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Patterns of persistence: Exploring spatial factors behind the longevity of British high streets

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A R T I C L E I N F O

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A B S T R A C T

High streets are integral to urban life. They are crucial not only as economic hubs but also as venues for social interaction. Despite their importance, high streets have faced economic decline due to significant societal shifts. This has sparked a surge in research into recent trends, which potentially overlook longer historical processes. This study examines some 7000 high streets across Great Britain, focusing on the influence of built form, diversity, and centrality on their historical continuity. We analyse detailed morphological features, land-use characteristics, and space syntax-based centrality metrics across multiple scales to test two main hypotheses: first, that high streets established in different historical periods show distinct statistical differences across these domains; and second, that those with prolonged continuity possess higher land-use diversity and are more central at neighbourhood and city-wide scales. Additionally, we introduce and validate a novel method for estimating the age of high streets using historical maps. Our findings reveal that high streets from various epochs exhibit significant differences in morphological and land-use domains. While there are clear associations between the longevity of high streets and their land-use diversity and centrality, these relationships are modest in size, underscoring the intricate interplay between urban form and socio-economic processes.

1. Introduction

'High street' is a term predominantly used in the United Kingdom and other Commonwealth countries to describe the central street of a town or a city. These streets exhibit a wide variety of built forms and characteristics, which are influenced by historical background and geographical context. Research shows how high streets were historically typically highly diverse in the array of functions available along them compared to their surroundings (Bowlby, 2022). Picard (2006) provides a vivid illustration of this diversity by listing the land uses within 42 houses along a high street in London during 1855, which included grocers, a baker, an ironmonger, a second-hand clothes dealer, a surgeon, a veterinarian, tailors, a furrier, an undertaker, an umbrella-maker, a jeweller, a lapidary, a percussion cap producer, a mineral teeth producer, a straw bonnet-maker, a trimming-seller, a lodging-house, a surgeon, a furrier, pubs and a brewery. This multifunctional nature underpins local economies, community ties, cultural activities and everyday encounters.

Despite their historical importance, high streets across Great Britain have experienced a notable decline in economic functionality (Hallsworth & Coca-Stefaniak, 2018), marked by reduced retail occupancy and economic downturns. Often termed 'the death of the high street', this phenomenon has attracted significant scholarly attention, particularly over the last four decades. Much of this research has centred on economic challenges, including recessions (Wrigley & Dolega, 2011), the impact of online shopping on the economic resilience of retail centres (Singleton et al., 2016), shifting consumer behaviours (Munson et al., 2017), suburban retail parks (Thomas et al., 2006), and planning decisions (Carmona, 2021). However, this emphasis on retail often overlooks the high street's historical significance as a hub of social, communal, cultural, and economic exchange (Zukin et al., 2015, cited in Carmona, 2021). This socialising quality links the survival of high streets in the present to the towns and cities in the past, in the face (and in many respects *as the face*) of far-reaching socio-economic change (Gray, 2024).

In exploring what makes high streets successful, researchers have proposed that factors such as mixed land use, sustainability, liveability, adaptability, and resilience contribute to urban longevity (Ntounis et al., 2023). Building on such ideas, Wrigley and Dolega (2011) have provided evidence suggesting that retail diversity plays a crucial role in enhancing the resilience of high streets during economic downturns.

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More recently, Yoshimura et al. (2022) observed that higher retail diversity results in higher sales volumes. While traditional economic geography is concerned with attraction, it does not take account of the historical specificity of street configuration as a possible source of attraction in itself. If it is concerned with the street scale at all, urban agglomeration theory is ‘spatial analytic’ in the urban-morphological sense laid out by Kropf (2017, p. 18). It tends to focus on relations of metric proximity such as clustering, projected onto an essentially static and ahistorical background space. By contrast, the ‘configurational approach’, as Kropf refers to it, starts with the topological description of the actual, historical, routes available to people moving around their districts. These routes are said to constitute relations within an emergent pattern of lived space, in which each spatial element (for example a road or a street) is differentiated by its position within the larger network at a given scale of analysis. This ‘configurational approach’ is deployed in this paper because it lends itself to a more dynamic historical analysis of high streets (Kropf, 2017).

Recent studies into the urban morphology of urban high streets have confirmed the importance of land use diversity. This is consistent with the movement economy theory in space syntax (Hillier, 1996b, p. 44), which proposes that the configuration of the urban grid is the primary driver in structuring the distribution of pedestrian traffic around street networks. The inequalities in this distribution of movement, in turn, influence the “dense patterns of mixed-use encounter” that characterise successful local centres. As stated by Rudlin et al. (2023, pp. 193-194) in their recent book *High Street*, Hillier's studies suggest that such “high streets served their tightly packed surrounding communities as well as providing specialised activities that served much wider markets. The intensity of the movement economy determined the scale of economic activity”.

Such emergent patterns of mixed land use intensity that characterise high streets are a feature of towns and cities around the world, “from London to Limassol, Toledo and Tripoli, showing that local places are shaped and formed over time according to their accessibility to long-term patterns of human, social and economic networks of activity across scales” (Vaughan, 2015, p. 7). In seeking to understand the economic decline of active urban centres in this context, Kickert (2016) analyses the dynamics of urban morphological change in Detroit, Michigan, US, and The Hague, Netherlands, to understand the variety of factors, spatial, cultural, and political that have influenced this decline. Citing Palaiologou and Vaughan (2012), he highlights how the “urban rhythm” of both sides of a street's active facades is a contributory factor in sustaining mixed patterns of land use on the one hand and social interaction on the other. The social and the economic, in other words, are intrinsically linked in the life of high streets. However, if these factors are not spatially anchored in a configurational description of historical high streets, they are likely to continue being treated separately and in relatively generic terms.

It follows that concepts such as sustainability, liveability, adaptability, and resilience that are commonly used to describe *processes* of vitality – the degree to which a high street is considered lively (Ntounis et al., 2023) and viability – the ability of a centre to attract continuous investment to maintain the urban form and enable adaptation to external forces (Millington et al., 2014) are limited by a rather simplistic and generic conceptualisation of how high street spaces mediate long-term social change. This highlights the difficulties of conceptualising socio-economic processes in configurational terms when so many relatively well-documented factors relating to socio-economic and cultural determinants will often appear to offer a more straightforward explanation of a specific situation at a particular time (Kropf, 2001). Indeed, the tacit relegation of the built environment to a background surface on which socio-economic processes play out arises, in many respects, from the conceptual and analytical difficulties involved in expressing the temporality of inhabited space. These effects are likely to unfold over a longer period than applies to a given building development or system of governance. The configurational proposition, in terms that Jane Jacobs (1969) would have approved (“new work on the basis of old”, see Froy and Rocco (2018)), is that historically resilient high streets realise new but non-specific potentials for socio-economic activity through their continuing effects on structuring pedestrian movement.

This ability to adapt and sustain socio-economic activity over time brings us to the concepts of longevity and persistence, which are often associated with resilience. Longevity, in particular, highlights the temporal endurance of high streets, while persistence underscores their ability to withstand and adapt to external shocks (Pendall et al., 2010). Although these terms are frequently used interchangeably, we distinguish between them in this study to reflect the configurational approach's ability to provide precise spatial-morphological descriptions of network centrality. Specifically, *longevity* refers to the temporal aspect of a high street in a configurational sense, while *persistence* describes its ability to adapt to socio-economic and environmental challenges without significant loss of function, or relevance. By linking longevity to persistence, we emphasise that the long-term viability of high streets invokes their capacity not only to survive profound socio-economic change but also to remain relevant and functional as attractive (in both the configurational and socio-economic sense) social spaces. We believe this proposition makes for a useful update to historical-geographical theory, where at present patterns of land-use and urban centrality are understood to be linked – but lack a clear spatial-morphological rationale as to why this should be the case (for example Whitehand, 1977, p. 406). Indeed, centrality in a network sense is marginal to established historical-geographical theorisations of urban morphology, which prioritize the influence of socio-economic and institutional processes on cities over the morphological ones (Oliveira, 2019). This starting point enables us to argue that the emphasis on mid-term (5–10 years) decline and vitality in the existing literature may overlook valuable lessons from the emergent patterns and historical longevity of high streets. A deeper understanding of what contributes to the longevity of high streets is likely to enhance the scholarship around the importance of local centres for the future social – and indeed health and well-being (Daly & Allen, 2018) of people living in towns and cities.

