

CASE STUDIES

Urban Farming in Inner-city Multi-storey Car-parking Structures- Adaptive Reuse Potential

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The future direction of transport and new global concepts of low-carbon mobility are likely to increase the number of obsolete inner-city multi-storey car-parking structures. The adaptive reuse of these garages is challenged through the continuity of urban change and the need for new mixed-use typologies. The development of technologically advanced farming in these structures could become an innovative strategy that as an interim solution justifies renovation versus demolition and new construction.

The paper presents findings from the first stage of the multiple-site case study research on car-parking structures strategically selected in 3 UK cities (Portsmouth, Bristol and Brighton). In order to develop a better understanding of the conditions that enable the implementation of urban hydroponic farming in selected structures planning and technical limitations and opportunities have been identified through the analysis of policies, exploration of layouts using Revit software, field observation and photography.

The analysis demonstrated that there is a range of possible uses that may be developed in the process of up-cycling of inner-city car-parking structures, of which one might be hydroponics. Looking at three multi-storey garages has shown that these have similar problems for adaptive reuse, which can be overcome with appropriate architectural strategies. Converting these structures for farming could support addressing social, environmental and economic problems. However, the proposed development requires innovations in planning documents. Further analysis needs to be conducted to assess whether the amount of food that could be produced in such a structure is efficient and comparable with other means of achieving it.

Keywords: Multi-storey car-parking structures; Adaptive reuse and up-cycling; Sustainable architecture; Urban farming; Hydroponics; Local food production

Introduction

Building-based farming is increasingly recognised as an innovative method for developing agricultural practices in urban areas, where the competing demands for space became a significant limitation for ground-based farming (Despommier 2011; Gould & Caplow 2012; Specht, Siebert & Thomaier 2015). While growing food in and on buildings is rather seen as a qualitative improvement of a current food system than a contribution to food security in cities (Thomaier et al. 2015) the research on arising concepts of low-space or no space food cultivation techniques, such as Zero-Acreage Farming (ZFarming) (Specht, Siebert & Thomaier 2015) or Building-Integrated Agriculture (BIA) (Caplow 2009), identified potential benefits and challenges in the social, economic and environmental dimensions. An innovative idea for implementing building-based farming is to adaptively reuse existing buildings

that have become obsolete or are not considered useful in the urban environment (Despommier 2011; Puri & Caplow 2009).

The growing traffic congestion in UK cities resulted in new ideas for developing more sustainable urban transport and for designing accessible mixed-use areas for pedestrians. The emerging concepts of low-carbon mobility and restrictions for private transport use are mainly focused on inner-city areas, where cars negatively impact the environment and social life. A number of UK cities decided to reduce vehicular access to the city centre, such as London, Cambridge and Oxford; while other cities such as Brighton & Hove are currently examining these ideas for their future (a phenomenon that is happening in numerous European cities, including Copenhagen, Vienna and Rome). In this context, many inner-city car-parking megastructures built over the last 60 years may become redundant (Merriman 2016).

The underlying hypothesis of the paper is that firstly inner city multi-storey car parks from the 1970s era located on valuable land in regeneration areas will become redundant; and secondly, that urban farming is one of the use options to which these obsolete structures can be put.

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There is some evidence that supports the hypothesis. The prediction of the future of mobility in UK cities is complex and involves a number of issues. While the idea of the adaptive re-use of multi-storey car parks is a good question to address, the authors make the assumption that private vehicle demand in UK city centres will reduce, as the move to electric cars and autonomous vehicles is likely to have spatial consequences.

While some multi-storey car parks will still be needed, the value of inner-city land in regeneration areas will be too high to justify its use for parking. The authors further argue that these structures cannot be simply demolished (in most cases, these are very large concrete structures) and that these have a number of possible uses that could realise the considerable value to the urban regeneration developers and also communities. Usually, if a structure becomes redundant and is retained, then its value and operational cost for new uses will need to be assessed. There are some examples of multi-storey car parks being demolished and replaced, such as Tricorn Centre built in 1966 in Portsmouth and demolished in 2004 or Trinity Square built in 1967 in Gateshead and demolished in 2010. There may be good reasons for that, and these reasons need to be acknowledged. A number of ideas and examples of reuses of multi-storey car parks have been proposed for conversion to other uses and usually, there is an economic, as well as a social case for this. For instance, the Daimler Car Hire Garage (1931) and the Bluebird garage (1924) in London were converted to offices. The authors' research project is not a full cost-benefit analysis whether this is viable, but an architectural exploration on the various scenarios and opportunities for such adaptive reuse.

The argument about food security is still under-researched, and it is another large and complex issue. Urban farming has been researched extensively over the last decade (Despommier 2011; Specht, Siebert & Thomaier 2015) as an option to grow local food in the city and converting multi-storey car parks may be a viable solution if the amount of food that could be produced in such a structure is efficient and comparable with other means of achieving it (for example by using intensive hydroponic urban farming, as suggested by the authors).

Research methods applied

Methods primary sites

The main goal of this research is an architectural exploration of the various scenarios and opportunities for the adaptive reuse of inner-city car-parking structures for urban hydroponic farming. The first stage of the study aims to develop a better understanding of the conditions that enable the implementation of urban agriculture in obsolete multi-storey garages as an innovative form of up-cycling supporting the local food supply.

As a result of this research guiding principles will be designed as a technical tool to enable the identification of the adaptive reuse potential of inner-city car-parking structures for technologically advanced farming operations. This process consists of two steps – first, the definition of limitations and opportunities for the development of advanced urban farming techniques in inner-city

multi-storey garages. This step includes the analysis of planning, agricultural, technical and environmental criteria through a literature review. Second, the defined criteria will be verified by conducting semi-structured interviews with the key stakeholders and practitioners chosen with the aim of understanding their points of views, experiences and vision concerning four main topics: planning, agriculture, environmental requirements and technical aspects. The collected primary and secondary data will be critically analysed to formulate guiding principles for the adaptive reuse of inner city car parking structures for urban farming and local food supply.

