in London (www.peabody.org.uk: 2004). One of the trusts current aims is to contribute to regeneration in London, by supplying people with affordable housing in sustainable communities (Frith: 2003). The trust’s commitment to sustainable living is twofold. First the trust is committed to its social responsibility, providing affordable homes, sustainable communities, fighting poverty and improving the quality of life for Londoners. The trust also has an environmental responsibility and buildings are intended to be sustainable and carbon neutral (Frith: 2003). The Peabody trust values good quality in the living environment and the important role that green spaces including public parks can improve the quality of the urban environment (Frith: 2003). Frith argues that housing associations are well placed to adopt innovations:
‘Evidence suggests that innovation and bold ventures towards sustainability will come primarily from the voluntary or charitable – housing sector; housing associations and trusts.’


Fig 16. BedZED

The Green Roofs

Among the many innovations at BedZED are the green roofs that partly achieve BedZED’s characteristic (‘Telly-tubby’) appearance. Sedum mats were installed on the roofs to reduce rainwater run-off and second floor flats are complimented by the ‘sky gardens’, which provide outdoor space for residents. The green roofs reduce the overall footprint of the development and at the same time provide an amenity for occupants, improving the quality of their home environment (Dunster: 2003):

‘We hope to demonstrate that it is possible to reconcile the suburban garden village with the Urban Task Forces (Towards an Urban Renaissance: 1999) agenda to substantially increase residential densities.’

(Dunster: 2003)
Frith (2004) comments that:

'It is not inaccurate to suggest that given the environmental innovations built throughout BedZED the green roofs and sky gardens were almost overlooked. The Trust did not have the necessary guidance or expertise to design or specify a green roof to meet its needs; the green roof was provided through the existing green-roof retailers marketing standard Sedum mats. The quality of materials used was not as high as it could have been. Importantly, however, the green roof and sky gardens were included because the Trust wanted them.'

The Drivers and Benefits

The sedum mats were installed to help reduce the rainwater run-off (Frith: 2003). Rainwater that is not absorbed by the sedum mats is collected and stored in underground tanks, 40% of this collected rainwater is used for toilet flushing whilst some is used for irrigation (Frith: 2003)

Fig 17. A ‘Sky Garden’ at BedZED

The ‘sky gardens’ (see fig. 17) have been constructed to provide an amenity for residents (Frith: 2003). BedZED is a high-density scheme yet almost every dwelling on the development has the benefit of its own garden, at a density where normally most homes would merely have a balcony. At BedZED, the architects aimed to reconcile the ‘suburban garden village’ with the urban taskforces’ (1999) plan to increase
residential densities (Dunster: 2003). For many urban dwellers, the most unattractive part of flat dwelling - usually the reality of living in a high density area - is living without a garden, an area of solace, perhaps, in an ever chaotic city. Naomi Martin a resident of BedZED describes how despite living in a high density development there is still a feeling of spaciousness ‘partly because of the sky gardens and roofs and partly because of the glass sides of the houses’ (pers coress: 2004). The UK government estimates that 3.8 million new homes are needed by the year 2021 (Urban Task Force: 1999, p. 46) not allowing for increases in the population. The green roofs are an example of BedZED’s brilliant economy of space. Workspace roofs, for instance, are used as garden space for the adjacent gardens (Hawkes and Forster: 2002).

By constructing the green roofs it was also hoped that the biodiversity in the area would be improved (Frith: 2003). Despite the fact that there was, at the time, no reliable evidence that such sedum based roofs would support a diversity of wildlife (Frith: 2003). However, Kadas (2002) subsequently found that the sedum roofs of the buildings (but not the sky gardens) did support a surprising number of invertebrate species, some new to London (as cited in Frith: 2003). Martin commented that the ‘birds love’ the sedum roofs. She also noted that there was a wasp’s nest in the sedum roof during her first summer at BedZED. This disappeared with the cold weather.

The green roofs were not incorporated into the design to contribute to the insulation of the building. Instead the building benefits from a
300mm ‘overcoat’ of super insulation, which is applied to the roofs, floors and walls (Frith: 2003). The core temperature of the building is further controlled by high quantities of thermal mass, provided by the high density intermediate concrete floors and by triple glazing (Hawkes and Forster: 2002). According to Hawkes and Forster (2002) ‘the thermal performance of the building envelope is three times more efficient than the current UK regulations require.’