This study seeks to fill this gap by analysing the historical continuity of nearly 7000 high streets across Great Britain, investigating how their built form, diversity, and street network centrality within their locale have influenced their endurance. This is set in the context of anticipating that diversity will naturally increase over time, so long as the built environment offers the essential spatial conditions to support this development.

Using a detailed database of high streets created by the Ordnance Survey (OS) (Kingston, 2019), the UK's national mapping agency, we examine specific morphological features, land use, and centrality metrics from space syntax theory (Hillier, 1996a; Hillier & Hanson, 1984) across multiple spatial scales. This methodology allows for an in-depth examination of the character of high streets in relation to their longevity over the past two centuries. The study tests two main hypotheses: first, *that high streets established in different historical periods show clear differences in their urban form and function*; and second, *that those which have persisted for longer periods typically exhibit greater diversity in land use and maintain more central roles in their urban contexts*.

Furthermore, this paper introduces a new method for estimating the age of high streets using historical maps, providing urban historians and planners with a valuable tool for their work. This innovative approach supports our analysis and deepens our understanding of how and when high streets emerge.

This research extends existing explorations into the factors influencing the longevity of ‘high streets’ as focal points of socio-economic, and cultural activity undertaken over the past decade (Törmä et al., 2017; Vaughan et al., 2013, 2022). We examine how the land use composition and physical form of high streets reflect the socio-economic period in which they emerged. While the link between the longevity of high streets and their diversity and network centrality is modest, it underscores the intricate factors that influence the survival and success of these urban areas.

1.1. From Concept to Analysis: Defining High Streets as Spatial Phenomena

High streets often lack a clear definition. This is true for their socio-economic and cultural aspects, but more importantly for their spatial boundaries and time of emergence. This ambiguity can create challenges in taking high streets from being an amorphous concept, to being a testable feature of the built environment. Although socio-economic determinants are key to explaining the elements that constitute a high street at any given time, and historical-geographical factors are crucial for understanding the character of high streets as places, neither approach fully captures the essence of what a high street truly is. We argue it is reasonable to consider a high street to be, at least partially, a spatial phenomenon. This is evident from even a superficial familiarity with British high streets, as many are situated on historically busy thoroughfares, or more recently, close to train stations.

The urban theorist Bill Hillier proposed that local centres are the outcome of a socio-spatial *process* (Hillier, 1999). He posited that there is an underlying – temporally evolved – spatial structure to street networks which contributes to the environmental, economic and social sustainability of cities over time. The concept of 'pervasive centrality' arises in this context (Hillier, 2009), whereby Hillier proposes that the phenomenon of centrality pervades the urban grid intricately, creating spatial differentiation, and ensuring inter-accessibility between local centres, rather than establishing rigid boundaries. This is attributed to centrality being an emergent spatial-morphological property, observable across scales and not confined to a specific set of socio-economic indicators at a particular time and location.

Pervasive centrality diverges from traditional geographic-economic theories like central place theory (CPT), which conceptualises centres as idealised locations distributing services and goods within a fixed hierarchy (Berry & Garrison, 1958). In contrast, pervasive centrality sees centres as emergent properties of spatial configuration, where central locations naturally arise from the morphology of the urban street network. While CPT addresses the distribution and size of cities and centres, pervasive centrality examines how spatial morphology generates centrality at the street level and across multiple scales. This distinction is crucial for our research: unlike CPT and other attractiveness models, which assume stable, hierarchically organised centres without specific spatial representation, pervasive centrality accommodates multiple, scale-dependent centres (see Krenz, 2018, for a comprehensive comparison of CPT and configurational approaches).

In extension of this idea, Hillier demonstrated how centrality is shaped, illustrating that it is not merely a result of grid intensification along a main road, but a network of interrelated connections operating at multiple scales. For example, in a supposedly local high street such as in Chiswick, west London, the street's segments are central at different scales, with the oldest section being home to the original church and central for the most local trips on foot, while at the other end of the high street's length we find the train station and much wider levels of connectivity to surrounding streets and across the city (Chiaradia et al., 2009). This perspective supports our use of a space syntax-based, mixed-methods approach: by focusing on the street level as the unit of analysis, it captures the dynamic, non-hierarchical nature of high streets and offers insights into longevity patterns shaped by spatial accessibility and urban morphology.

Building on Hillier's proposition of centrality as a process, earlier research into the emergence of high street centrality found that network configuration and built-form adaptability are crucial for long-term socio-economic sustainability. The work showed how networks are preferentially used, adapting to the overlapping demands of movement and access for different purposes, at different times of day, and over varying distances (Vaughan et al., 2013). Subsequent research identified variations in the fine-grained spatial morphology of local centres that supported the contention that land use patterns follow a spatial logic, which may vary from one street segment to the next and can transform over time (Törmä et al., 2017; Vaughan, 2015).

More recent studies (Vaughan et al., 2022; Vaughan & Griffiths, 2021) of peripheral high streets such as London's Chipping Barnet and 19th century Islington, in the UK, also revealed a finely-grained diversity of land use characteristics, as opposed to a clustering of any single category, with similar differentiation of street network centrality, built form and land uses from one segment to the next. The qualities of urban centres that give them the potential to sustain such localised diversity in the face of extensive socio-economic change are clearly essential to understanding their historical endurance.

The significant methodological challenges involved in establishing the temporality of contemporary high streets have resulted in a scarcity of empirical research on their morphological history, often leading to a narrow focus on the present. Traditional landscape and urban-morphological approaches have tried to correct the balance. For example, Slater and colleagues have noted the profound impact that earlier marks in the landscape can have over the centuries in the case of Hertfordshire, UK (Slater, 2008) and in the US, a century-long pattern of change has revealed how "buildings, plots, blocks and streets" affect change or inertia (Hallowell & Baran, 2021).

In this context, we propose to combine quantitative and qualitative methods from the field of historical, social and spatial data science. This is done by: i) using historical maps to date a 10 % sample of high streets captured by the Ordnance Survey in their high street database (hereafter referred to as the *OS High Streets*), ii) creating and linking additional information on built form, land use and centrality, and iii) performing a series of statistical analyses to gain insights into the spatiotemporal nature of the gathered data, making it possible to test the two primary research hypotheses. The research contribution is therefore threefold. First, it provides insights into spatial patterns of high street emergence. Secondly, it proposes and evaluates a methodology to date high streets, and thirdly, it elaborates on the relative contributions of built form, diversity, and centrality to high street longevity.

2. Methods and Data

2.1. Datasets

We employed detailed, vector-based geospatial data sourced from OS, encompassing OS Highways Roads and Paths (Ordnance Survey, 2023) and OS Retail Geographies – High Streets (Goodwin, 2023; Kingston, 2019). The roads and paths dataset provides an intricate and contemporary overview of the urban road network across Great Britain (i.e., England, Wales, and Scotland). It includes coverage of various pathways and alleys, outlining the geographical scope of high streets, and detailing their specific land uses.

The *OS Retail Geographies – High Streets*, is an experimental dataset capturing 6969 high streets: their extent, buildings and auxiliary information across Great Britain (Kingston, 2019) (Fig. 1). High streets are defined by the OS through a step-wise selection process (Kingston, 2019). The process begins with the identification of clusters of retail activity, each of which must comprise at least 15 retail addresses within a 150-m radius of each other. Following this, non-high street retail clusters, such as those in retail, business, or industrial parks, are excluded. This exclusion is achieved by considering address types, street names, building-to-address ratios as well as the absence of residential land uses. The resulting high street extent is then used to gather additional auxiliary information on, for example, the number of buildings, their footprints, the number of addresses, and their land use classes. The chosen distance and count criteria for defining high streets are grounded in an approach that aims to capture the spatial and functional character of high streets as dense, continuous areas of diverse community activity, distinct from other types of commercial clusters.

