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Urban Form and Socioeconomic Sustainability: Data-Driven Assessment of the Impact of the Regent's Canal on Its Surrounding Neighbourhoods

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Abstract

The spatial structure of cities results from a space-making process that develops over long processes of time. During this process, inner-urban waters as urban components have become a significant urban agenda in shaping the spatial configuration of cities and have diverse forms of interactions with the urban systems. Although there is a significant number of studies that examine the water-city relationship from social, economic, and ecological perspectives, the spatial configuration has not been identified as a determinant factor in the sustainability of waterfront settlements. In that sense, the study investigates the impact of Regent's Canal, London, with socioeconomic properties embedded in the urban form. The case study area is located along a section of the Regent's Canal between King's Cross and Camden Town. It aims to analyse the possible spatial effect of the canal on the socioeconomic culture of its surrounding neighbourhoods. Hence, the research mainly takes Bill Hillier's study on "Sustainability of Urban Form" and Lars Marcus concept of "Spatial Capital" which present the main variables of spatial structure to measure the performativity of urban form. A series of spatial analyses with demographic and land use data is done to investigate socioeconomic development in the neighbourhoods by applying space syntax methodology and tools. GIS is used to create Integrated Urban Model layering space syntax measures of spatial integration, population and retail density, and land use diversity on each street segment to identify differences between neighbourhoods on either side of the canal. The method enables us to understand geographic patterns of potential movement, land use distribution, and social interaction. The main finding of the research is that the spatial effect of the canal is different on each of these sides. This effect depends on the location of the waterbody and the way it is combined with the street network.

Keywords: sustainability, data-driven urbanism, urban form, space syntax, water-city

1. Introduction

A growing body of academic research has addressed the interstitial and fluctuating constellation of blue space with regard to urban waterfront development, which maintains the character of a border area between city and water. In the relationship between the city and water, inner-city water structure has categories such as sea, river, canal, and lake, which determines the

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development of urban patterns in waterfront settlements. Hence, waterfronts have their own distinct story according to how different elements and functions are arranged. Recently, the transformation of water bodies from functional elements serving the transportation of materials during the industrial phase of cities to recreational elements in the post-industrial era. Hence, they have been more visible as an expression of the urban culture in contemporary cities. Therefore, with various production potentials in economic, environmental, and social senses, waterfront areas have increasingly become a source of design and policy concern. The understanding of urban water shifted, especially after the decline of many canals and port areas. However, the transformation from a waterfront brownfield into marketplaces and mixed-use neighbourhoods created water-oriented economies that impact the blue space's functionality in city environments (Kinder, 2015). Following the recent studies about the water-city relationship, the project aims to explore the urban performance of waterfront spatial structures as being subjected to the regeneration of canalside urban areas. The study analyses the Regent's Canal at the city scale and focuses on the area between King's Cross and Camden Town at the neighbourhood scale to uncover what water signifies in its surrounding neighbourhoods and inquiries about the canal's impacts on the spatial network. The regeneration of old industrial lands- such as King's Cross- may bring about gentrification, which might be contrary to social and economic aspects of urban sustainability, in contrast to creating more integrated urban areas for inhabitants.

The paper offers a new conceptualisation of the water body as an urban interstice that creates in-between situations while dividing the urban land. The in-betweenness refers to being surrounded by other spaces that are either more institutional or formal and therefore ecologically, socially and economically more powerful and recognisable (Brighenti, 2013). As discussed by Hillier, the configurational ordering of space and spatial forms affect the interaction between environmental, economic and social factors, which are the main domains of sustainability (Hillier, 2009). Hence, the relationship of the water body with the urban form is so critical for environmentally and socially sustainable urban development in Canalside. The paper investigates how the city's spatial structure deals with the socioeconomic sustainability of canalside and how the Regent's Canal as a geographical phenomenon affects the spatio-functional distribution in its surrounding neighbourhoods. It questions if the canal as an urban interstice creates a natural barrier effect with social and economic consequences in the city environment. The study uses space syntax techniques as the main methodology to analyse the generic properties of urban form and human activity patterns in the canal's space. GIS is used to create Integrated Urban Model layering space syntax measures of spatial integration, population and retail density, and land use diversity on each street segment to identify differences between neighbourhoods on either side of the Regent's Canal.