The green roofs have proved broadly popular among the residents of BedZED a resident satisfaction survey concluded in 2003 (Frith: 2003). However there were concerns about “the privacy problems from the sky gardens above” and the upkeep of the gardens “the grass has died, so it is not very nice to look at” explained one resident (Frith: 2003). Naomi Martin (pers coress: 2004) described a problem that occurred with the roof of her house:

‘We had a leak at in the roof nothing to do with the sedum but because it acts as a sponge it was very difficult to work out where the leak was coming from as it took about 24 hours to soak through. We were concerned what a messy job it would be to repair the roof now that the sedum is on but it turned out to be linked to the wind cowl so we didn't have to remove the layers on the roof.’

On the whole the aesthetics of the roofs seem to be appreciated by the residents, Naomi Martin (pers coress: 2004) describes how the sedum roofs are ‘a lovely colour at all times of year.’ Martin did not see green roof maintenance as a problem and stated that a member of the Peabody Trust visits annually to maintain the sedum roofs. According to Martin her roof garden is a manageable size (she also has a small garden at ground level) and gardening is enjoyable, though there is a small challenge in that the substrate is shallow. Occasionally sedum falls off the roofs and takes root in the gardens below but this is not seen as a problem (Martin, pers coress: 2004).

The sedum roofs and ‘sky gardens’ at BedZED contribute to the overall idea of BedZED to prove that sustainable living does not have to be uncomfortable and costly and maintenance need not be high. Rather, sustainable living can improve the quality of life of urban dwellers, even at high densities, providing green spaces, where normally this would not be possible. Though on the whole the roof gardens have been very successful some concerns have been raised about the lack of privacy and maintenance of the roof gardens.
Case Study 3

The National Wildflower Centre, Knowsley, Liverpool

Construction completed in 2004

Background

The National Wildflower Centre (NWC) situated in Knowsley on the outskirts of Liverpool, is only the second centre devoted entirely to wildflowers in the world, the other being The Lady Bird Johnson Wildflower Centre in Texas (Architects Journal, p 26, 08.03.2002). The centre is a millennium commission funded project, situated on a 35 acre estate in a deprived area of Merseyside. The NWC functions as a botanical research and visitor centre involving the public in 'creative conservation' a unique concept, which embodies regeneration, nature conservation and biodiversity (Architects Journal, p 26, 08.03.2002).

The NWC was conceived and developed by Landlife, an established trust (it celebrated its silver jubilee in 1999, www.guardian.co.uk: 06.09.2000) devoted to wildflowers, wildlife and regeneration, which now has its headquarters at the centre (www.guardian.co.uk: 06.09.2000).
‘Landlife works for a better environment by creating new opportunities for wildflowers, and wildlife and encouraging people to enjoy them’


Landlife developed the innovative concept ‘creative conservation,’ combining ecological and regenerative concerns to bring about positive change (www.landlife.org.uk: 2004). They began applying the creative conservation technique by establishing native wildflowers in areas of high unemployment, engaging locals in conservation management. The trust has applied this technique to some of the most deprived and rundown areas in the country, areas that were seen to be both socially and environmentally destitute. Fortunately the poor soils of these environmentally degraded areas make suitable growing mediums for wildflowers (Architects Journal, p 26, 08.03.2002). The intended result is that areas are regenerated, local economies are boosted and the biodiversity of both flora and fauna is greatly improved (www.landlife.org.uk: 2004). At the same time the trust value the importance of brownfield sites for the conservation of biodiversity (www.guardian.co.uk: 06.09.2000). According to the founder and director of Landlife and the NWC, Grant Luscombe:

‘Creative conservation is not a substitute for existing habitats, and we need to make that distinction. We can’t recreate ancient woodlands, and the impact of climate change is very much locked in now. But the wildflowers are a huge food source for many species that are on the decline
in the countryside, and we have seen the reappearance of linnets, finches, skylarks, grey partridge, hares and insects.'

(www.guardian.co.uk: 06.09.2000)

He describes the success of the creative conservation projects so far:

'Conservation has been dealing with puddles, not ponds. We had to scale up to show the benefits. Our early plantings are hopping with life and its common sense to show that it feeds through the food chain. Now there are insects, skylarks and goldfinch where there was wasteland.'