The requirement of at least 15 addresses within a 150-m radius

Fig. 1. Distribution of Ordnance Survey classified high streets in Great Britain (A), and the location of a representative sample of high streets and their buildings in the North of London, UK (B). Contains data from © Ordnance Survey Limited 2024 and CartoDB.

ensures a concentrated level of activity that aligns with the high street's role as a central, accessible hub for a range of services, retail, social, and civic functions. This density threshold helps to distinguish high streets from smaller, isolated clusters, which may not fulfil the same local and communal roles. In addition to these theoretical considerations, practical reasons also support the criteria. Without such thresholds, clusters may become too small to represent the true extent of a high street, or a single high street may fragment into multiple clusters during the computational clustering process. These practical constraints help ensure that the clustering process accurately reflects the cohesive and continuous nature of high streets, preserving their spatial integrity as unified areas of community and commercial activity. We acknowledge that the OS High Streets dataset may not capture every high street in existence and may overlook some smaller high streets. However, the method is designed to focus on the most representative clusters of locations that people visit to shop, eat and drink along streets across the country. This ensures a consistent and scalable approach that identifies high streets at large, even if some smaller streets may fall outside the defined thresholds.

We combine this information with historical cartographic material from various sources (i.e., Town Plans, National Grid, and County Series) and time periods (i.e. 1830–2020), to date a sample of the OS High Streets dataset by using the EDINA Historic Digimaps Collection (EDINA, 2024). The geographically stratified sample was taken based on standard geographical regions (EU NUTS3), comprising approximately 10 % (i.e., 707) of the initial 6969 high streets. The sample was dated using historical, georeferenced OS maps, following the methodology described below. To validate our dating method, we statistically compared the results from two different coders who independently dated the same 10 % subset of our initial sample. This approach enables approximate dating within a decade, starting from the 1840s. Notwithstanding the two substantial revisions in OS mapping within the 19th century, the archive allows for some precision in dating, given that updates were applied at different times across the UK's region.

In addition, a country-wide segment model has been constructed to compute space syntax-based centrality metrics (i.e., angular segment analysis integration and choice) across various scales. The model is based on the OS Highways Roads and Paths road-centre line data which combines streets, alleys, and urban paths. The road-centre line information has been simplified through a modified approach, which, unlike the original simplification method proposed by Krenz (2017a), retains the representation of dual roads. With this model, segment length weighted angular segment analyses for choice and integration at four radii, i.e., 800, 2000, 5000, and 10,000 m, have been computed using the Place Syntax Toolkit (Stavroulaki et al., 2023). The selected radii represent different movements within the city from a neighbourhood to an intercity scale. Specifically, a neighbourhood scale, characterised by a short 10-min walk (800 m), signified by a long walk or bike ride (2000 m), an inter-city scale, representing journeys between different neighbourhoods (5000 m), and a city-wide scale, covering journeys between all parts of the city (10,000 m). These scales serve as general approximations for movement behaviour and may vary among cities of different sizes. Outliers for integration values, which occur particularly but not only at low radii, have been removed using an adapted formula proposed by Krenz (2017b).

2.2. Dating of high streets

A sample of 10 % of high streets were dated by overlaying the OS High Streets dataset boundaries with historical cartographic material and assessing the first year in which a high street fulfils the selection criteria outlined in Table 1.

Fig. 2 provides an example of how these criteria have been applied in the case of Coldharbour Lane. A high-street boundary is superimposed and the year this high street fulfilled the criteria, i.e., 1930, is specified. The selection of non-domestic functions as indicators of when a road or street became functionally a high street was based on two main factors. First, the maps do not provide specific information on the locations of individual shops or businesses. Second, extensive literature recognises high streets as active centres of non-domestic activity. This literature supports using non-domestic functions as sufficient indicators for identifying the presence of a centre. This assessment is supported by histories

Table 1
Methodological criteria for determining high street age.

#	Criteria	Description
1	Boundary location	The street must lie fully within the contemporary high street boundary, excluding streets that only touch the edge.
2	Central placement	The street must be centrally located within the designated boundary.
3	Continuity of buildings	The street must feature a continuous line of at least three buildings along one side, with ‘continuous’ meaning no significant gaps.
4	Building density	The building density on the street must be at least equal to, if not greater than, the average density of the surrounding area, assessed by comparing the number of buildings, their spacing, and their footprints per unit length of the street with those in nearby areas.
5	Non-residential uses	The area must include at least two non-residential functions, such as post offices, banks, markets, train stations, police stations, town halls, churches, schools, pubs, hotels, libraries, clubs, theatres, cinemas, hospitals, and breweries.

of the OS that indicated that a focus on principal buildings was part of the mapping procedure (Seymour, 1980), as well as personal communication with the authors from a renowned historian of the OS (Bryars & Harper, 2014). More broadly, the concept of ‘principal buildings’ constituting the 19th-century townscape can be traced through newspaper records, as outlined by Griffiths (2016). If a building's shape in recent maps is unchanged, its original function was inferred, even when earlier descriptions were missing or illegible, assuming its structure indicated its purpose. We recognise that, while unchanged building shapes can suggest continuity of function, this assumption has limitations, as uses may change over time. However, such cases were rare. We conservatively assigned dates only when land use was explicitly indicated, primarily inferring function for buildings with distinctive types – such as churches, pubs, or central halls – rather than for ambiguous structures that may be in residential terraced houses. Finally, these non-residential functions needed to be directly accessible from the street or within a short walking distance (i.e., within 50 m).

We measured the intercoder reliability to assess whether this definition can be used to date high streets in a uniform way. Intercoder reliability refers to the extent to which different independent coders consistently assign the same codes to the same data (Gisev et al., 2013). A total of 60 samples were dated by two coders. The reliability of their coding was assessed using the following statistical techniques: *Cohen's Kappa*, a measure which evaluates the agreement between coders while adjusting for chance agreement (McHugh, 2012); *Intraclass Correlation Coefficient* (ICC), is an assessment of the consistency of measurements made by multiple coders measuring the same samples (Gisev et al., 2013); *Mean Absolute Difference* (MAD), sometimes referred to as Mean Absolute Error (MAE), which indicates the average of the absolute difference between the coders' assessments in years; *Root Mean Squared Error* (RMSE) (Willmott & Matsuura, 2005), which provides a measure of the square root of the average differences between the coders' assessments, serves as a way to aggregate the magnitudes of errors into a single measure of dating accuracy.

Cohen's Kappa yielded a value of 0.647, indicating substantial agreement ($z = 12$, p-value < 0.001). This was supported by the Intraclass Correlation Coefficient (ICC), which showed high levels of consistency with an *average fixed raters* model (ICC3k) resulting in 0.927. The F-statistics for the ICC were significant ($F = 13.756, p < 0.001$), with confidence intervals reinforcing the robustness of these estimates (lower 0.878 and upper bounds 0.957). Additionally, the Mean Absolute Difference (MAD) between the coders' assessments was 7.833 years, and the Root Mean Squared Error (RMSE) was 16.073 years, further confirming the reliability and precision of the coders' judgments in this dating task. While a high street might have existed earlier or later than the assigned date, given the results of the intercoder reliability evaluation, we can be certain that this error ranges within ± 16 years.

This dating exercise revealed various ways in which high streets had emerged from earlier socio-spatial processes. These ranged from the consolidation of high streets (or centres) that clearly pre-date the mid-19th century in historic towns both large and small; those that emerged along the pre-urban network throughout the 19th and early 20th centuries; others that appeared on newly constructed 19th-century streets; a third type of densified and/or extended high streets in existing village centres (often in relation to a railway station); and a much smaller sub-set were those that were constructed as stand-alone centres from the mid-20th century onwards. Future research may focus on these historical-morphological types.