The project also analyses the major impacts of canalside post-industrial urban redevelopment projects as nodes where different land-use types and transportation systems join. These places can be defined as the catalyst for the economic and ecological upgrading of waterfronts in London. Accordingly, the common opinion about canals is that they, as inner-urban waters, create a positive impact and amenities around but limit people's mobility in the city environment. The canalside redevelopment projects become integrators for the diversity of space use and social gathering along canals. The project aims to test this idea, and thus, the main research questions are formulated as follows: "What is the impact of the canal in the spatial configuration of the neighbourhoods along the Regent's Canal? " and "What contribution does the canal make to the distribution of land uses in the surrounding areas?" To answer the questions, the main theoretical background of the study consists of Bill Hillier's study on "Sustainability of Urban Form" and Lars Marcus' concept of "Spatial Capital", which present the main variables of spatial structure to evaluate the performativity of urban form (Hillier, 2009; Marcus, 2010).

2. Theoretical Background

Literature on sustainability has made an essential contribution to urban and architectural design and provided a considerable shift to transform cities' economies and communities into more sustainable and resilient modes of space production (Coenen, Benneworth, & Truffer, 2012). However, the concept of spatial sustainability has been essentially discussed in the urban literature through regional studies on the spatial distribution of socioeconomic activities or the urban environments' ecological footprint. Hillier emphasised that these studies mainly consist of living standards, population, and ecological demand rather than the configuration of urban form. He investigates the syntactic concepts of urban form by focusing on the configurational ordering of space to discuss contemporary urbanism's key problem: sustainability. He puts a significant debate on a range of evidence about how a city's spatial form can be subjected to sustainability concepts (Hillier, 2009). The dual generic form of the city, which is the foreground and background network, is associated with social and economic factors in the urban system (Hillier, 2007). How the foreground network syntactically relates to the background network is a significant analytical discussion in understanding the movement and co-presence between inhabitants moving with the urban system and others moving in and out of the system (Hillier, 2009). Waterfront settlements are socially, ecologically, and economically sensitive environments where waterbody plays a subtle role in creating spatial structures at different scales. In that context, the study offers to investigate both the foreground background network to understand the economic functioning of waterfront areas, optimising movement potentials and minimising energy needed for movement within the canalside settlement and between the city and canalside settlement.

Hillier also combines movement with creating places, and street network systems are defined as an expression of human purposes. Hence, the spatial configuration of an urban form is a powerful indicator to study the diversity and density of population and functions. Following Hillier's space syntax theory and the concept of the generic city, Marcus introduces the concept of capital into the analytical theory of the social performativity of urban form by referring to Pierre Bourdieu (Marcus, 2010). Marcus explains the possibility of measuring the urban form and its associated structures with the socioeconomic characteristics of the urban system. The exchange-value of spatial capital offers how the urban form is associated with economic capital; the use-value of spatial capital refers to the cultural aspects of everyday urban life. This theory conceptualises the spatial structure as an organiser of the interactions between environmental, economic and social factors in the space and production of this interaction. According to this, the spatial capital of an area is investigated with correlations between urban form and indices of spatial accessibility, density and diversity of social and economic functions (Marcus, 2010).

The segment angular integration value in space syntax theory corresponds to the movement potential of spatial structures. It measures how close each segment is to all other segments about the sum of angular changes made on each route (Hillier & Iida, 2005). It provides an accessibility measure to understand whether correlations exist between the accessibility to specific contents and the diversity or density of functions. In that context, Marcus emphasises the influence of accessibility on land use types. The characteristics of land use are associated with the socioeconomic activities in the city. Concerning spatial diversity as a spatial capital of an urban system, different analytical methods are applied in urban and landscape studies to assess the distribution of diversity, such as Shannon-Weiner index, Simpson's index, MacArthur's index, Margalef index, 1-D index (Dhanani, Tarkhanyan, & Vaughan, 2017; Yoshida & Tanaka, 2005).

3. Methodology and Data Sets

The study uses space syntax techniques as the main methodology to investigate the spatio-configurational characteristics of urban form. GIS is used to create Integrated Urban Model layering space syntax measures of spatial integration, population and retail data on each street segment to identify differences between neighbourhoods on either side of the Regent's Canal. After the study's theoretical background, the approach presented in the paper focuses on the three principal spatial characteristics: First, the street network measured by space syntax analysis; second, residential population; third, land use. The readily available data in the UK enables the study to produce different spatial variables by layering different datasets. Table 1 shows the list of the datasets used in the study.