(www.guardian.co.uk: 06.09.2000)

The National Wildlife Centre has been developed as a creative conservation project. It is located in Court Hey Park, which, before the Second World War was the home of the Gladstone family. The park was donated to Knowsley Metropolitan Borough Council. Landlife won a £1.9 million millennium commission grant, which enabled the first stage of the NWC development. An old derelict stable block was refurbished and Landlife moved in (Architects Journal, 08.03.2002). Meanwhile the trust raised funds for the new visitor centre. Hodder Associates a Manchester based architects’ practice won the competition to design the visitor centre. They came up with a 160m long and 4m wide building, which was more related to the outbuildings than the footprint of the old house which had been demolished shortly after the war (Architects Journal: 08.03.2002). Hodder Associates term the building ‘a working wall,’ referring to its topography and function (Architects Journal: 08.03.2002). The buildings’ purpose is in part to provide an educational amenity for visitors. This has been facilitated by the design of the building which allows visitors to not only wander through the building but over the walkway on the roof, where visitors can enjoy views of the surrounding displays in the park (Architects Journal, 08.03.2002).

The Green Roofs

There are two green roofs at the centre, built on existing flat roofs. Both roofs have been planted with wildflowers. The first green roof was constructed on the kitchen and toilet block of the centre and the second was built over the new visitor centre (www.nwc.org.uk: 2004).

The kitchen and toilet block roofs had originally been covered with cobbles. Unfortunately the cobbles made convenient missiles for vandals to use to throw at nearby windows (pers coress, Luscombe: 2004). Mr Luscombe stated that the centre decided to take action and
removed the cobbles in 2002, replacing them with a trial green roof, which imitates a wildflower meadow.

Landlife had successfully built a similar meadow eight years previously as part of a land reclamation experiment. For this the trust used ‘wildflower blankets.’ Recycled clothing, reclaimed from the flock and felt industry, is converted into ‘blanket,’ (with a loose texture resembling lint from a washing machine). The blanket is layered to form a substrate, four layers in all with a central layer of vermiculite (hydrated silicate used to aerate soil) commonly used as a growing medium; it can maintain the moisture level of the substrate; as Landlife feared drought on the roofs would be a major problem. The substrate was then sown with wildflower seeds in April 2002 and top dressed with grit.

The second green roof is built on the walkway roof on top of the visitor centre. The walkway is accessed at both ends of the building by open stairs and by a lift. From the vantage of the walkway the whole of the centre and Court Hey Park can be viewed as well as the nearer displays of wildflowers. Roofs are a particularly important design issue as far as Hodder are concerned, who state that, ‘no matter what goes on underneath the roof is a constant’ (Architects Journal, 08.03.2002). Hodder had intended the roof to remain as they had designed and were not complicit in the green roof idea, preferring the building to remain in its original minimal form.
Landlife decided to go ahead and build the green roof on the walkway in 2004. To prevent moisture from seeping through to the building below a pond liner was installed on top of the existing roof. Drains were installed to take excessive moisture to the outlets. The substrate of the roof was made up of rotted wood bark, which was topped with crushed sandstone and a final layer of cockleshells.

The roof was then sown with a variety of native wildflower seeds, seven species of plants altogether. During the early stages of the roof, the roof is susceptible to drought and so some watering has to be undertaken to maintain the roof in an attractive state for visitors to the centre.
The roof is described as very successful by Mr Luscombe who comments that the walkway roof has established successfully and has been a much appreciated attraction. Direct observation confirmed that many wildflowers had become established on the roof, though much of this had died down. It was the end of the growing season for the wildflowers at the centre and the wildflowers on the ground were in a similar condition (ticket prices were half price because the displays were past their best). However, plants on the kitchen and toilet block roof were still in flower. The wildflower displays at the height of summer were very appealing according to Mr Luscombe.
Barriers and Problems

In the early stages, the toilet and kitchen block roof was not seen as a success. Water leaked into the building below and some of the paving slabs were wobbly. Unfortunately the roof was not popular with visitors. According to Mr Luscombe, visitor feedback identified the roof as the least appreciated aspect of the Centre.

Mr Luscombe described how to begin with the roof planting was successful and germination of 13 out of the 22 wildflower species were recorded in the first three months, a further five species germinated over the following year.
"The wildflower roof was subject to severe frosts during the winter of 2002/3 and an eight week drought up until 21st April 2003. During the long summer of 2003, record temperatures were recorded. A survey carried out by Landlife during the late summer of 2003 found that the roof had suffered greatly and there was a very sparse coverage of 12 species..." Mr Luscombe went onto say that "...it became evident that the installation was incapable of maintaining a suitable moisture balance through the year and that the plants were unable to survive the stress. However, there is periodic recovery of grasses and a few wildflowers, and the few sedums introduced as an insurance policy are spreading. The roof will be left to colonise naturally and new species (possibly better adapted and capable of surviving the conditions) have already been noted."