2.3. Variable selection

Table 2 provides a detailed overview of all collected variables, covering morphological characteristics, land uses, space syntax measures of centrality as well as temporal information. Depending on the

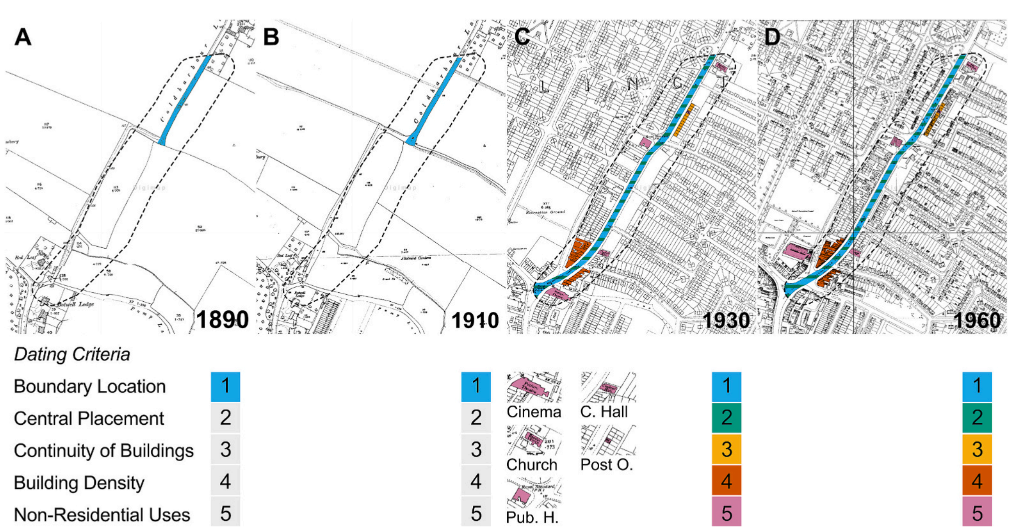

Fig. 2. Dating high streets: historical cartographic material showing Coldharbour Lane, Hayes, Greater London (outlined in vermilion) in 1890, 1910, 1930, and 1960. The occurrence and location of non-domestic land use is revealed on the 1930 dated map – thus this case is said to date from that decade. Contains data from © Ordnance Survey Limited 2024.

Table 2
Variable domains, names, and descriptions.

Domain	Variable name	Variable description
Built form	bdng_ct	Count of the polygon geometries classified as a building within a high street extent
	bdng_a_med	Median building footprint area of buildings within a high street extent
	bdng_a_max	Maximum building footprint area of buildings within a high street extent
	t_len	Total length of the lines comprising a high street
Land-use	a_ct	Count of address points (of class retail, office, community, leisure and recreation, and residential) within a high street extent
	ret_a_ct	Count of address points classed as retail within a high street extent
	of_a_ct	Count of address points classed as office within a high street extent
	comm_a_ct	Count of address points classed as community within a high street extent
	l_r_a_ct	Count of address points classed as leisure and recreational within a high street extent
	rs_a_ct	Count of address points classed as residential within a high street extent
	bdng2a_ct	Ratio of the building count to total address count
	res2a_ct	Ratio of residential addresses to total address count
	shan_res	Shannon's Diversity Index including all address types
	shan_nores	Shannon's Diversity Index including all address types except residential addresses
Space syntax	ac800_max	The maximum value of a segment length weighted segment angular choice analysis at a radius of 800 m of all segments comprising a high street
	ac2k_max	"choice […] at a radius of 2 km […]; "choice […] at a radius of 2 km
	ac5k_max	"choice […] at a radius of 5 km […]; "choice […] at a radius of 5 km
	ac10k_max	"choice […] at a radius of 10 km […]; "choice […] at a radius of 10 km
	ai800_max	"integration […] at a radius of 800 m […]; "integration […] at a radius of 800 m
	ai2k_max	"integration […] at a radius of 2 km […]; "integration […] at a radius of 2 km
	ai5k_max	"integration […] at a radius of 5 km […]; "integration […] at a radius of 5 km
	ai10k_max	"integration […] at a radius of 10 km […]; "integration […] at a radius of 10 km
Temporal	year	The decade a street has been classed as high street
	age	The age of a high street in years
	epoch	The epoch a high street's dating falls into (i.e., 1840–1880; 1890–1910; 1920–1940; 1950–2020)
	century	The century a high street's dating falls into (i.e., < 1900, ≥ 1900)

statistical analysis variables have been transformed using a Box-Cox transformation, scaled, and tested against normality and multi-collinearity assumptions. Where variables have correlated highly (i.e., $R^2 \geq 0.8$) the theoretically more meaningful variable has been retained.

Land use diversity was quantified utilising Shannon's Diversity Index (Shannon, 1948). This index serves as an indicator of the variety of land uses present; high streets with a broader and more even mixture of land uses are assigned a higher value. The analysis involved counting the number of unique addresses classified into one of four land use categories: leisure, office, retail, and community, for each high street. In addition, we also computed Shannon's Diversity Index including residential land use.

We used the dated decennial year of a high street to i) calculate the length of its existence in years; ii) to differentiate high streets into two groups, i.e., high streets that emerged pre-19th century and those that emerged afterwards, and iii) to differentiate high streets into one of four historical epochs. These epochs are pre-mid 19th century (1840–1880), late Victorian/Edwardian (1890–1910), interwar (1920–1940), and post-war (≥ 1950). Each of these epochs is associated with distinct historical, cultural, and architectural trends that influenced the character and development of the high street built environment in the UK.

2.4. Statistical approach

In order to answer the two hypotheses posed by this study, the statistical approach is divided into three sections: 1) an explorative spatial data analysis of the collected and dated data using statistical description, GIS mappings and measurements of spatial clustering; 2) a multivariate analysis of variance to test the statistical differences between epochs and the identification of variables which most contribute to this difference, and 3) a linear regression to test whether high streets that have persisted for longer periods are more diverse and central at varying scales.

2.5. Exploratory spatial data analysis

We employ an exploratory spatial data analysis approach to gain insights into the spatiotemporal dimension of high street emergence. Specifically, we investigate whether high street occurrence can be described as clustering, dispersing or randomised at a given time and distance and whether this pattern changes through time. We do this by simplifying high street locations into their centre points and employing the K-function, a method from the field of point pattern analysis. The K-function, often referred to as Ripley's K-function or the reduced second-moment function (Diggle, 2014), serves as a tool for examining the relationships between points in a given space. This function quantifies the count of points within a specified proximity to a given event and compares this against the hypothesis of a random distribution of unrelated points within a given space, known as *complete spatial randomness* (CSR). One key advantage of the K-function is its capacity to delineate characteristics of point patterns across various distances. This enables the detection of both clustering and dispersion effects that might be occurring concurrently at different scales. In addition, we evaluated the distribution of years and compared the mean and max values of selection centrality metrics as well as the mixture of land uses.

2.6. Multivariate analysis of variance

To test hypothesis 1 (high streets originating from earlier periods exhibit statistical differences when contrasted with those established more recently), a Multivariate Analysis of Variance (MANOVA) is conducted. MANOVA is a statistical technique used to test for differences across multiple dependent variables simultaneously, considering the inter-correlations among them (Stevens, 2002, pp. 178–181). It extends the ANOVA framework to accommodate the analysis of multiple continuous outcomes, making it particularly useful in experimental designs where multiple related measures are assessed for each observation. MANOVA is generally robust against small differences (<1.5:1) in sample sizes between groups, however, large (>1.5:1), unbalanced groupings can potentially compromise the validity of the results. As demonstrated in the results section, the distribution of years within the 707 sampled high streets is highly skewed towards earlier years. A sensitivity analysis was conducted using a balanced subsample of 60 randomly sampled high streets from each epoch to ensure that the results were robust and not unduly influenced by the initial imbalanced sample.

The relative importance of each selected variable (see below) has been determined by its ability to discriminate between groups across our four different sample strategies. This was done by performing a Linear Discriminant Analysis (LDA). LDA is a statistical technique used for dimensionality reduction and classification. It operates by finding a linear combination of features that best separates two or more classes of events or objects. The method works by projecting the data onto a lower-dimensional space where the classes are as distinct as possible. LDA achieves this by maximising the ratio of between-class variance to the within-class variance in any data set, ensuring that the classes are wellseparated. Furthermore, LDA enables the identification of variables that contribute to group differentiation, as well as the strength of this contribution. The LDA analysis was undertaken only on the following variables that did not have collinearity (namely, with a correlation coefficient of <0.75): bdng_ct, bdng_a_med, bdng_max, t_len, capturing morphological characteristics; ret_a_ct, of_a_ct, comm_a_ct, l_r_a_ct, rs_a_ct, bdng2a_ct, shan_res, shan_nores, capturing land-use characteristics; and ac800_max, ac10k_max, ai800_max, ai10k_max, to capture neighbourhood and city centrality characteristics.