The second stage of the research will focus on the application of guiding principles to multi-storey car parks selected as case studies. This process will allow identifying one car parking structure, where various scenarios and opportunities for the adaptive reuse for urban hydroponic farming will be considered. Finally, an urban farm will be designed in accordance with the collected primary and secondary data. As the last stage of the research, the potential productivity of the development and its contribution to the self-sufficiency of the urban area will be calculated.

This paper presents findings from the first stage of the research including critical analysis of:

- The current policy for inner-city areas of Portsmouth, Bristol and Brighton & Hove,
- Technical limitations and opportunities for the adaptive reuse of selected car-parking structures using Revit software for analysing plans, field observation and photography.

Selection of cases for analysis

To achieve the main goals of the study, Portsmouth, Bristol and Brighton & Hove have been strategically selected for the comparative multiple-case study research as they are representative cases of coastal cities of a similar size, but different population density (**Table 1**), they are a similar distance from the capital city London and all located in the South of England (**Figure 1**). The temperate, mild and maritime climate offers an opportunity for the implementation of innovative farming practices as both open-field and indoor agriculture. The selected locations allow for developing hydroponics to increase local summer crops and winter production that requires lower energetic input for heating, in contrast to the cooler parts of the UK.

Table 1: Portsmouth, Bristol and Brighton & Hove: relevant data for the case study selection (Portsmouth City Council 2012; Bristol City Council 2011; Brighton & Hove City Council 2009).

	Portsmouth	Bristol	Brighton & Hove
Area	40.25 km ²	110.07 km ²	87.54 km ²
Population	207,100	428,200	273,400
Population density	5028/km ²	3890/km ²	3445/km ²
	313 022/sq mi	10 080/sq mi	8 923/sq mi



Figure 1: Map of the geographical location of the three cities selected for the multiple-site case study.

The increasing institutional awareness of the benefits that urban farming can bring to the urban environment leads to a supportive relationship between decision-makers and farming initiatives (Bristol Food Network 2009; Portsmouth City Council 2015). The analysis of urban farming strategies shows that the permanent implementation of agriculture practices is a complicated process due to competing demands for space and the need for more compactness within the urban fabric. Therefore, in selected cities, it is worthwhile to explore new opportunities for the adaptive reuse of obsolete buildings by using them for highly intensive hydroponics.

In all three cases, there are serious concerns regarding the increased traffic in the city centre. Hampshire County Council declares that one of the main goals in the nearest future is ‘widening travel choice to offer people reasonable alternatives to the private car for everyday journeys, and reducing the need to travel, moving towards a low-carbon economy’ (Hampshire County Council 2013: 9). In this context, inner-city parking garages are likely to become obsolete in the future.

The case study research will focus on the inner-city areas of Portsmouth, Bristol and Brighton & Hove where multi-storey parking garages have been identified (**Table 2**):

1. The Isambard Brunel Car Park in Portsmouth: a single-function structure,
2. The Prince Street Car Park in Bristol: a multiple-function structure: car park and the Bristol Hotel,
3. The London Road Car Park in Brighton & Hove: a multiple-function structure: 3 apartment buildings (Mayflower Square) and two sports fields are located over the London Road multi-storey car park.

Case study 1: Portsmouth

The development of Portsmouth as a compact city

Portsmouth is one of the major urban areas located on the south coast of the UK, with an estimated population of 207,100 across 40.25 km². A population density of 5028/km² makes Portsmouth the most densely populated

Table 2: Portsmouth, Bristol and Brighton & Hove: relevant data for the parking garage selection.

	The Isambard Brunel Car Park	The Prince Street Car Park	The London Road Car Park
City	Portsmouth	Bristol	Brighton & Hove
Date of construction	1970	1966	1976
Number of parking storeys	5	5	3
Number of car parking spaces	468	297	528

urban area in the UK outside of London (Portsmouth City Council 2012).

The development of the city has been strongly influenced by its predominantly island location and its connection to the sea. Portsmouth has been the Royal Navy’s base since the 17th century. This maritime heritage is recognised as a strong driver of the local economy. The ferry port and the naval dockyard offer a number of jobs and generate an essential income. Moreover, the maritime heritage is a base for the development of tourism, which is mainly concentrated in the area of the historic dockyards and the sea-front. The calculations show that Portsmouth is visited by 7.6 million tourists per year, who spend £373 million and support over 7000 jobs (Portsmouth City Council 2012).

Even though Portsmouth is a strategic centre providing employment, health care, higher education and shopping facilities in the South Hampshire sub-region, the analysis conducted by the City Council has not identified opportunities for urban extensions (Portsmouth City Council 2012). Moreover, very few large sites are available for development within the city. In this context, it is a challenge for Portsmouth to develop an optimal density and compactness, which would support the quality of life of residents and the built and natural environment of the city.

The development of a local food supply system in Portsmouth

Portsmouth plays a significant role in the global food supply. The city is one of the largest fruit handling ports in the UK, with fruit supply from the Caribbean, Morocco, South Africa, Central and South America, New Zealand and the eastern Mediterranean. Portsmouth City Council owns and operates the port and a fruit distribution company MDD. 70% of the bananas and all of the Moroccan citrus fruit consumed in Britain are imported through the city of Portsmouth. During 2010, approximately 610,000 tonnes of fruit, vegetables and salads were delivered on board 224 ships to wharves in Portsmouth (Food Matters 2015).