However, Luscombe stated on 6th August 2004 that the wildflowers were now thriving and that the harsh weather conditions in the early stage of the roof had caused the problems. Direct observation of the roof on the 6th September 2004 confirmed that the wildflowers had become established on the roof and there was now an attractive display including poppies and chamomile. These flowers were populated by many insects including honeybees, presumably from nearby hives, bumble bees and dragon flies.

![Bee in clover on the visitor centre roof](image)

**Drivers**
The green roofs at the NWC are very much influenced by Landlife's creative conservation practice, which fosters the regeneration of deprived areas, through the planting of wildflower meadows, improving
the local economy, environment and biodiversity. The roofs are used as an amenity for visitors, providing a pleasant area to enjoy wildflowers, a vantage point from which to view the centre and as an educational tool. The green roofs have also been adopted to insulate the building and to attenuate rainwater runoff. The perceived benefits as set out in this research are almost comprehensively represented by the drivers of this case study. The New Visitor Centre green roof was built with knowledge gained in hindsight after the original green roof was built on the kitchen and toilet block.

The Kitchen and Toilet block

The trust took action when the original cobbled roof became a facility for vandals. It was decided to build the green roof. The Trust believed this would insulate the building, would attenuate rainwater runoff, would create an additional and attractive visitor attraction and could improve biodiversity. It was hoped that the ‘wildflower blanket’ would be a low cost effective means of establishing a green roof.

The New Visitor Centre

The green roof was installed to reduce rainwater run-off and to make an important contribution to the site’s visitor attractions. Another driver was the benefit to biodiversity the trust believed the wildflowers would bring. Unlike the toilet and kitchen block roof Landlife did not install the green roof to insulate the new building, believing that it would not offer thermal benefits.
Fig 29 Kitchen and toilet block roof
Discussion and Analysis

The green roofs at Greenside Place were adopted for their aesthetic benefits on a highly visible roof built in a sensitive area where the visual impact of new developments is significant. The roofs were also adopted because of their amenity value and are now used by office workers and hotel guests, providing a tranquil area for recreation in the heart of a capital city. Above all, the two types of green roofs at BedZED, sedum roofs and roof gardens, were respectively adopted to attenuate rainwater runoff and to provide an amenity for residents. The roofs at the National Wildflower Centre were adopted primarily to provide an education amenity for visitors and supply a habitat for wildlife and wildflowers. The amenity benefits of green roofs therefore have emerged as important drivers in all three cases. There are also lesser drivers in each case, which are summarized in the table below. It has also emerged that the economic factors associated with green roofs were not significant according to the interviewed stakeholders and were considered neither barrier nor driver. No significant barriers were found by this research and all the findings match the theory as established in the literature review.
The following table shows how the perceived barriers and drivers in each case match the actual barriers and drivers in each case:

Table 3. Significant Drivers and Barriers

<table>
<thead>
<tr>
<th>DRIVERS</th>
<th>GREENSIDE PLACE</th>
<th>BEDZED</th>
<th>NATIONAL WILDFLOWER CENTRE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amenity/Recreation</td>
<td>Provided roof terraces for office workers and hotel guests with pleasant outlook onto Calton Hill</td>
<td>Provides garden space for residents in a high-density development.</td>
<td>Provided an educational space and vantage point to see surrounding flower displays.</td>
</tr>
<tr>
<td>Rainwater Attenuation</td>
<td>No</td>
<td>Sedum roofs installed to attenuate rainwater run-off</td>
<td>It was hoped that the wildflower blankets would attenuate the rainwater run-off.</td>
</tr>
<tr>
<td>Increased Lifespan of the Roof</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Improved Air Quality</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Insulation</td>
<td>No</td>
<td>No</td>
<td>It was hoped that the green roof on the toilet block roof would insulate the building below, but this was not a driver for the second green roof.</td>
</tr>
<tr>
<td>Reduced Noise Levels</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Aesthetic</td>
<td>The aesthetics of the 'fifth elevation' were seen as important as it is overlooked by an important hill in the city, which has both touristic and historic importance.</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Economic</td>
<td>Was not a primary reason for adopting the green roofs. However the architect believed that the green roofs could provide an economic asset to owners in terms of improved rental returns</td>
<td>No</td>
<td>This was not identified as a direct driver but the Wildflower Centre as a whole is a venture to improve the economic prospects of the area.</td>
</tr>
<tr>
<td>Reduction of Urban Heat Haze Effect</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
All the roofs are seen as successful by the stakeholders interviewed and those involved in the decision to adopt the green roofs would certainly like to be involved in future projects. It was difficult to comprehensively explore the diffusion of innovation (Rogers: 1983) using the methodology of this research as the decisions to adopt each green roof had been made before the research began. The diffusion of innovation is discussed in more detail in the following chapter.
Chapter 5