2.7. Bivariate linear regression

A series of bivariate linear regression models was conducted to investigate hypothesis 2 (high streets that have persisted for longer durations have higher land-use diversity and are central at varying spatial-morphological scales). The age of the high street served as the independent variable in each model, while land use diversity and network centrality were analysed as separate dependent variables. This analytical approach allows for the examination of how the longevity of high streets correlates with their current functional composition and spatial centrality. The selected variables for this analysis, are age, capturing the length of high street existence in years, shan_res, shan_nores, capturing land use diversity, and ai800_max, ac800_max, ai2k_max, ac2k_max, ai5k_max, ac5k_max, ai10k_max, ac10k_max, to capture centrality at varying scales. To ensure result robustness, we conducted outlier diagnostics, re-estimated models without high-influence points, and applied robust regression, all of which confirmed the stability of our findings (see Supplementary Table S1).

3. Results

3.1. Descriptive statistics and mappings

The distribution of years within our sample (Fig. 3) reveals a predominant emergence of high streets appearing in the contemporary OS High Streets dataset in the years between 1840 and 1910. Subsequent periods, specifically the interwar and post-war periods, including the 21st century, are characterised by peaks in high street development. This delineation underscores the different birth patterns of high streets and is broadly consistent with the historical-geographical periodisation of socio-economic transformations and associated phases of urban development from the early 19th century (Whitehand et al., 2014). Epoch 1 is characterised by the consolidation of high streets in historic towns and cities that pre-date the mid-19th century. Epoch 2 typically consists of high streets that developed to connect suburban railway stations to existing village centres, whether along the line of a pre-urban road or along a newly constructed road. The influence of the railway on the pre-urban network is equally strong in the interwar period but high streets attributed to Epoch 3 correspond with a new type of residential development in which the compact urban form of the 19th and early 20th century is displaced by expansive suburban landscapes of semi-detached housing. High streets belonging to Epoch 4 have the weakest configurational antecedents in the pre-urban network; they belong to the post-war new towns and more recent town-centre regeneration projects.

These transformations are also expressed through different spatial patterns. Fig. 4 presents four maps that illustrate the spatial emergence of high streets in Great Britain across different epochs, with a set of four additional detailed maps focusing on Greater London. Each map is colour-coded to represent distinct time periods: sky blue for 1840–1880, bluish green for 1890–1910, orange for 1920–1940, and vermilion for the period from 1950 onwards.

In the earliest epoch (1840–1880) (A), the distribution of high streets appears relatively even across the country, indicating an era of widespread and balanced urban development. This phase is characterised by the emergence of high streets in various locations. However, the maps of subsequent epochs, particularly the map of 1890–1910 (B) and the map of 1920–1940 (C), reveal a concentration of high street development within existing urban agglomerations. While the central areas initially show dense high street developments, new developments in each succeeding period progressively extend further from the city centre. The post-war period, depicted in vermilion (D), marks a noticeable shift. Besides the ongoing trend of expanding high streets from city centres, there is also an emergence of high streets in new towns and areas between major urban conurbations, such as between London and Birmingham.

The assertion that high street emergence has a distinctive spatial pattern through time can also be demonstrated statistically using the K-function. Fig. 5 features four K-function plots for selected years that illustrate variations in clustering within 20-year intervals across distances ranging from 0 to 20 km. It also includes an aggregated K-function plot that contrasts the findings from a 10 km radius for the initial decade of each 20-year observation window. In these plots, the observed spatial distribution of high street centroids is depicted by a vermilion line. This is set against a dashed line representing the expected distribution under a hypothesis of CSR, with a blue shaded area indicating the confidence envelope derived from 1000 simulations of a CSR process. When the observed data's curve exceeds this confidence envelope, it

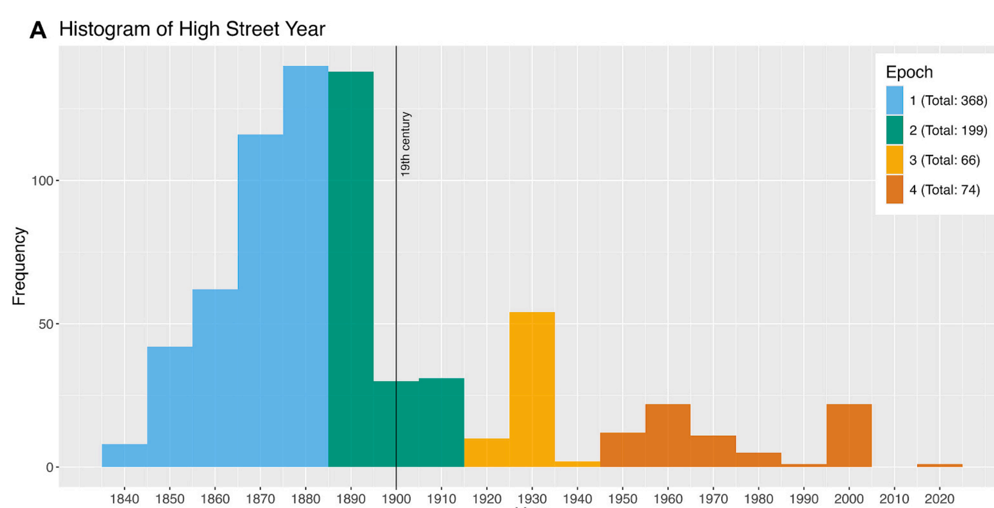

Fig. 3. Histogram of years of the dated high street sample. Epochs highlighted in sky blue (1840–1880), bluish green (1890–1910), orange (1920–1940), vermilion (≥ 1950). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

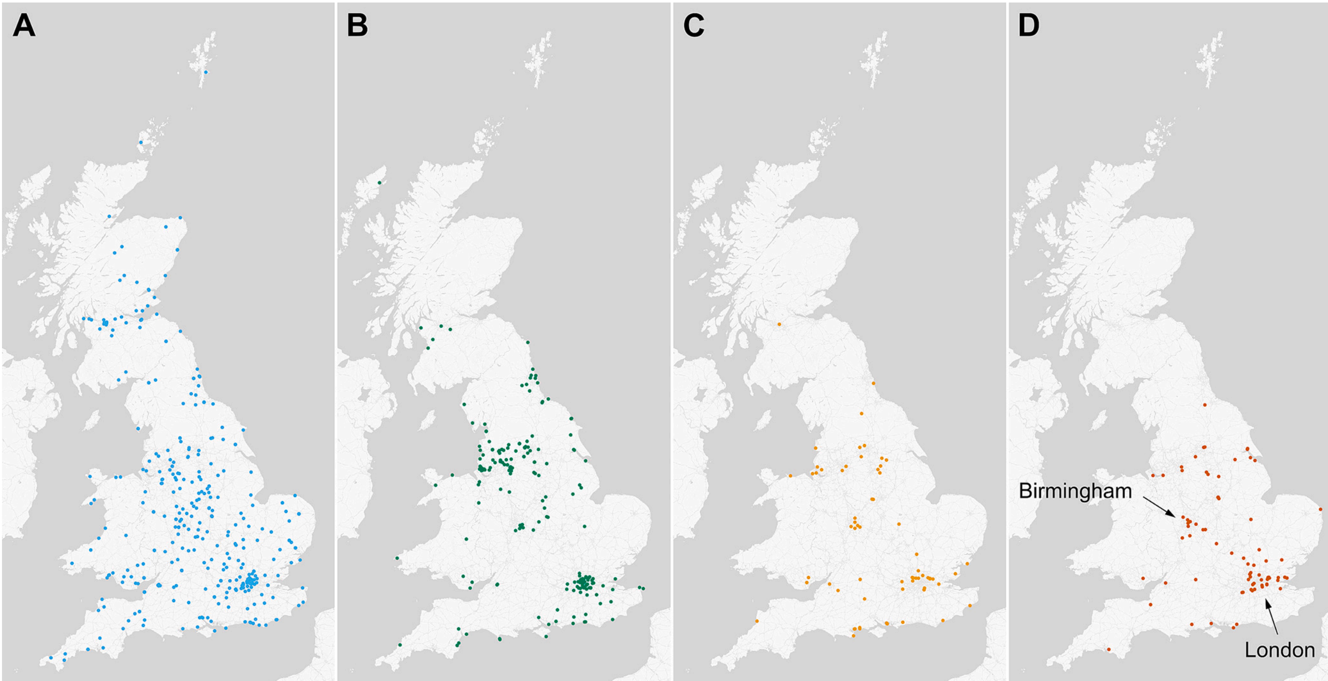

Fig. 4. Location of high streets by epoch across Great Britain, with detailed views of Greater London. (A, E) 1840–1880 sky blue, (B, F) 1890–1910 bluish green, (C, G) 1920–1940 orange, (E, H) ≥1950 vermilion. Contains data from © Ordnance Survey Limited 2024 and CartoDB. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

signifies a departure from randomness, indicating spatial clustering. The distance between the observed curve and the envelope quantifies the degree of clustering.