Table 1. Datasets Used in the Study

Datasets	Variables		
	Street Network	Land Use	Resident Density
LSOA from London Data Store UK Population Data			X
OpenStreetMap Website Road Centreline Map	X		
Colouring London Website Land Use Data		X	
Ordnance Survey Master Map Buildings, Plots, Street Data	X		
Ordnance Survey Parks, Rivers, Canals Data		X	

With the city's syntactical properties, three modes of measure are introduced in the study: Spatial accessibility, density, and diversity of functions. First, the street segment is determined as a spatial unit, and spatial accessibility, population and retail density and land use diversity is calculated in QGIS (Table 2).

Table 2. Indicators of a Built Environment to Assess the Performance of the Urban Form

Indicators		
Spatial Accessibility	Density	Land Use Diversity
• Space Syntax Angular Segment Analysis • The Length of Street Segment	• Population Density per Street Segment • Retail Density per Street Segment	• Land Use Type per Street Segment (Calculated by Shannon's Diversity Index)

For the accessibility analysis, the space syntax angular segment integration value (1) is the main accessibility measure of the study. The street segments are obtained from the road centreline network data of OpenStreetMap. Depthmap is used to calculate the integration measure that was developed by Alasdair Turner (Turner, 2001).

$$\boldsymbol{INT}_{(i,r)} = \frac{(N_i-1)}{\sum_{j=1}^{J} Dep_{(i,j)}}, \{dis_{(i,j)} \leq r\} \quad (1)$$

$\boldsymbol{INT}_{(i,r)}$ is the angular integration value at the radius r is shown as the reciprocal of the mean angular depth $Dep_{(i,j)}$ from segment i to all reachable street segments j within a zone defined by a radius r.

LSOA is Lower-layer Super Output Area that defines a small area designed to be a similar population size. The population density (2) is calculated with an assumption of that the population distributed proportionally by the length of the street, and the sum of segment lengths in each LSOA unit is calculated in QGIS, then the formula was applied into each street segment as follow:

$$pop\ \rho_i = \frac{\text{TOT}POP \times \left(\frac{LEN_i}{\text{SUM } LEN}\right)}{LEN_i} \quad (2)$$

In this equation, i is the street segments where $pop\ \rho_i$ represents the population density of a street segment; LEN_i denotes street segment length; SUM LEN is the sum of street segments' length within the LSOA unit; **TOT*POP*** is the total population of the LSOA Unit.

Point of interest (POI) data is a specific point location representing the location of businesses, schools, parks, stations etc. To calculate the retail density, the POI data of retails are generated from Colouring London and Google Maps. The retail density (3) is calculated as follow:

$$\text{retail } \rho_i = \frac{\text{SUM Retail POI}}{LEN_i} \quad (3)$$

Where i is the street segments, retail ρ_i represents the retail density of a street segment; LEN_i denotes a street segment length; **SUM Retail POI** is the sum of the total number of retail POI in the street segment.

Physical activity is significantly influenced by land use. Land use diversity is a measure to determine to what degree a mix of a categorised land uses within a pre-defined area is presented (Dhanani et al., 2017). An entropy-based measure of diversity is a commonly applied method in urban studies. Hence, the study adopts. Shannon's Diversity Index accounts for the composition of land uses within a given unit (4). The computation of land use diversity can be formally presented as follow:

$$H = -\sum_{i=1}^{s} p_i \times \ln p_i \quad (4)$$

In this equation, ***H*** represents Shannon's Diversity Index where i is the land uses; pi is the proportion of land uses ***i*** relative to the total number of land uses presented in a street segment. The neighbourhood boundaries of Camden and Islington Council are used to analyse the impact of the canal on its north and south side neighbourhoods. The average of the street segments' angular segment integration, density and land use diversity values within the neighbourhood boundary are calculated in GIS to measure the canal's barrier effect on the distribution of functions and accessibility within the canalside.

4. Introduction to Case Study Area

The Regent's Canal provides a link from Paddington Basin to the Limehouse Basin and the River Thames. The length of the canal is 8.9 miles (13.8 km) and has two branches: Hertford Union Canal and Limehouse Cut. The spatial character of the canalside varies along the canal. While some sections contain more industrial heritage than others, some have more green structures and less built-up area (Figure 1, 2).