CONCLUSION

Why the green roofs were built

The perceived benefits, drivers and barriers were matched by the actual benefits, drivers and barriers as they occurred in each case study. Rainwater attenuation, biodiversity and the amenity value of the green roofs were all significant drivers that appeared in two or more cases. The green roofs were also adopted because of their aesthetic value, and in one case it was also hoped that the green roof would in some way insulate the building. On the whole the plans to build the green roofs were greeted with enthusiasm and all the green roofs are seen as highly successful. Many of the major stakeholders are keen to get involved with future green roof projects.

At Greenside Place the roofs were seen as a particularly important dimension as the roofs were overlooked by the popular tourist attraction of Calton Hill. The surrounding World Heritage site was an important influence for the architects during the design of the roof. The planting of the roof terraces was seen as the most appropriate way to treat the 'fifth elevation' so that the roof could in some way blend with the adjacent hill and could at the same time be used as an amenity for hotel guests and office workers. At BedZED roof gardens were adopted to provide garden space for residents at a density where normally this would not be possible. In addition sedum roofs were adopted to attenuate rainwater run-off. It was also hoped that the roofs would attract wildlife. The green roofs at the National Wildflower Centre are part of a 'Creative Conservation' scheme, which aims to regenerate inner city areas, bringing money, and jobs into run down areas by improving the local economy through wildflower enterprises. The two wildflower-covered roofs provide an educational tool for visitors to the centre and a vantage point to view surrounding displays. At the same time an important function of the roofs is to improve biodiversity, of both flora and fauna. The green roofs were also adopted to attenuate rainwater run-off and it was hoped that the toilet block green roof would insulate the building.
Barriers and Problems

Where green roofs have been adopted, no major barriers were encountered. Initial Costs, maintenance, lack of awareness, lack of public demand, physical structure, government policy and absence of political drivers did not occur in the research as important barriers. To some extent the aesthetics of the green roofs were problematic to the architects and visitors of the NWC and to the occupants of BedZED, though these problems are not seen as important barriers and the green roof projects have still been deemed successful. As a result of the harsher conditions at roof level some of the vegetation suffered. For example, at NWC there were some teething problems in the early stages of the wildflower roofs and wildflowers took some time to establish, wildflower meadows are often difficult to establish. This meant that in its early stages, the first green roof at NWC did not fulfil its requirement to provide an attractive amenity for visitors. This problem was overcome and a second green roof constructed at the centre. It was hoped that the roofs at BedZED would provide a habitat for birds and insects, this proved correct. However, the wasp nest that was reported by one of the residents was home to insects that were less welcome. The sedum roofs at BedZED also made it difficult to detect the origin of a leak. In the incidence described this was not a significant problem and the sedum did not have to be removed, furthermore the green roof was not the cause of the leak.

Exploring the Diffusion of Innovation

Innovation is an overarching theme in this research, appropriate to all of the adopted green roofs. Each of the studied green roofs had been adopted by innovative organisations, all of whom see innovation as an important factor in the delivery of quality.

It was difficult to explore the decision stage of the case studies as the research was conducted a long time after this stage had elapsed and it was hard for appropriate stakeholders to recall this stage. In future studies the methodology would need to be modified in order to successfully explore the stages of the process by which the innovation is adopted. It is difficult to assess the influence of social networks on the uptake of the green roofs. The buildings are all ‘flagship’ buildings, which either appeared in professional journals and mainstream publications or are highly visible in their situation. It would be interesting to discover how influential the buildings have been to the adoption of green roofs of future developments. Rogers (1983) describes how the Diffusion of Innovation is a social process and how the successful diffusion of the innovation depends to a large extent on the influence the early adopters of the innovation. All the stakeholder members
responsible for the adoption of the green roofs were influential. Stakeholders included either architects with strong reputations or as in the case of the NWC the Director of the centre. A partner of an established and well-respected Architecture practice should be well placed to influence others as to the viability of the innovation and this was certainly the case at Greenside Place.

As discussed in the literature review, during the decision stage of Rogers’s diffusion of innovation theory, the innovation may be trialed, or may have been ‘trialed by others’ before it was decided to adopt the innovation in order to cope with uncertainty. The green roofs at Greenside Place and BedZED were tried and tested systems installed by a high tech specialist. At the NWC the first green roof on the kitchen and toilet block was used as a trial roof from which lessons were learned for the second roof. The ‘wildflower blanket’ on the original roof had itself been trialed on the ground.