In Fig. 5 the sequence of plots demonstrates a notable trend: minimal clustering in the year 1840, escalating to a significant clustering peak by 1860, followed by a gradual decline until 1970, when clustering becomes negligible. This indicates that the advent of high streets in and around 1860 followed a process where streets emerged close to each other – which likely took place within urban centres. Overall, the maps as well as the statistical analysis collectively depict a transformation in the pattern of high street emergence in Great Britain – from an initial even distribution to a focused expansion around and outward from existing urban centres, complemented by the post-war emergence of new urban areas.

3.2. Statistical differences between high street epochs and centuries

We evaluated the statistical differentiation of observed groups, irrespective of the sampling method (balanced vs. unbalanced) or the level of granularity in the grouping (epoch vs. century). In addition, we identified the most group-differentiating variables using an LDA.

Table 3 presents the results of a MANOVA conducted to assess the statistical differences between high street characteristics across four epochs, with both balanced and unbalanced samples. For the balanced sample, the results show a Pillai's Trace of 0.60891 indicating a strong multivariate effect, an F value of 3.549, and a highly significant *p*-value (<0.001). The unbalanced sample shows a similar pattern with a slightly lower Pillai's Trace of 0.478, a higher F value of 6.784, and a highly significant *p*-value.

Table 4 shows a comparable result of a MANOVA assessing the statistical difference across two centuries. The Pillai's Trace value of 0.238 of the balanced sample suggests a moderate difference exists between the two centuries and the measured high street characteristics. The F value of 4.357, and a p-value below 0.001 indicate a strong statistical significance. In the unbalanced sample, the analysis still shows significant results with a Pillai's Trace of 0.180 and a higher F value of 9.463, maintaining a highly significant p-value.

Remarkably, both balanced and unbalanced sampling methods consistently yielded statistically significant differences among the groups. This consistency is evident in Pillai's Trace values and the significant *p*-values (<0.001) across all tests. The occurrence of statistical significance in both more conservative (balanced) and more inclusive (unbalanced) sampling strategies highlights the underlying robustness of the group differences, suggesting that these differences are not merely artefacts of the sampling approach but rather indicative of genuine variations among the groups.

Furthermore, the transition from coarser groupings (centuries) to finer groupings (epochs) did not diminish the statistical significance of the group differences. In fact, the epoch-based groupings, with their larger effect sizes, as indicated by higher Pillai's Trace values, suggest that there are more nuanced differences between a larger set of groups than the two centuries. This is noteworthy as it implies that regardless of whether the analysis employs broader or more detailed categorisations, the statistical differences between groups remain prominent and significant. In essence, the findings provide robust evidence in response to the posed hypothesis (1). The observed statistical differences among groups are not contingent on the specificities of the sampling strategy or the granularity of the groupings. Both balanced and unbalanced samples, as well as century and epoch categorisations, consistently reveal significant differences, underscoring the fundamental distinctions that exist between the groups under study.

Using the result of the Linear Discriminant Analysis, the five variables which consistently show the highest and lowest importance across the tables have been selected to provide insights into which high street characteristics differentiate the most and least between the sample cases. The top five variables, ranked by their relative importance (from most to least influential) are the median building area, the number of retail addresses, the number of buildings, the length of the high street, and land use diversity including residential land uses. The lowest ranked (from least to most influential) five variables are: the maximum choice and integration value at a radius of 800 m, the maximum choice and integration value at 10 km, and the number of addresses classified as

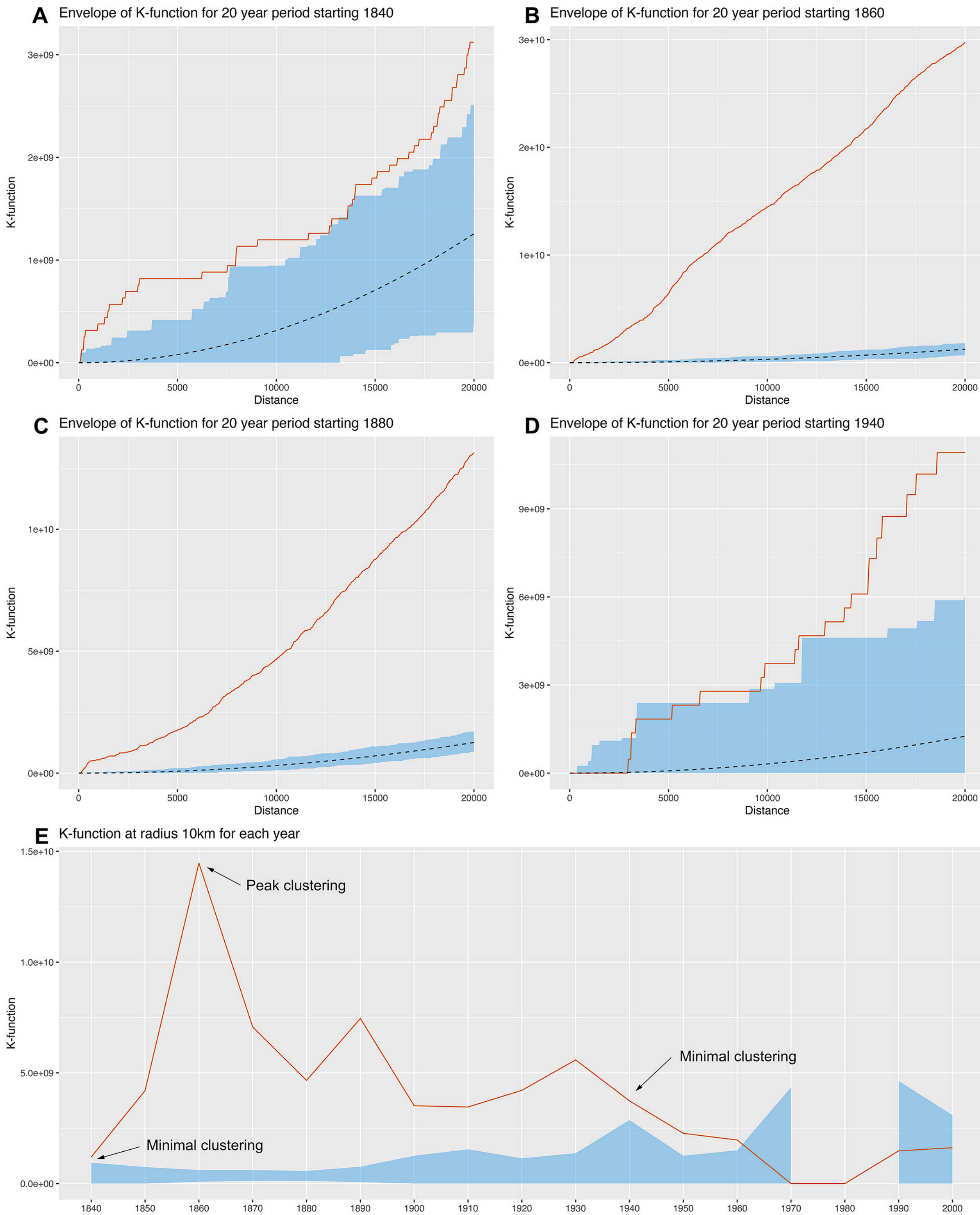

Fig. 5. Results of a K-function analysis, with dashed lines showing distribution under CSR, a sky blue envelope showing CRS under 1000 simulations, and a vermilion line showing the distribution of observed data. Including, K-function results for the four epochs at scales ranging from 0 to 20 km (A-D), and for each year at a 10 km distance (E). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

community.

This result may suggest that differences in morphological and land-use characteristics are higher between epochs than their relative centrality. *In fact, all four centrality variables are among the least important variables to differentiate groups*. Several explanations could account for this, either a) high streets across epochs share similar degrees of centrality at both neighbourhood and city scales, and/or b) centralities are inconsistent within epochs, i.e., within the same epoch one high street may be central at a city scale and less central at a neighbourhood scale, and another may be less central at a city scale and central at a

Table 3
MANOVA results for four epoch groups using balanced and unbalanced sampling.