Figure 1. King's Cross

Figure 2. Camden Lock

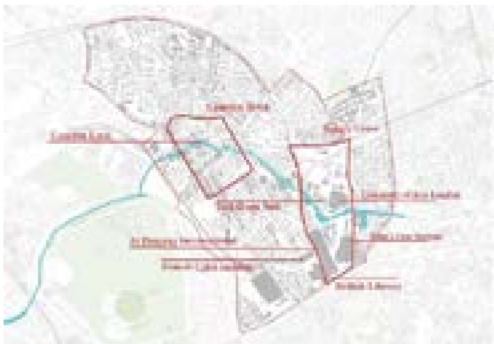


Figure 3. Site Context

The case study area at the neighbourhood scale is located along a section of Regent's Canal between King's Cross and Camden Town and focuses on the redevelopment plans of King's Cross and Camden Area. The area contains important facilities such as the British Library, Francis Crick Institute, University of Arts London, Camden Town Centre etc. (Figure 3).

5. Site Analysis

5.1 City Scale Analysis

The city-scale analysis aims to research the influence of spatial conditions along the canal on the street network configuration. Therefore, angular segment integration measure in both local and global levels (800 m and 2400 m radius) is used to compare the mean values of analysis between the canalside, which are defined by 800 buffered zone (10 min walking distance) from the canal, and outer-canalside (Figure 4). The method also enables the study to combine demographic data geographically and investigate the population distribution with the syntactic results of the urban fabric.

The analysis clearly shows that the canalside urban form's mean angular segment integration value is less than the city, which indicates less connectivity to the network. On the other hand, the canalside has a higher mean street segment length value, probably due to the more significant building blocks and longer town paths along the canal (The canalside 65.06, the outer-canalside 61.85) (Table 3). This could also affect the connectivity of the canalside street network in the urban system. On the other hand, there is no significant difference in the population density average (Table 3). This result demonstrates that the canal does not have any positive or negative impacts on the city's population density distribution.

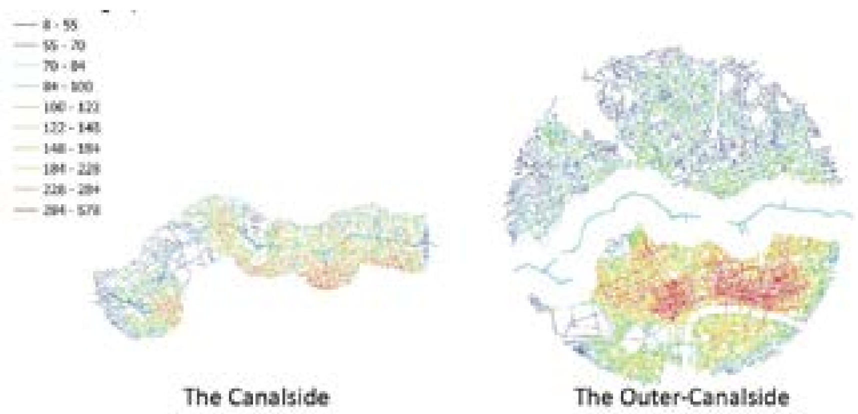


Figure 4. Angular Segment Analysis INTr800m

Table 3. The Comparison of Street Network Variables between the Canalside and Outer-Canalside.

Variables	The Canalside	The Outer-Canalside
Mean Value of INTr400	45.20	58.19
Mean Value of INTr800	132.11	167.76
Mean Value of INTr1200	256.22	316.82
Mean Value of INTr2400	802.21	919.17
Mean Value of Street Length (m)	65.06	61.85
Mean Value of Population Density	0.29	0.22

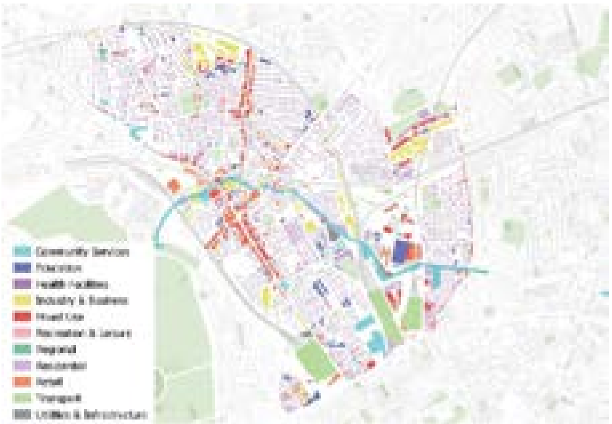
5.2 Neighbourhood-Scale Analysis

The spatial integration analysis in radii 800m and 2400m clearly shows that the accessibility of the south canalside is located with better connectivity to the global street network compared to the north. While the Camden Town area has well-integrated local and global high streets on both sides, the north part of King's Cross lacks global and local integration into the city's structure (Figure 5, Figure 6).