On the whole, the proposed green roofs were welcomed. The only exception was at NWC where the architects of the visitor centre objected to the green roof, as they felt that the wildflower roof would harm the aesthetics of the roof, which they saw as an important element of their design.

**Suitable Methodology**

The research methodology has proved an engaging and generative method in which to explore the questions of the research. During the research process it was necessary to adopt multiple lines of enquiry, rather than a single line of enquiry, as set out in the research proposal. This original method relied solely on interviews to generate the data. By using multiple lines of enquiry the influence of bias can be reduced and additional information generated. The interviews proved problematic. It was difficult to come across willing respondents to take part in the research. Those who were interviewed were very helpful and able to assist in providing additional information, which included the names of additional stakeholders, as well as documents, cost sheets and project lists. The remaining lines of enquiry were more straightforward and could be used according to how appropriate they were to each case.

As discussed earlier in this chapter, the framework in this research did not prove to be a useful tool for exploring the diffusion of the innovation.
Suggestions for Further Research

It would be useful to explore the economic value of the green roofs. This has not been directly identified by the study as an important driver. That being said the green roofs at NWC are important attractions at a commercial enterprise and play a part in the wider aims of the organisation to improve the economic situation of the local area as part of an active regeneration scheme. According to Gillian McLaren the green roofs at Greenside Place could potentially generate improved rental rates of the offices and increase the number of guests at the Glasshouse hotel.

Future research could focus on the economic advantages associated with other perceived benefits, including the amenity, insulating, rainwater attenuation, or protective (increased lifespan) value of the green roof. For example, if the amenity value were to be explored the research could investigate how the green roof is enjoyed and whether or not the green roof has an affect on staff-turnover rates, rental prices and so on. Such a study could potentially prove the economic viability of the green roof, appealing to prospective owners and developers of buildings with green roofs.

This preliminary study has been fairly limited in scale focusing only on three buildings with green roofs. All these buildings varied in size and purpose. A study using a larger sample of a broader spectrum of green roofs is needed to understand better the research questions. Unfortunately, it is doubtful whether a large enough sample of green roofs is available to answer the questions using a quantitative methodology.

The absence of barriers in this research does not prove the absence of barriers that affect the adoption of green roofs in urban Britain and the research methodology is not seen as a good way to discover the barriers that affect the adoption of green roofs in urban Britain. To assess the existence of barriers it is suggested that a research methodology should focus on a wide sample of buildings, with or without green roofs. Again the limited sample of green roofs available in the United Kingdom may adversely affect the possibility of this research.

Further research should note that the methodology used in this research was not useful for exploring the diffusion of innovation (Rogers: 1983) as the decision to adopt the green roofs in each case had been made a long time before the research was begun. A long-term study would be a more appropriate method if it were begun before the decision to build a green roof has been made. A very large sample group would be required.
Summary

This report has discussed the importance and viability of green roofs. Not only do green roofs provide a simple solution to offset the impact of the built environment on the natural environment, green roofs offer amenity and aesthetic benefits as well as effective economic benefits. By exploring the benefits, drivers and barriers that affect the adoption of green roofs in urban Britain using three case studies of existing green roofs and by comparing the findings with Roger's Theory of Innovation, it is hoped that the research may contribute to the improved uptake of green roofs.
### Selected Green Roofs