Growing food locally in and around Portsmouth is challenged by the city's island location. The growing demand for development land gives priority to more cost-effective investments in the city. A review of the food system in Portsmouth (2015) indicated that there is no commercial agriculture within Portsmouth and for that reason, local food supply depends on diverse producers in Hampshire. Large suppliers based nearby who offered local, seasonal and organic vegetables and fruit are Riverford farm and Abel and Cole. For instance, Waitrose and the Southern Co-operative are supplied locally by over 75 small-scale producers from the Hampshire area. The local food system in Portsmouth is also promoted by the Portsmouth City Centre Market in Commercial Road, Southsea Farmers' Market and fish markets (though recently fishing in Portsmouth Harbour was severely reduced due to naval activity).

Support for local food production and supply is presented in the Supplementary Planning Document- Food Growing published by the Portsmouth City Council in 2015. The strong need to encourage new urban farming initiatives in the densely populated urban area of Portsmouth is driven by a number of objectives defined in policies, for instance:

- 'Encouraging and enabling healthy choices and making Portsmouth a sustainable city' (Portsmouth City Council 2012: 13);
- 'Promoting the sustainable use of energy, water and land' (Portsmouth City Council 2010: 9, 13);
- 'Incorporating lifestyle features in housing that cuts emissions and encourages food production' (Portsmouth City Council 2009: 1);
- 'Delivering sustainable communities set in a quality low carbon environment' (Portsmouth City Council 2009: 19);
- 'Creating an age-friendly city by encouraging healthy lifestyle choices which promote physical, emotional and mental wellbeing' (Portsmouth City Council 2010: 19).

The most common option for urban farming in Portsmouth are allotments. However, the competing demands for space, urban soil contamination and degrading ecosystem services are recognised as significant limitations for their further development (Portsmouth City Council

2015). Therefore, current policy identified a number of opportunities for communities and developers to implement agriculture in the existing urban fabric and new development, such as productive facades, internal gardens, green balconies and roof gardens (Portsmouth City Council 2015). The Supplementary Planning Document Food Growing (2015) indicates the strong need for innovative forms of urban farming as a way of dealing with increasing urban density and compactness.

The Isambard Brunel Parking Structure

The Isambard Brunel Car Park (**Figure 2**) is located in the city centre of Portsmouth. The building was designed by the Council Architect W. D. Worden and constructed in 1971 as a five-storey single function concrete structure where 468 parking spaces are located.

Each storey of the car park is connected through a system of ramps and complemented with two concrete staircases (**Figure 3**) with lifts located in the northern and southern elevations and one steel staircase in the middle of the eastern elevation. The typical floor height is 2,90 m (**Figure 4**). The ground level of the car park is partly secured by solid walls. Other levels are limited by steel and concrete railings, which allow for natural light to penetrate the interior. The roof of the garage is flat and free from installations.

Planning criteria analysis

Limitations for the adaptive reuse of the Isambard Brunel Car Park for urban farming

The major limitation for urban farming in Portsmouth is the island location of the city, which constrains the available development land and prioritises more cost-effective investments. The supplementary planning document- Food Growing (2015), identified the main opportunities for commercial urban farming in peri-urban areas, outside of Portsea Island. Inner-city food production is seen rather as a tool for bringing social benefits, such as reducing deprivation and community building, than an actual qualitative contribution to the food system (Food Matters 2015). Moreover, analysed policies do not consider building-based farming as a site allocation and this fact further



Figure 2: W. D. Worden, Isambard Brunel Car Park, Portsmouth, United Kingdom. Photo: Szopinska-Mularz.

limits the implementation of agricultural initiatives in the city as both ground-based and building-based practices.

The dense inner-city area is dominated by the demand for commercial uses (Portsmouth City Council 2013), which require parking space. To accommodate this, the City Centre Masterplan (Portsmouth City Council 2013) emphasised the need to retain the Isambard Brunel Car Park as the main off-street parking location. In this planning context, the adaptive reuse of the garage is a forward-looking concept, for when current planning specifications are modified.

Opportunities for the adaptive reuse of the Isambard Brunel Car Park for urban farming

The City Centre Masterplan (2013) emphasised the adaptive reuse of existing architecture as the most sustainable approach and indicated that retrofitting should focus on

developing a multifunctional architecture. This approach offers an opportunity for implementing building-based farming as one of the uses while converting the Isambard Brunel Car Park to mixed-use development. Importantly, the analysed garage is expected to accommodate two new buildings that would form the strategic corner and key building elevations in the area (Portsmouth City Council 2013). In the future, these planned buildings could create a mixed-use development which incorporates with the Isambard Brunel Car Park adaptively reused for urban farming.

The Supplementary Planning Document – Food Growing (2015) highlighted the need for implementing elements of green infrastructure and, as examples, listed roof gardens, internal gardens, green balconies and innovative solutions that would enable year-round access to fresh vegetables and fruit, especially those difficult to grow in the UK. These solutions, adapted to the needs of technologically advanced urban farming techniques, could offer a significant opportunity for local food production as a secondary food source in the inner-city of Portsmouth. In this planning context, various architectural scenarios for the adaptive reuse of the Isambard Brunel Car Park should be analysed with the focus on delivering high-quality green infrastructure and improving biodiversity (Portsmouth City Council 2015).

Technical criteria analysis

Limitations for the adaptive reuse of the Isambard Brunel Car Park for urban farming

The Isambard Brunel car-parking structure is an example of architecture created for cars. This fact has led to some limitations, which need to be overcome during the adaptive reuse process. First, the layout of ramps and staircases is not sufficient for the planned functions and should be redesigned considering user safety. Second, according to the technical specifications, the floor-to-floor height of the car park is too low to implement additional uses, such as restaurants or offices. For that reason, concrete slabs need to be partially taken out in order to have double-high spaces and voids. Third, hydroponic installations are recognised as an indoor urban farming technique, which requires an enclosed space. Therefore, each storey, cur-



Figure 3: W. D. Worden, Isambard Brunel Car Park, Portsmouth, United Kingdom, Concrete staircase. Photo: Szopinska-Mularz.