	Df	Pillai's trace	F value	Num Df	Den Df	Pr(>F)
Epoch (balanced sample)	3	0.609	3.549	48	669	<0.001
Residuals	236					
epoch (unbalanced sample)	3	0.478	6.784	48	2070	<0.001
Residuals	703					

Table 4
MANOVA results for two century groups using balanced and unbalanced sampling.

	Df	Pillai's trace	F value	Num Df	Den Df	Pr(>F)
Century (balanced sample)	1	0.238	4.357	16	223	<0.001
Residuals	238					
century (unbalanced sample)	1	0.180	9.463	16	690	<0.001
Residuals	705					

neighbourhood scale. The latter (b) could point to what Hillier termed 'pervasive centrality' (Hillier, 2009). It suggests that centrality on multiple scales operates as a widespread characteristic in urban areas, exhibiting distinct spatial-morphological associations rather than simply representing a hierarchical system of places.

Such pervasive centrality is more likely given that there are clear statistical differences between epochs when comparing mean and maxima values (Table 5). The table highlights how the period from 1890 to 1910 features the highest average values across all scales, but maxima values are inconsistent across epochs.

3.3. High street longevity and land-use diversity

The regression analyses reveal subtle yet significant associations between the age of high streets (measured in years) and a range of land-use and centrality variables (Table 6). Most notably, older high streets are associated with greater land-use diversity, both including and excluding residential uses (shan_res and shan_nores, respectively), with these associations being statistically significant ($p < 0.001$). However, the effect sizes are relatively small, indicating that while these relationships are statistically robust, the practical impact of high street age on land-use diversity is modest.

Table 6
Bivariate Linear Regression results between high street age and land-use/centrality variables.

Model	Variable	Predictor Coef	Std. Error	R^2	Adj. R^2	p-Value
1	shan_nores	0.001	0.000	0.034	0.033	***
2	shan_res	0.003	0.000	0.062	0.061	***
3	ai800_max	12.790	3.094	0.024	0.022	***
4	ac800_max	23.593	4.454	0.038	0.037	***
5	ai2k_max	14.85	12.48	0.002	0.000	##
6	ac2k_max	9.655	3.351	0.012	0.010	**
7	ai5k_max	−0.022	0.018	0.002	0.001	##
8	ac5k_max	0.246	0.145	0.004	0.003	#
9	ai10k_max	−0.014	0.008	0.005	0.003	#
10	ac10k_max	0.037	0.022	0.004	0.003	#

*** <0.001, ** <0.01, * <0.05, # <0.1, ## <1.

Similarly, the association between high street age and street network centrality varies with the radius of measurement. At a radius of 800 m, both integration (ai800_max) and choice (ac800_max) are significantly associated with the age of high streets, suggesting that high streets that are central within neighbourhood scales tend to be older. The effect size, however, remains modest. For example, with age as the independent variable, each additional decade in age leads to a 0.8 % increase in choice at a radius of 800 m (e.g., a 50-year-old high street would have 4 % higher values, while a 100-year-old high street would exhibit an 8 % increase). As the radius increases to 2 km, the association of the choice variable (ac2k_max) with high street age remains statistically significant but weak, while the integration variable (ai2k_max) shows no significant association. At larger radii (5 km and 10 km), the influence of centrality on high street age (ai5k_max, ai10k_max, ac5k_max, ac10k_max) is marginal and practically negligible.

The findings of the bivariate regression analyses indicated only few significant associations between high street age and land use diversity or centrality. While potential linear relationships are visible in scatter plots (see Fig. 6), there is a distinctive change visible in this relationship around the 130-year mark, namely high streets that emerged in 1890 – the decade with the highest spatial clustering concentration and a period of rapid urban growth. This shift points to a more complex relationship that may be influenced by the location of the high street within its urban conurbation, more than the age itself. While the analysis shows statistically significant correlations between high street age and land-use diversity and street network centrality, the influence of high street age on these factors is relatively limited, as indicated by the small effect sizes across all models. This suggests that other factors might also play critical roles in determining land-use diversity and the centrality of a high street to its age.

Table 5
Differences in centralities at varying scales for Great Britain, all high streets, and the four epochs. Reported values are logged means and maxima rounded to 3 digits for each group.

Variable	Great Britain	All HS	1840–1880	1890–1910	1920–1940	1950–present
ac800_max	19.465	19.258	18.718	19.258	18.100	18.835
ac2k_max	22.362	22.320	21.914	22.102	21.283	21.496
ac5k_max	25.505	25.505	25.364	25.047	24.557	24.552
ac10k_max	27.979	27.892	27.856	27.521	27.172	27.132
ai800_max	10.016	10.016	9.804	9.946	9.586	9.672
ai2k_max	11.230	11.163	11.163	11.077	10.814	10.792
ai5k_max	12.369	12.358	12.305	12.254	11.956	11.957
ai10k_max	13.210	13.205	13.142	13.080	12.919	12.918
ac800_mean	15.640	17.403	17.357	17.545	17.161	16.975
ac2k_mean	18.206	20.334	20.202	20.551	20.179	19.862
ac5k_mean	20.735	23.074	22.873	23.305	23.115	22.561
ac10k_mean	22.594	25.001	24.782	25.270	25.163	24.476
ai800_mean	8.080	9.050	9.013	9.146	8.976	8.862
ai2k_mean	9.348	10.215	10.164	10.320	10.164	10.116
ai5k_mean	10.571	11.280	11.194	11.397	11.250	11.258
ai10k_mean	11.463	12.045	11.937	12.128	12.057	12.044