<table>
<thead>
<tr>
<th>PROJECT</th>
<th>DESIGNER/BUILDER</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INTENSIVE GREEN ROOFS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Birmingham Children's Hospital, Birmingham</td>
<td>Lever/ Bauder</td>
<td>Lawn</td>
</tr>
<tr>
<td>Plantation House, London</td>
<td>Arup (Stephen Burrows)/Bauder</td>
<td>Shrubs and perennial borders</td>
</tr>
<tr>
<td>Wesleyan Assurance, Birmingham</td>
<td>Hing and Jones/ Bauder</td>
<td>Low flowering shrubs in roof garden</td>
</tr>
<tr>
<td>South Bank, Youth Resource Centre</td>
<td>Bauder</td>
<td></td>
</tr>
<tr>
<td>Virgin Headquarters, Crawley, Gatwick.</td>
<td>Bauder</td>
<td></td>
</tr>
<tr>
<td>Carlton House, Royal Leamington Spa</td>
<td>Bauder</td>
<td></td>
</tr>
<tr>
<td>Cumberland Place,</td>
<td>Bauder</td>
<td></td>
</tr>
<tr>
<td>PROJECT</td>
<td>DESIGNER/BUILDER</td>
<td>REMARKS</td>
</tr>
<tr>
<td>---------</td>
<td>----------------</td>
<td>---------</td>
</tr>
<tr>
<td><strong>EXTENSIVE GREEN ROOFS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Almeida, Kings Cross, London</td>
<td>Burrell Foley Fisher/ Bauder</td>
<td>Sedum blankets on steeply pitched roofs Theatre Refurbishment</td>
</tr>
<tr>
<td>Calthorpe Project, Kings Cross, London</td>
<td>Architype</td>
<td>Turf</td>
</tr>
<tr>
<td>Cambridge University Sports Centre, Cambridge</td>
<td>ARUP,</td>
<td>10000m square of earth-sheltering, on 12,000 m2 sports centre.</td>
</tr>
<tr>
<td>Making Place, North Kensington, London</td>
<td>Architype</td>
<td>Turf roof on a School building.</td>
</tr>
<tr>
<td>Millennium Seed Bank, Wakehurst (RBG Kew)</td>
<td>Alumasc</td>
<td>Sedum</td>
</tr>
<tr>
<td>Moorside Road (14 houses), Lewisham, London</td>
<td>Architype</td>
<td>Turf, 1997. Housing cooperative</td>
</tr>
<tr>
<td>National Wildflower Centre, Court Hey Park, Roby Road, Liverpool, L16 3NA</td>
<td>Hodder (above Cube)</td>
<td>1998. Wildflower Meadow. RIBA Award 2001</td>
</tr>
<tr>
<td>Nottingham University Campus</td>
<td>Hopkins/ Bauder</td>
<td>Sedum</td>
</tr>
</tbody>
</table>
Interview Questions

1. Please provide a description of your occupation.

2. Please provide an overview of the building development and the role played by your company

3. Why was the green roof built?
   In hindsight was this a good decision?
   What were the key discussion points in project meetings?

4. How important were perceived benefits of green roofs to this project? Could any of the benefits be described as drivers for the adoption of the green roof?

   Benefits include:

   i. Improved air quality
   ii. Attenuation of rainwater runoff
   iii. Biodiversity
   iv. Insulation
   v. Reduced noise levels
   vi. Improved aesthetics
   vii. Recreation
   viii. Economic

   a) Which benefits were seen as important?
   b) Do you agree with the perceived benefits?

5. Do you have any comments concerning the perceived barriers of green roofs? Are there any barriers that you would question?
Perceived barriers include:

i. Initial costs

ii. Maintaining costs

iii. Negative perceptions

iv. Aesthetics

v. Lack of awareness

vi. Physical structure

vii. Government policy – absence of political drivers

6. A recent study\(^1\) found that a lack of awareness among stakeholder groups and the public was seen as one of the greatest barriers to the adoption of green roofs. In this study it was suggested that flagship buildings could raise awareness, particularly amongst architects. Do you have any comments concerning these findings?

7. Can you identify any further barriers, were any further problems encountered?

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\(^1\) Ingleby, A. 2002 Green roofs; A study of their benefits, and barriers to their installation, in London, London: Birkbeck College.
Correspondence from Interviewees

Grant Luscombe, Landlife, Liverpool
National Wildflower Centre, 2004

Background

The National Wildflower Centre is a millennium commission funded project that was conceived and developed by Landlife. The project included the creation of a 150m long RIBA and Civic Trust award winning building set in Court Hey Park in Knowsley, Merseyside.

The new visitor centre and offices designed by Hodder Associates, is a modernist glass and concrete construction with a roof top walkway. It incorporates an older building on the site as the Kitchen and toilet block that has been converted to have flat roofs.

The Centre opened to visitors in 2001.

Why a Green Roof

The rooftop walkway enabled visitors to view the surrounding displays. Comprising an asphalt roof with insulation and concrete paviours set on plastic stands, problems had been experienced with some water ingress and wobbly paviours.

Visitor feedback also identified the roof as the least appreciated aspect of the Centre by the majority of people although a minority were highly appreciative of its minimalist architectural qualities.

The kitchen and loo block trocal roofs were covered with cobbles, which had been used by vandals to attack glazed areas.

In 2002, it was decided to remove the cobbles and trial the waste clothing ‘wildflower blanket’ Landlife had successfully used in land reclamation experiments some eight years earlier where areas of the blanket had survived on a concrete base (probably due to capillary attraction of moisture from the surrounding soil).