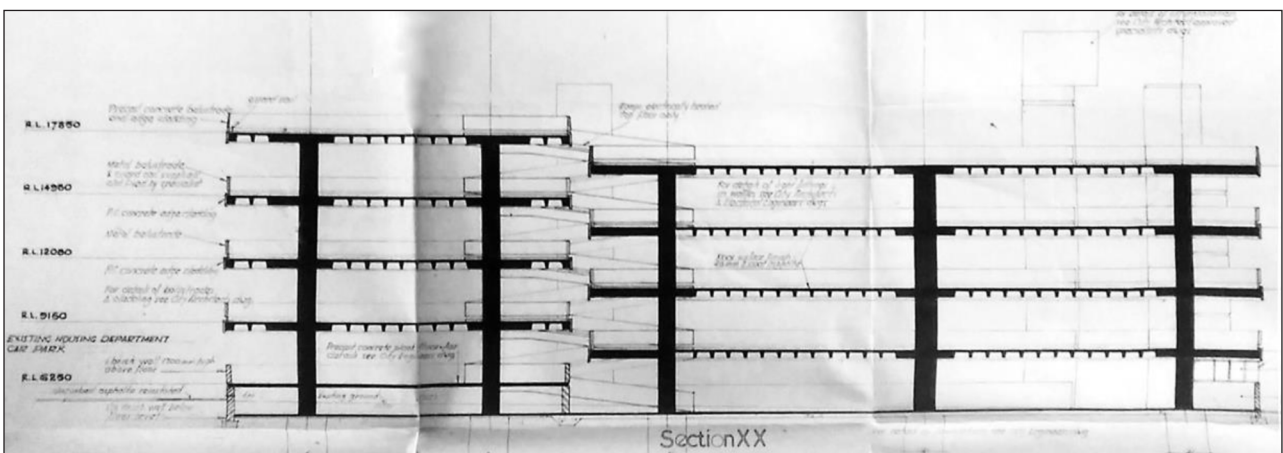


Figure 4: W. D. Worden, Isambard Brunel Car Park, Portsmouth, United Kingdom, Section XX.

rently limited only by railings, should be partly closed to create a controlled environment for food cultivation. Fourth, the car park is a single-function structure where each elevation is permeable. However, daylighting is significantly limited in the central area of each layout. This central space should be designed for hydroponic installation, which may use LED lighting for vegetable cultivation. The space with natural light could be adapted for the needs of additional facilities.

The module for clean span construction in the Isambard Brunel car-parking structure is 16 metres. This span is much longer than other forms of concrete buildings. Therefore, a far higher risk of long-term deflections and cracking could be identified (Henderson, Johnson & Wood, 2002). Before proceeding with the adaptive reuse process, the technical and construction conditions of the Isambard Brunel car-parking structure should be examined.

Opportunities for the adaptive reuse of the Isambard Brunel Car Park for urban farming

The structure is a single use building. In many cases, the adaptive reuse of a single function architecture may be more advanced due to fewer technical connections or risks present than in the case of multifunctional buildings (Henderson, Johnson & Wood 2002). The architecture of the Isambard Brunel Car Park offers flexible open space, which has minimum supports and maximum spans and that creates opportunities to upcycle the structure as a mixed-use development as required in the city centre (Henderson, Johnson & Wood 2002). Moreover, in the analysed garage, urban farming could be implemented together with sustainable technologies, which may contribute to the reduction of the energy use of hydroponics, to the savings of water resources and to the recycling of organic waste. The roof of the Isambard Brunel Car Park is flat and free from installations. This would allow for implementing a greenhouse complemented by a solar system, such as photovoltaic panels (Sanyé-Mengual et al. 2015; Specht, Siebert & Thomaier 2015).

Case study 2: Bristol

The development of Bristol as a compact city

Bristol is one of the eight core cities in England and the largest urban area in the South West region, with an estimated population of 428,200 on 110,07 km² (Bristol City Council 2011). According to the Bristol Development Framework (Bristol City Council 2011), Bristol's population is expected to grow to 519,800 by 2026. This expansion is projected to be accompanied by increased traffic congestion, more urban sprawl, decreased affordability of home ownership and relatively high levels of economic exclusion.

The main aims that need to be achieved to address the environmental and physical issues defined in the Bristol Development Framework (Bristol City Council 2011) are concentrated around the balanced urban renewal strategy, which protects the built and historic environment of Bristol, enhances it by implementing high quality sustainable urban design and by ensuring attractive places through the city. An important goal is to protect the

natural environment and green open spaces during the process of urban renewal and densification. The retention of existing trees and gardens is acknowledged as a priority as the urban greenery plays a crucial role in mitigating causes of climate change and adapting to its effects, especially the potential floodings in the inner-city area (Bristol City Council 2011).

The development of local food supply system in Bristol

The awareness of social, environmental and economic benefits brought about by local food supply to the city and its surroundings is presented in the Sustainable Food Strategy (2009). This document has been developed by the Bristol Food Network in order to implement a local food economy for the city. The main goal of the strategy is to create a mutually supportive relationship between producers, suppliers and communities from the intra-urban and peri-urban areas in order to support the health and well-being of the communities and provide a resilient and sustainable food supply system for Bristol (Bristol Food Network 2009).