Within the study area, the canal has only one path located on the north canalside, and the mean integration value of the path is 117.75 for the local integration (INTr800) and 787.57 for the global integration (INTr2400). Thus, the analysis shows that the canal's path is segregated from the urban structure.

Figure 5. Angular Segment Analysis INTr800m   Figure 6. Angular Segment Analysis INTr2400m

In terms of the economic impact of the canal, the study attempts to investigate the effect of the canal's spatial condition on the city' economy. Land use distribution and retail density are the two determinants to examine economic activities in the canalside.



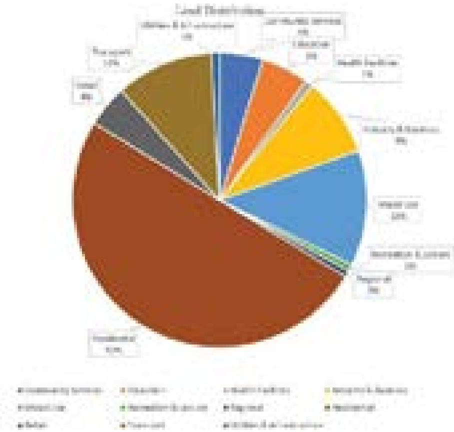


Figure 7. Land Use Distribution of the Area   Figure 8. Land Use Distribution Chart

Although the residential function dominates the land distribution in the area, there is a high proportion of the transportation infrastructure and industrial areas in the close canalside area (Figure 7, Figure 8).

Figure 9. Retail Density of the Street Network   Figure 10. Functional Diversity of the Street Network

Figure 9 provides evidence that the retail functions are mainly located at the high streets attracting high local and global movement and then influencing land use choices. Camden Lock and King's Cross redevelopment projects have a high volume of economic activity by containing 38.2% of the total retail shops in the area. The global and local integration analysis (Figure 5, Figure 6) illustrates that Camden Town is structured well with global and local to-movement and high retail density (Figure 9). However, the functional diversity of the street network, which is calculated with Shannon's Diversity Index, does not follow the spatial connectivity and retail distribution, and the analysis shows that the canal has no apparent impact on the diversity of functions (Figure 10).

As the second step in neighbourhood scale analysis, the study investigates the possible barrier effect of the canal on the socioeconomic development of its surrounding neighbourhoods. Hence, Camden and Islington neighbourhood boundaries were used to examine how the canal affects the degree of spatial connectivity, land use diversity and population density. The street network values are spatially joined with the boundaries, and the mean values of integration analysis, diversity and density measures are calculated to compare canalside neighbourhoods.

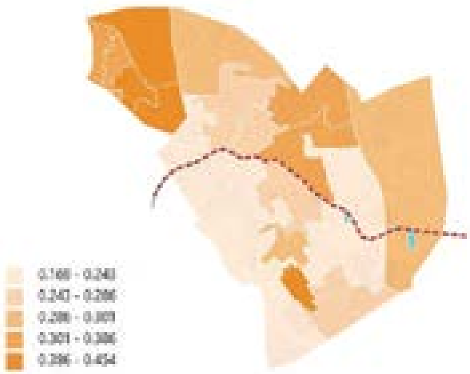


Figure 11. The Comparison of Population Density

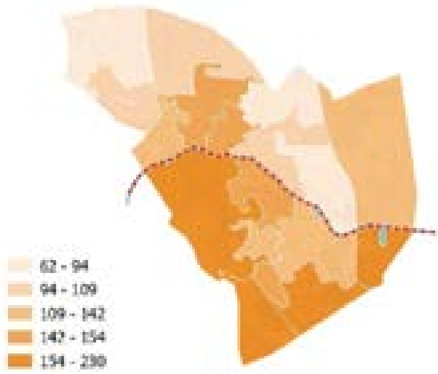


Figure 12. The Comparison of the Mean Values of INTr800m

In terms of population distribution, the north canalside neighbourhood has a higher population density than the south (Figure 11). On the contrary, the south canalside street network is more connected to the urban form with higher integration values. Hence, it could be interpreted that the canal impacts the spatial accessibility of northern neighbourhoods (Figure 12).