In 2004, Landlife decided to resolve any future problems and create an attraction on the main walkway by installing a green roof as a additional element to enhancement works taking place at the Centre.
**Benefits**

In the case of the kitchen and loo blocks it was felt that the installation would increase insulation, absorb rainfall and create a further visitor attraction. The use of the wildflower blanket would, if successful, offer a simple low cost effective means of establishing green roofs.

However, in relation to the walkway it was felt that it would add little to insulation but would reduce runoff and make a significant contribution to the sites visitor attractions.

Both sites would also contribute to biodiversity.

**Barriers/ Problems**

**Wildflower Blanket**

The 2002 installation had few barriers or installation problems. Four layers of blanket were used with a central layer of vermiculite, as it was feared drought would be the major problem. The site was sown in April 2002 and top dressed with grit. The roofs were served by one drain and two drains respectively.

Successful germination of 13 out of the 22 wildflower species was recorded in the first three months and further five species germinated over the following year. Severe frosts were noted over the winter of 2002/03 followed by an eight week drought to 21st April 2003. Record temperatures were also recorded through 2003. The late summer survey found very sparse coverage of 12 species.

It became evident that the installation was incapable of maintaining a suitable moisture balance through the year and that the plants were unable to survive the stress. However, there is periodic recovery of grasses and a few wildflowers, and the few sedums introduced as an insurance policy are spreading. The roof will be left to colonise naturally and new species (possibly better adapted and capable of surviving the conditions) have already been noted.

**Walkway**

The installation of the walkway green roof was very different. A pond liner was installed on top of the existing roof in order to retain moisture. Drains were installed to take excessive moisture to outlets. A core of rotted wood bark topped with crushed bunter sandstone capped with cockle shells was sown with cornfield annuals undersown with perennials and planted with cowslips in April 2004. In all seven species have been used. During
establishment phase it is susceptible to drought. As it is a visitor attraction, one watering has been undertaken. The architect was not keen on the idea of this installation.

This has established successfully and has been a much appreciated attraction.
Gillian McLaren, Alan Murray Architects Ltd Edinburgh, Greenside Place, 2004

Greenside Place

Your email concerning green roofs has been passed to me. I was one of the team of Architects who worked on the project and hope that I can be of some assistance. Unfortunately, I was not involved at concept design stage, but did see the job through from construction drawing stage to completion.

The Greenside site should be considered in the greater urban context of Picardy Place and Calton Hill. It is part of a World Heritage Site and the view onto the highly visible roofscape of both buildings was always considered exceptionally important and referred to as the dynamic “5th Elevation”. This was primarily as a consequence of the close proximity of the development to Calton Hill, a significant public open space located at the East end of Edinburgh’s City Centre.

Below is an excerpt from the statement contained in our Supporting Information Document in respect of our detailed Planning Application, which might be helpful in explaining why it was decided to build green roofs in the first place:

The building is within a World Heritage Site and the quality of the architecture and urban design must reflect that unique position. The scale and massing of the building must compliment and reinforce Edinburgh’s unique landscape and topography.

Edinburgh and it's citizens must benefit not only by participation in the building’s activities but also in the building’s contribution to the streetscape and public spaces.

The Greenside site should, however, be seen within the greater urban context of Picardy Place and Calton Hill, where our key considerations encompass the following:

- World Heritage Site status
- Significant interchange within the city centre, and key link space between Leith Walk and Princess Street
- Part of Edinburgh’s commercial, retail and entertainment epicentre.
• Large expanse of open space for over 30 years increase sensitivity of site. Views towards the West of Calton Hill are only a recent phenomenon.

• Site accommodates complex level changes typical of Edinburgh’s topography.

• Roofscape is exceptionally important, particularly when viewed from the elevated position of Calton Hill.

The support document also contained a section relating specifically to “Roofscape” as follows:

Our proposal for the roofscape (a fifth elevation) is shaped by the elevated view from Calton Hill. The roof elements help reinforce the principle east/west edge to the site on Picardy Place and the secondary perpendicular north/south (feu pattern) roofs to Calton Hill. The provision of an extensive landscaped garden on top of the leisure building will be flanked by a “crust” of roofs similar in scale to the surrounding tenements. The roof garden will create a visual link with the heavily foliaged north slope of Calton Hill.

...The roofscape, therefore, becomes a significant asset to this World Heritage Site, rather than a “dead zone”.

One of the key issues addressed at the design stage was also the need to break down the scale to the valley side and the roofscape elements have a scale commensurate with traditional Scottish tenement blocks. The roof gardens break down the mass of the building and create perimeter edge buildings. (Historically also, there had been gardens on this site at the time when it was occupied by a Carmelite Monastery).
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