The sustainable and resilient vision for food supply in Bristol is based on three long-term aims:

- (1) 'all residents are able to access and afford food that has been produced by local farmers and producers with respect for the health and wellbeing of the environment, animals and local communities, and sold by a diversity of collaborative local businesses;
- (2) all residents know much more about where their food comes from and the impact their food choices have on all those involved in supplying their food and really value and enjoy the local produce they are buying;
- (3) all residents have pride in their City being nationally recognised as an inspirational example of a diverse, vibrant, thriving food culture based on Bristol's myriad sustainable food initiatives' (Bristol Food Network 2009: 1).

The report *Who Feeds Bristol?* (Carey 2011) assessed current local food supply of the city, which is defined in the document as *food that has been grown reared and processed 'within a radius of 50 miles around Bristol city'* (Carey 2011: 55). This includes food production in Bristol, Somerset, Gloucestershire and Wiltshire, which is concentrated on the staple foods: potatoes, lamb, beef, poultry and eggs, milk and dairy products. The report presented that the local provision of potatoes, lamb, beef, poultry and eggs, milk and dairy products is adequate to the needs of Bristol city. The supply of quality wheat, vegetables, fruit, pork and bacon is insufficient (Carey 2011). The area of agricultural land needed to produce food for Bristol is much bigger than the sub-region. Carey (2011) estimated that in Bristol potentially 2,000 hectares of land could be adapted for food growing, including existing farmland and allotments, council-owned greenfields, private gardens, land within school grounds and 20% of green spaces. Despite all the regu-

lations formulated in the Site Allocations and Development Management Policies (Bristol City Council 2014), the availability of these areas for the permanent implementation of urban farming is challenged and limited by the competing demands for space. In addition, the growing value of land gives priority to more cost-effective investments (Zasada 2011). For instance, the 10,000 houses are planned for south Bristol and supplemented by the Park and Ride area on a grade A agricultural land (Bristol Food Network 2009).

In order to build the sustainable and resilient local food system Bristol Food Network (2009) introduced six core programmes: (1) reaching wider audiences, (2) food production, (3) food chains, (4) schools and early years, (5) advocacy and (6) communications. The program aims are listed in **Table 3**.

The work done by the Bristol Food Network is a significant step towards the enhancement of a sustainable food system for Bristol, where food is grown and produced naturally, without chemicals, fertilisers and packaging, sold locally by local enterprises that minimise food miles and fairly support the local community (Bristol Food Network 2009).

The Prince Street Parking Structure

The Prince Street Car Park (**Figure 5**) was designed by Kenneth Wakeford, Jarram & Harris and constructed in the Old City of Bristol in 1966 as a five-storey structure where 297 car parking spaces are located. The multi-storey car park was initially built for the adjacent Unicorn Hotel, now called the Bristol Hotel. In 1994 the garage was overbuilt with hotel facilities.

The Prince Street Car Park is a concrete structure. The east and west elevations are designed as a highly permeable geometric composition of X-components. The north elevation is the negative pattern of the east and west and the fourth side is a party wall. On the ground floor, the concrete lattice of the east and west elevations is propped up by V-shaped supports. Each storey of the car park is connected through a system of ramps and complemented with one staircase adhered to the north elevation. The ground floor height is 3.20 m and the upper typical floor height is 2.50 m.

Planning criteria analysis

Limitations for the adaptive reuse of the Prince Street Car Park for urban farming

While the pedestrian-centred model of urban design is the priority in the inner-city of Bristol, the essential level of transport is accepted in policies and design strategies ((Bristol City Council 2012; Bristol City Council 2014). The Public Realm and Movement Framework (2012) proposed an inner access loop route running around the city centre as an element of rapid transit. The route will be complemented by vehicular access zones, which allow entering the central area for operational servicing and parking purposes. Prince Street is part of a system of rapid transit running through the Old City. In this context, the Prince Street Car Park may be needed as an off-street garage, which accommodates the demand for parking in the inner-city, and this limits the potential adaptive reuse of the analysed structure.

A significant constraint on the implementation of technical equipment related to food production using the hydroponic method is the potential noise and air pollution that can be triggered by the development. The Old Town in Bristol is designated as an Air Quality Management Area (AQMA) (Bristol City Council 2014).

Opportunities for the adaptive reuse of the Prince Street Car Park for urban farming

The mixed-use development priority in the inner-city area highlighted in the Bristol Development Framework (2011) may become an opportunity for implementing hydroponics in the concrete car-parking garage. Technologically advanced urban farming could be supported by other uses significant for the active development of Bristol City Centre, for instance, retail development, entertainment, culture and arts facilities, leisure, sport and recreation uses or offices (Bristol City Council 2014). While the transportation development plans aim to encourage cycling by implementing non-residential facilities for cyclists, the Prince Street Car Park could accommodate secure cycle parking and additional functions, for instance, showers, changing and drying facilities, which will contribute to the increased use of bicycles in the area.

Table 3: 6 core programmes defined by the Bristol Food Network (2009) to support the local food system in Bristol.

Programme	Programme Aims
1 Reaching wider audiences	Reconnect communities and transform their relationships with food – particularly Bristol’s most disadvantaged communities
2 Food production	Increase the production of sustainably-produced food in and around Bristol – by commercial operations and community groups
3 Food chain	Increase the availability and consumption of sustainably produced food in and around the city, in the public and private sector
4 Schools and early years	Support Bristol schools and nurseries to develop and implement holistic sustainable food strategies
5 Advocacy	Food-related policies locally, regionally and nationally are consistent with a move towards a more sustainable food system
6 Communications	Support all activities of Bristol Food Network through quality communications



Figure 5: Kenneth Wakeford, Jarram & Harris Prince Street Car Park, Bristol, United Kingdom, Façade. Photo Szopinska-Mularz.