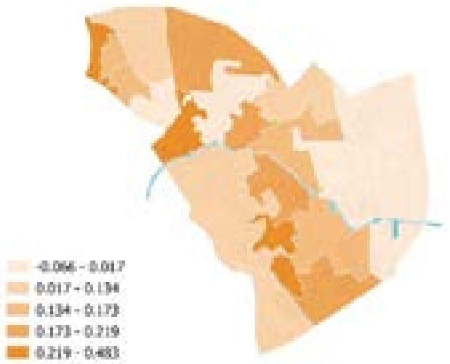


Figure 13. The Comparison of the Mean Values of Functional Diversity

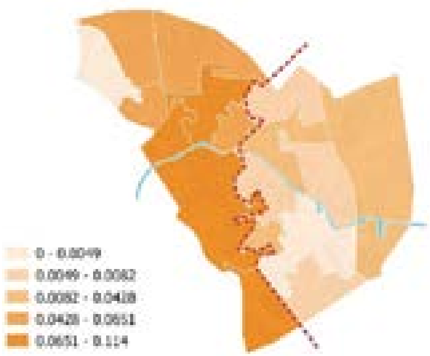


Figure 14. The Comparison of the Mean Values of Retail Density

The comparative analysis of the land use distribution indicates no considerable impact of the canal on the land use diversity (Figure 13). However, there is a big difference between Camden Town and King's Cross neighbourhoods regarding retail density (Figure 14).

6. Discussion

The canalside neighbourhoods consist of socioeconomic properties that distinguished them from other city parts, mainly consisting of mixed-use redevelopment projects, transportation structures, and residential developments. The city-scale analysis shows that the canal creates a separation in the urban form resulted in the low integrated north canalside, and the correlation between distance and the space syntax measures is contrary in the north and south canalside.

The canal does have some spatial impact on the surrounding neighbourhoods. It largely depends on the location of the waterbody and the way it is combined with the street network. The canalside may overlap the city's global and local centre, which produces a positive socioeconomic effect with high retail density and land use diversity, such as Camden Town. However, the canalside areas with low population density and integration value have weak global and local connections to the city, and the blue space does not contribute to the movement economy, such as King's Cross.

As Hillier referred to the project about city centres and non-centre parts of the grid, the property of the smaller street segment is associated with the city centres (Hillier, 2009). Camden Lock waterfront zone has city-centre characteristics with its land use diversity, retail density and smaller street segment property. On the other hand, the urban grid is locally intensified in the Camden waterfront area, which emerges from self-organisation. The main factor of this difference can be explained by how the urban structure of the area was shaped in relation to the canal. While the Camden area has been shaped organically during the city-growing process, King's Cross is a designed area with high investments to regenerate the segregated industrial wasteland.

7. Conclusion

London has developed new mechanisms to upgrade its waterfront areas into more sustainable settlements. However, it is crucial to indicate that the sustainability of the area is significantly related to how it responds to the inhabitants living there. In that context, Hunter evaluates the change in the canal space in his book "Reading the Regent's Canal" from a sociological perspective. He explains that it is possible to find the signs of hip gentrification along the canal from Broadway Market into Camden. This change is defined as stylish and moneyed rather than just getting by. However, he also states that the areas are defined by public spaces for leisure activities rather than private spaces. Also, the expensive and inexpensive restaurants, shops etc., are next to each other in the same space (Hunter, 2019). In comparing the two areas (Camden Town and King's Cross), it is helpful to stress that Camden Town is embedded into the urban network and has been part of the evolution of the city of London, while King's Cross is the result of regeneration. Therefore, this comparison identifies what lessons canalside regenerated areas can learn from areas such as Camden Town.

The project analysis shows that the waterbody of the canal and its associated spatial functions, such as industrial zones, transportation infrastructures etc., become a significant indicator in shaping the urban form and socioeconomic activities along the canalside. However, the towpaths in the canal bank do not enable more significant integration and a more comprehensive range of uses to share in the benefits of its closest surroundings in Regent's Canal. The redevelopment projects' role is significant in that sense, and they became a matter of enhancing functional mix and increasing densities. They generated new job opportunities and new spaces for residential development in the city. The project results also support that these changes created a paradigm shift in canalside's socioeconomic functionality by forming a new water-oriented living pattern. However, their spatial integration is determinant in terms of their long-term socioeconomic sustainability. Accordingly, the future remark of the research is to expand the analysis of Regent's Canal spatial network to cover a broader study on the spatial pattern of canalside.

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Conflict of Interests

The author declares no potential conflict of interest was reported by the author.

Endnotes

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