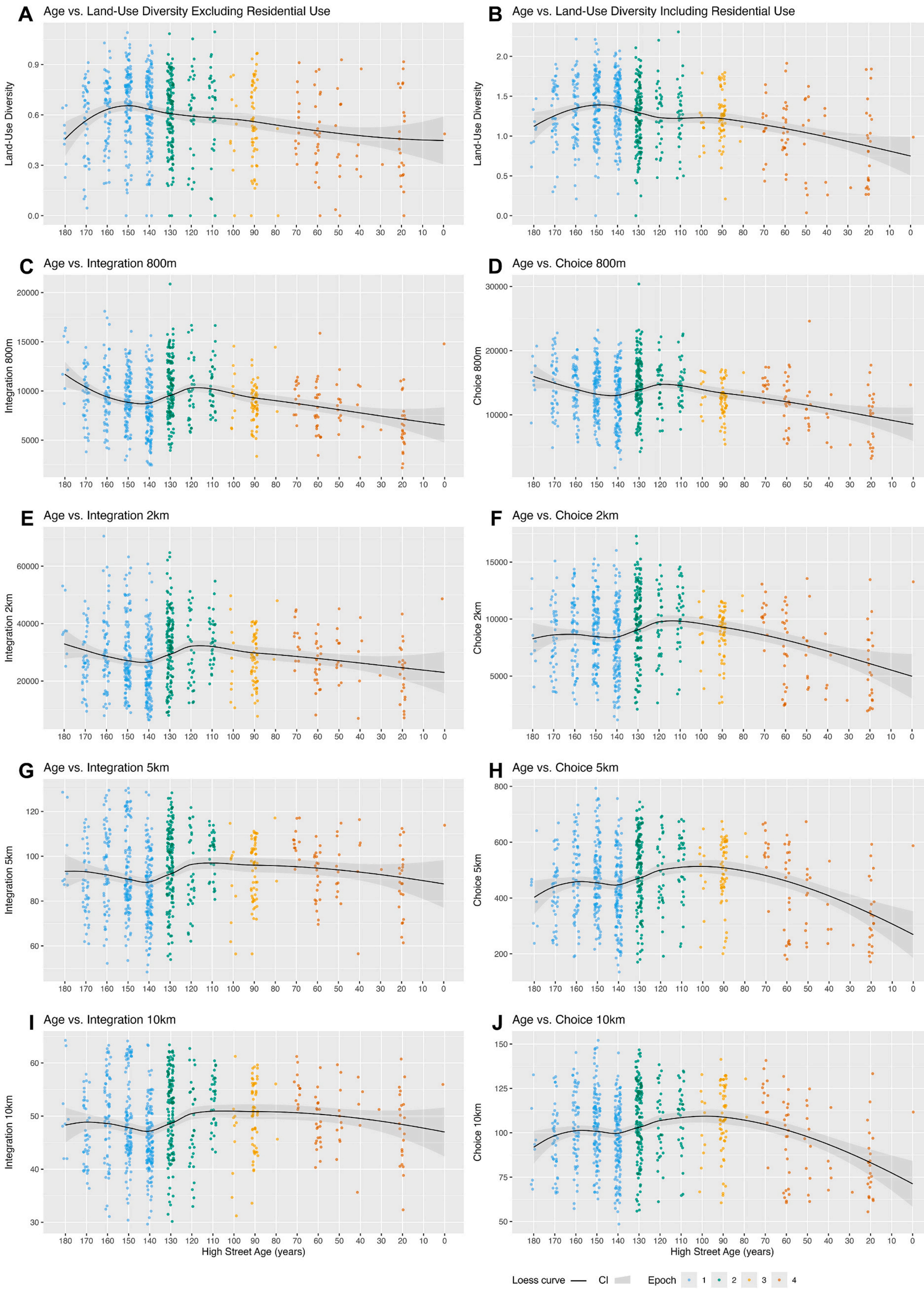

Fig. 6. Scatter plots for bivariate linear regression models, testing for associations between high street age and diversity and centralities at various scales. Colours represent classified epochs, and the black lines show a locally estimated scatterplot smoothing (LOESS) line highlighting general data trends. The gray shaded area around the fitted smoothing line represents the 95 % confidence interval, illustrating the range within which the true mean response is likely to lie with 95 % certainty.

It is important to note that the relationships identified in this study between high street longevity and built environment features are associational rather than causal. The methodology does not establish causation, so these associations should be interpreted as correlational findings, highlighting patterns without implying direct causal effects.

4. Conclusions

In this paper, we utilised a database of the location and size of nearly 7000 high streets extant in Great Britain today. We proposed and evaluated a method for estimating the year of high street emergence and used this to date >700 individual cases from the OS High Streets database. Using this dataset, we examined the role of built form, diversity, and centrality in high street longevity.

We tested two primary hypotheses: first, that high streets established at later stages have statistically significant differences in their urban form and function compared to those established earlier; and second, that high streets persisting for longer durations tend to have higher land-use diversity and maintain network centrality across varying spatial scales. The analysis confirmed the first hypothesis, revealing strong statistical differences between high streets of different temporal groupings. However, these differences cannot be solely attributed to the age of a high street. Instead, spatial location emerged as a crucial factor influencing built form, land-use diversity, and centrality characteristics. In other words, new high streets tended to emerge in similar types of geographies (e.g., within cities, city edges, or principal roads between cities) within the same epoch. Distinct temporal clustering patterns in high street emergence were also identified throughout the centuries, aligning with major historical epochs. There were distinctive phases when current-day high streets emerged, driven by social, economic, and technological progress, often transforming previously undeveloped or sparsely populated landscapes.

Regarding the second hypothesis, we found a significant association between high street age and both land-use diversity and neighbourhood-level centrality at walkable scales, suggesting that older high streets tend to be more integrated within their local urban fabric. However, the explanatory power of age alone remains modest, as the regression models do not account for other potentially influential factors. Despite this limitation, the findings indicate that high street age shows a notable relationship with the urban structure and centrality at small scales. At larger spatial scales, we did not find sufficient statistical evidence to support an association, indicating that any potential relationship may weaken or become less detectable as the spatial context broadens. Thus, the second hypothesis could only be partially confirmed.

The results indicate that planners may benefit from considering ways to support the local centrality of high streets, ensuring they remain vibrant hubs within their neighbourhoods. Given the weaker association at larger scales, planning approaches to broader scales of centrality should be context-dependent, considering additional socio-economic and infrastructural factors. Emphasising local, place-based strategies would allow urban regeneration efforts to align more closely with the historical and socio-spatial context of high streets. Additionally, recognising the "coral reef-like" adaptability of high streets, as described by Richard MacCormac (1996), underscores the importance of sustaining the enduring relationships between buildings, streets, and their neighbourhoods.

These findings suggest that the relationship between high street age and network centrality exists at neighbourhood scales, emphasising the historical development as a factor associated with the local central role of high streets. Although the effect sizes are modest, they reveal subtle but meaningful patterns that, when considered cumulatively, can inform more nuanced urban planning strategies. By understanding how high streets have historically adapted to socio-economic and spatial changes, planners can design interventions that preserve their resilience while addressing contemporary challenges.

High streets also benefit from flexibility in diversifying land uses, rather than being constrained by rigid use classes. Such diversity reduces dependency on any single type of user, enhancing resilience and adaptability. Our findings indicate that older high streets possess an embedded spatial ecology that supports this diversity, highlighting the importance of preserving the rich possibilities these spaces offer. This adaptability is not confined to the UK, as global evidence demonstrates similar patterns of high street diversity shaped by street network conditions.

However, contemporary planning deregulation, such as recent changes to commercial land-use classifications, introduces new dynamics that may not always align with historical adaptability. In England, for example, the introduction of Use Class E consolidates a broad range of commercial, business, and service uses into a single category, allowing greater flexibility in repurposing high street properties. Chng et al. (2024) critically examine the impact of such deregulation policies, particularly in London, finding that while they have accelerated housing delivery, this has come at the cost of residential amenity, environmental quality, and equitable access to green space – along with, crucially for our study, the broader social and economic functions that high streets provide.

Our study suggests that while greater land-use flexibility can enhance adaptability, it must be carefully implemented to account for local needs and prevent the erosion of high streets as vital socio-economic "ecosystems". As highlighted in a recent report (Hopkirk, 2020, cited in Carmona, 2021, p. 19), as well as retail activities high streets offer essential local services and public benefits, including employment, leisure, civic and social functions, which may be undermined by unchecked deregulation leading to uneven closure of facilities.

These findings reinforce the need for place-sensitive planning policies that balance flexibility with safeguards against negative externalities. While deregulation can support adaptation, it must be managed carefully to protect urban diversity and ensure that high streets continue to serve their essential public functions. Past planning approaches, which often relied on rigid land-use classifications or overlooked socio-spatial dynamics, require a more context-sensitive framework – one that maintains adaptability while preventing unintended consequences such as loss of key amenities within local centres.

Moreover, global examples from the US, Netherlands, Israel, and China reinforce the universal importance of street network conditions in shaping high street resilience, demonstrating that these findings hold relevance beyond the UK context. Ultimately, these insights can guide the development of high streets as resilient, inclusive, and sustainable urban spaces that adapt and thrive in the face of ongoing challenges.

At the start of this article, we highlighted the potential contribution of this study to research on local centres. As interest in evidence-based approaches to high street regeneration continues to grow, our findings reinforce the value of increasing mixed land uses and accessibility. As highlighted in a recent *Lancet Global Health* article, 'Creating healthy and sustainable cities: what gets measured, gets done,' such interventions are crucial for fostering healthier and more sustainable urban environments (Giles-Corti et al., 2022).

Future research may explore more complex multivariate modelling approaches, investigate differences in high streets based on location rather than time, and examine their relationships with local socio-economic, communal, and geographical factors. Furthermore, we aim to explore in greater detail how street configuration, built form, and land-use characteristics of high streets are sustained and evolve over time.

Limitations

There are two limitations worth highlighting: Firstly, the research is predicated on a pre-existing dataset of high streets, delineated by retail activities. This confines observations exclusively to the principal street and surrounding buildings of settlements, thus failing to encapsulate the broader active centre proximate to a high street. Secondly, there is an inherent potential for survivorship bias, which arises because our initial dataset did not include high streets that may have since disappeared. Survivorship bias refers to the distortion of results from only considering surviving subjects, in this case, we studied only high streets still in existence, which may not accurately represent all cases that existed over the past two centuries. However, we determine this effect to be small, with minimal impact on our overall findings.

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CRediT authorship contribution statement

Kimon Krenz: Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Investigation, Data curation, Conceptualization. **Laura Vaughan:** Writing – review & editing, Supervision, Methodology, Investigation, Conceptualization. **Sam Griffiths:** Writing – review & editing, Methodology, Investigation, Conceptualization.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data will be made available on request.

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