Site Allocation and Development Management Policies (2014) highlighted the role of existing inner-city markets and a need for new proposals for markets and market-related developments. When implementing a market as one of the uses in the adaptively reused Prince Street Car Park, crop yields cultivated in the structure could be sold locally. This would limit transportation (food miles) and packaging needs and reduce the loss of product occurring on different stages of the long-distance food supply. Shorter food supply chain would minimise the use of heavy vehicles within the inner-city area, thereby contributing to the mitigation of noise pollution and the improvement of air quality in the city centre designated as an AQMA.

The Conservation Area Enhancement Statement (1993) indicated a need to diversify a range of uses on ground and upper floors in order to attract tourists. As the Prince Street Car Park is located directly on the river, to justify the adaptive reuse of this building, which is considered incongruent in the conservation area, new uses on the ground floors would have to reinforce the connection to the dockside and introduce new leisure opportunities that are attractive for pedestrians and cyclists.

Technical criteria analysis

Limitations for the adaptive reuse of the Prince Street Car Park for urban farming

The limitations for the transformation of the Prince Street Car Park are mainly focused on improving the human dimension of the architecture. This includes the redesign of circulation and layout of spaces needed for facilities supporting technologically advanced urban farming. The floor-to-floor height of the second, third, fourth and fifth floor are insufficient for the planned functions. Therefore, the concrete slabs should be taken out partially to have double-high spaces and voids in order to meet technical requirements.

The Prince Street Car Park and Bristol Hotel form a multiple-function structure. The revitalisation of this building was conducted in 1994. However, dynamic loadings caused by vehicles moving around the garage could negatively influence the quality of construction. Therefore,

before any work is done, a technical examination of the concrete structure should be conducted.

The geometric composition of X-components on the east and west elevation significantly limit natural lighting inside the garage and that may challenge the development of uses, which require daylight, for instance, offices or housing. Moreover, concrete patterns on elevations create a unique architectural composition. However, the building is perceived as a 'low-quality post-war development' (Bristol City Council 1993: 16). This fact creates a need to conduct further analysis in collaboration with stakeholders and the local community in order to decide if the elevation patterns should be retained as an element of the identity of the place.

Opportunities for the adaptive reuse of the Prince Street Car Park for urban farming

The up-cycling of this inner-city garage should focus on developing a symbiotic relationship between the existing hotel and the planned urban farm. The proposed adaptive reuse may contribute to urban sustainability by implementing a closed resource loop system, where resources from the existing hotel are exchanged with those from the advanced hydroponics. Moreover, the crop yields could be consumed by the hotel guests, which would limit the need to transport food (foodmiles), packaging and the loss of product occurring in the long-distance supply chain.

The structure offers multi-storey, repeatable space to implement urban farming complemented by additional uses, which together would form a mixed-use development. While the interior is divided only by a system of supports located on the central axis of the layout, the interior of the car park offers flexibility in designing hydroponic installations.

Case study 3: Brighton & Hove

The development of Brighton & Hove as a compact city

The administrative area of Brighton & Hove covers approximately 87,54km² with an estimated population of 273,400. By 2030, the population is expected to grow by 10.2% (Brighton & Hove City Council 2009). The city is located between the sea and the South Downs National Park. This location limits further urbanisation. Therefore, it is planned to increase urban density by implementing a medium rise and some tall buildings in the inner-city area. The process of urban densification is expected to be supported by new open spaces, which increase urban greenery and biodiversity (Brighton & Hove City Council 2009).

The central area of Brighton & Hove extends from Brighton Station to the seafront. It is a mixed-use and densely built-up district where some hotels, shopping centres, conference centres and landmarked buildings are located. The seafront is heavily urbanised and acknowledged by the English Heritage as one of the finest British urban seafront townscape (Brighton & Hove City Council 2015).

The ecological footprint of Brighton & Hove has been recently calculated as 5.14 global hectares (gha) per person. This footprint is considered as not sustainable and,

therefore, there is a strong need to move to a low carbon economy and city. The target set by the Sustainable Community Strategy (2015) is to reduce the ecological footprint of the city to 1.25 gha per person and to reduce carbon footprint by 80% by 2050. To achieve these goals, energy efficient strategies need to be implemented within the city in the nearest future.

The development of a local food supply system in Brighton & Hove

The Spade to Spoon: Digging Deeper- A food strategy and action plan for Brighton & Hove (Brighton & Hove Food Partnership 2012) indicated the need to improve local food systems in order to reduce the growing number of obese adults and children and identified diet-related diseases in the city such as diabetes, cancers, heart disease and strokes. The development of local food supply system is supported by environmental benefits, especially the reduction of the ecological footprint of the urban area of Brighton & Hove, where the 'foodprint' accounts for 26% of the city's ecological footprint (Brighton & Hove Food Partnership 2012) and the reduction of food waste produced by the households (35% of waste produced by households is food waste) (Brighton & Hove City Council 2011). As approximately 70,000 hectares of agricultural land is required to feed the population of the city, 625 million tonnes of fresh water and 750,000 barrels of oil are used each year to produce food. In this process, half-a-million tonnes of greenhouse gases are generated (Brighton & Hove City Council 2011).

In order to achieve high-level, citywide environmental, economic and social priority outcomes the Brighton & Hove Food Partnership has identified nine strategic aims:

Aim 1 People in Brighton & Hove eat a healthier and more sustainable diet.

Aim 2 All residents have better access to nutritious, affordable, sustainable food.

Aim 3 The city has a vibrant, sustainable food economy of thriving local businesses, local products and employment opportunities.

Aim 4 Public organisations have healthy, ethical and environmentally responsible food procurement policies and practices.

Aim 5 More food consumed in the city is grown, produced and processed locally using methods that protect biodiversity and respect environmental limits.

Aim 6 Waste generated by the food system is reduced, redistributed, reused and recycled.

Aim 7 Local and sustainable food is promoted and celebrated by residents and visitors.

Aim 8 High-quality information, support and training on sustainable food and nutrition issues are readily available. There are networking opportunities to encourage links between sectors.

Aim 9 Local policy and planning decisions take into account food issues, and the city is engaged with national campaigns' (Brighton & Hove Food Partnership 2012: 6).

To achieve the aims communities and private investors are encouraged to grow food locally within the city. Sustainable food projects are highly supported, especially those concentrated on developing food co-operatives, sustainable food retail models, community food projects and the alternative use of empty premises for urban farming (Brighton & Hove Food Partnership 2012).

The London Road Parking Structure

The London Road Car Park is located in the London Road Central Area of Brighton. It was opened in December 1976 as a three storey garage with 530 car parking spaces. There is a significant height difference between the Providence Place, where the entrance to the London Road Car Park is located, and New England Street, where the exit is. These levels are connected through a system of ramps and two staircases inside the car-parking structure or the external staircase. On the rooftop of the garage- on the New England Street level, there are three multifamily buildings (Mayflower Square) and two sports fields.

The north-eastern and north-western elevations of the structure are designed as permeable walls with unique vertical concrete elements, which separate the interior from the Providence Place and York Hill. The south-eastern elevation is partly permeable. The south-west elevation is created by an atrium, which extends from the ground level of the Providence Place to the New England Street level. The south-eastern section of the building is developed as a ramp, where car-parking spaces are also located.

Planning criteria analysis

Limitations for the adaptive reuse of the London Road Car Park for urban farming

The London Road Central Masterplan (2009) indicated the demand for a parking garage in the area. However, in the document, the re-allocation of the London Road Car Park is accepted (Brighton & Hove City Council 2009). Therefore, the adaptive reuse of the London Road Car Park would cause a need for new development in the area in one of the locations pointed out in the masterplan. On the one hand, the alternative location of the car park could increase low carbon mobility in the London Road area and reduce the environmental impact of the existing car-parking structure. On the other hand, the new development would generate new carbon emissions.

Opportunities for the adaptive reuse of the London Road Car Park for urban farming

The London Road Central Masterplan (2009) highlighted the role of the adaptive reuse of existing buildings in the inner-city area as the most sustainable approach. The masterplan (2009) allowed for the redevelopment or replacement of the London Road Car Park within a wider comprehensive development and this is seen as an opportunity for converting the car-parking structure for farming. However, if the London Road Car Park is re-allocated, a number of alternative uses would be proposed for the obsolete structure. While the high demand for affordable housing and commercial floorspace in the area is emphasised in the London Road Central Masterplan (2009), this

use would be prioritised when considering the alternative function. In this planning context, converting London Road Car Park for farming could become an interim solution before the demolition.

There is the demand in the area for community management improvements, which are expected to diversify land uses while supporting upgrading of local business (Brighton & Hove City Council 2009). When setting up for profit as a community-led initiative, urban agriculture may serve as an innovation incubator, which offers a new strategy for urban quality food production and local supply as a contribution to the self-sufficiency of the area. The farm would require more innovative businesses, such as start-ups supporting urban food production, processing and supply. Further economic benefits for the inner-city area derived from up-cycling of the London Road Car Park for urban farming would include green jobs creation, new marketing opportunities, improved regional value chains and the development of services, which would attract tourists to the inner-city area. The adaptive reuse may contribute to social sustainability by organising social activities to educate residents about more sustainable ways of consumption and urban life. Moreover, the proposed development, when connecting productive, ecological and aesthetic principles could contribute to the improvement of the streetscape layout and maintenance of the Providence Place, which is considered poor (London Road Central Masterplan 2009: 20).

Technical criteria analysis

Limitations for the adaptive reuse of the London Road Car Park for urban farming

The south-eastern section of the building is developed as a ramp, where car-parking spaces are also located. This unique feature may become a limitation for the up-cycling of the garage for the urban farm because more advanced technical solutions need to be developed than when the slab is flat. That would increase the costs of the investment and may not be financially viable.

While three multifamily buildings are located on the rooftop of the London Road garage, it is of great importance to identify any construction defects and decide how the transformation should be done to ensure that safety is maintained. Therefore, the quality of construction needs to be checked before any work is done in order to identify potential hazards.

Opportunities for the adaptive reuse of the London Road Car Park for urban farming

The location of the three apartment buildings on the roof of the London Road Car Park offers opportunities to develop a mixed-use building where the resources derived from architecture and agriculture establish local resource saving systems that benefit the creation of a healthy urban environment. The exchange of resources (e.g., organic waste, waste heat, industrial or residential wastewater) between advanced hydroponic operations and residential buildings would contribute to the mitigation of the harmful impact of urban development on the natural environment (Specht, Siebert & Thomaier 2015).

The atrium adjoined to the south-western elevation brings natural light to the interior of the garage, which is seen as an opportunity to develop hydroponic installations, for instance in a greenhouse. While energy use and production methods are considered as among the most significant constraints for building-based farming (Despommier 2011; Specht, Siebert & Thomaier 2015) the possibility to employ natural light may significantly reduce costs associated with the energy use. Moreover, the atrium could contribute to the social visibility of food production in the inner-city structure and contribute to the social acceptance of the adaptive reuse for urban farming.

Discussion

The analysis indicated that it is planned to reduce private car use in selected inner-city areas in the future (Brighton & Hove City Council 2009; Bristol City Council 2012; Portsmouth City Council 2012). However, these districts will still be opened for operational servicing and parking purposes, which means, that in many instances, it may take a long time to start thinking seriously about an alternative use for the multi-storey structures. The example of Brighton & Hove shows that the reallocation of the garage is considered in planning documents (Brighton & Hove City Council 2009), but it is not said whether the building would be demolished or converted to another function. Both options could have some possible uses that could realise the considerable value to developers and also communities. Therefore, if inner-city car parking structures became redundant, the potential benefits for the social, environmental and economic sustainability need to be explored in order to decide if these garages should be retained and up-cycled to alternative use or demolished and replaced by another investment. The adaptive reuse of obsolete car parking structures for technologically advanced urban farming may become an interim solution before more beneficial development will be proposed or when the development will be stalled.

Implementing mixed-use buildings with integrated technologically advanced farms requires innovations in urban planning documents, particularly regarding zoning codes (Thomaier et al. 2015). In the USA, cities such as Chicago have started to incorporate urban farming in land-use and launch food policy planning (Mukherji & Morales 2010). That enhances the current development of building-based farming practices. Food policy planning could offer an opportunity to adaptively reuse obsolete multi-storey car parking structures for innovative agricultural activities. Another major issue is the readjustment of urban farming permitting and zoning processes. Mukherji & Morales (2010) reported two ways to include urban agriculture in zoning: either by establishing an urban farming district or by considering urban agriculture as a use which is forbidden, conditional or permitted, depending on the urban area. Such innovations in urban planning are not transferable and need to be developed for specific national settings with different regulatory and planning systems (Thomaier et al. 2015).

The analysis of planning policy indicated that the adaptive reuse of multi-storey car parks could offer new spaces

in cities, which have the potential to reduce social, environmental and economic problems reported in planning documents. Concerning social sustainability, the analysis has shown that offering new educational activities, such as workshops and tours focused on nutrition and quality food and involving the community in food growing, would become an opportunity for implementing the farm. Many building-based farms operate their groceries, restaurants and offer consulting services, which are seen as a contribution to community building and the creation of new economic opportunities (Thomaier et al. 2015). These facilities are needed in inner-city areas to diversify a range of uses and attract tourists (Bristol City Council 2011).

Regarding environmental sustainability, the adaptive reuse of inner-city multi-storey car parks for agricultural practices could contribute to the biodiversity improvement and greening the city, especially if the up-cycling process would include open rooftop farms and productive facades. Producing and selling food near consumers would reduce the need for food transportation (food miles), packaging and the loss of product (Girardet 2008). Furthermore, synergies between the existing building and urban farm should be developed in order to reduce environmental impacts through the exchange of water, energy and organic waste. However, these novel installations require innovative technical solutions in farming, architecture, infrastructure planning and other disciplines (Germer et al. 2011).

Economic benefits from the proposed adaptive reuse include new marketing opportunities, improved regional value chains, green jobs creation and the development of services which would attract tourists to the inner-city area. However, the value and cost of new uses need to be assessed to evaluate if it would be economically viable to up-cycle inner-city car parking structure for food production. This should include calculations of the amount of food that could be cultivated in such a structure and of the potential costs of associated technologies (Specht, Siebert & Thomaier 2015).

The analysis of technical criteria demonstrated that the adaptive reuse of multi-storey car parks for urban farming and additional uses would require architectural modifications and may involve construction changes related to the often too low floor-to-floor height, the layout of ramps, staircases and supports. Each analysed car-parking structure has some individual features, for instance, an atrium or elevation cladding, which may involve more advanced technical solutions to allow the up-cycling process. The costs of such investment may be high and, for that reason, it may be challenging to find investors to convert the structure and demolition may be chosen as an appropriate strategy.

Multi-storey space offered by car-parking structures is considered beneficial for developing technologically advanced urban farming in the inner-city. Hydroponic units could be multiplied in several storeys and existing ramps and staircases could be adapted for deliveries. Flat and empty roofs offer opportunities to implement greenhouses or open space agriculture. However, to up-cycle the structure, a technical examination should be conducted

in order to examine if the load-carrying capacity does not restrict the development of hydroponic installations. It may be that the structure must be upgraded, but that would involve higher initial costs (Hui 2011).

Developing technical solutions to produce and recycle energy, water and waste could contribute to the reduction of the environmental impact of the development and to its economic viability. Further opportunities could arise from synergies between farming and building, especially when the car park is a part of a multifunctional building. To build such synergies, innovative solutions need to be developed and these technical systems are still under-researched (Sauerborn 2011).

Conclusions

The speculative nature of this early research work is ongoing, and it is being planned to explore the issue in more depth in the following year. Looking at three multi-storey car parks has shown that these have similar problems for adaptive reuse. However, these can be overcome with appropriate architectural strategies. The analysis of planning documents has demonstrated that there is a range of possible uses that may be developed in the process of adaptive reuse of inner-city car parking structures, of which one might be technologically advanced urban agriculture. Converting these garages for farming could support addressing social, environmental and economic issues identified in inner-city areas.

The need for developing local food systems in Portsmouth, Bristol and Brighton & Hove is increasingly recognised. Despite this fact, analysed planning documents do not consider urban agriculture as a possible site allocation. In this context, the proposed adaptive reuse may need to gain recognition to be supported by local key stakeholders, especially the local authority. The local authority could allow meanwhile leases to enable urban farming to be developed as an interim solution before the multi-storey car park is replaced by a more cost-effective investment or when development is stalled.

Explored technical opportunities and limitations for the adaptive reuse of inner-city multi-storey car-parking structures need to be addressed with appropriate architectural solutions. The architectural analysis should not only focus on developing hydroponics, but also various uses prioritised in inner-city. Some architectural strategies could be transferable, such as the design of modular hydroponic installations. However, each car parking structure should be analysed individually to develop innovative solutions adjusted to the specific urban context and community needs.

Further analysis needs to be conducted in order to select appropriate architectural strategies and present them through the design of an urban hydroponic farm in one selected multi-storey car park. The presented research stage will be followed by the assessment of whether the amount of food that could be cultivated in such a structure is efficient and comparable with other means of food production.

Competing Interests

The authors have no competing interests to declare.

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