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Nationwide equity assessment of the 20-min neighbourhood in the scottish context: A socio-spatial proximity analysis of residential locations

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ABSTRACT

The 20-min neighbourhood (20 MN) is a method of designing neighbourhoods in such a way that individuals can meet the majority of their daily needs within a 10-min walk (therefore a 20-min return trip) of their home. The Scottish Government have committed to apply the 20 MN concept nationwide, focusing on disadvantaged communities.

The aims of this study were to: (1) create 20 MN catchment areas for health, transport, education, social and recreational domains; (2) describe the number of residential locations within 20 MN domain catchment areas; and (3) describe variation in access to 20 MN domains by area-level socioeconomic status and urbanicity.

20 MN catchment areas (800-m) were created for 10 domains using road and path network analysis. All Scottish residential locations (n:146,190) were plotted, assigned area-level socioeconomic status and urbanicity. A dichotomised (yes/no) variable was created to identify whether it was within a 10-min walk of individual 20 MN domains.

One in five residential locations had access to all 10 20 MN domains (Urban: 28%, Rural: 5%). There was variation in proportion of residential locations that has access to at least one facility by domains; 91% had access to at least one public transport stop and 84% a public open space. There was poorer access to primary care services (42%) and healthy food retailers (50%). Across all domains, access to at least one facility was greater within the most deprived areas.

Access to 20 MN domains was greatest in areas where individual health status tends to be worse. A policy focusing solely on improving access to key facilities and amenities for deprived areas may be ineffective in reducing health inequalities. Future studies should assess the quality of facilities and co-location with health damaging facilities, particularly within more deprived areas. Alternative policy approaches may be required for improving access to facilities and amenities for rural communities.

1. Introduction

It has been well established that area of residence affects health and the ability to lead a healthy life, after controlling for individual markers of income and social class (Diez Roux, 2001; Ellaway et al., 2001). Designing and creating healthy places is at the forefront of urban planning (Barton and Grant, 2013) and sits at the heart of many national and intergovernmental principles and policies, such as the United Nations Sustainable Development Goals (World Health Organization, 2016). The places we live, work and socialise hold significant importance in modern life and attention to it is essential for planners, policy makers and public health professionals (Hambleton, 2020). Creating a 'healthy place' is, in some senses, a holistic approach to creating a whole physical, social and institutional environment that supports health and healthy people (Forsyth, 2020).

The concept of a 20-min neighbourhood (20 MN) is receiving interest and strong policy support from local and national governments worldwide. At the end of 2020, 33 cities around the world had adopted or were considering adopting the 20 MN concept (Gower and Grodach, 2022). Whilst the specific wording differs internationally, the general concepts remain similar (Gower and Grodach, 2022). In Scotland, the 20 MN concept aims to achieve connected and compact neighbourhoods, designed so that people have access to essential daily facilities and amenities within a 10-min walk (800-m), in each direction, from

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their home (O' Gorman and Dillon-Robinson, 2021).

The 20 MN is rooted in a compact city approach that encourages the development of urban areas with short walking distances from residents home to access public transport, public open space and good destination accessibility to facilities and services for local daily living (Giles-Corti et al., 2016). Compact city designs are touted as beneficial for health. For example, modelling compact city scenarios for six global cities found its adoption would result in overall health gains of 420–826 disability-adjusted life-years per 100,000 population (Stevenson et al., 2016). 20 MN are not entirely about improving population health. They aim also to decrease health inequalities, as well as improve the local economy, improve liveable quality of life and reduce the impact of climate change (O' Gorman and Dillon-Robinson, 2021).

Improved neighbourhood connectivity and access to local destinations has been found to be important for both health and health inequalities. For example, deprived communities that have more walkable streetscapes, a more diverse land-mix and lower car ownership are associated with higher levels of active travel (Olsen et al., 2017) that may, in turn, reduce levels of and inequalities in chronic disease (Turrell et al., 2013). Since 2011, improvements in life expectancy in the United Kingdom (UK) have stalled and evidence suggests health inequalities are widening (Marmot, 2020). This highlights the need for a wider range of interventions that improve health and reduce inequalities. However, whilst the principles by which 20 MNs might affect health and inequalities are quite clear, the empirical evidence for their potential is rather mixed. For example, in the Liverpool City Region (UK), areas with the worst access to key facilities and amenities were often the most disadvantaged (Calafiore et al., 2022), but in Scotland access to a number of facilities and amenities for residents was more even across levels of deprivation, with the most deprived areas often having *better* access (Macintyre et al., 2008).

The adoption of the 20MN concept has largely been within specific towns and cities. To our knowledge, the 20MN has yet to be either assessed and implemented at a national scale or including both urban and rural communities. Scotland is unusual therefore in its aim (set out in the *Government Programme for Scotland 2020-2021* and *National Planning Framework: position statement)* to apply the concept of 20MNs across the whole country (Scottish Government, 2020a, b). The 20MN policy in Scotland will focus particularly on disadvantaged communities and specified facilities and amenities, including community, education, health and social care and sports and leisure facilities. The policy is ambitious by proposing the 20MN concept should be applied nationally, with the caveat that varying geographical scales may be needed for urban and rural environments (Scottish Government, 2020a). In particular, given the challenges faced by rural Scotland in access to health care, shopping facilities, and public transport (Velaga et al., 2012), it will be important to explore urban/rural variation in 20MN provision (Allam et al., 2022) and describe how variation in the geographical scale of the 20MN catchment area influences accessibility.

The relationship between deprivation and access to facilities and amenities may also be related to urbanicity. The most socioeconomically deprived populations in economically developed countries are often located in densely populated towns or cities, but these areas often have a greater density and range of destinations. Exploring equality in access to services within a 20 MN should take account of both deprivation and urbanicity (Lamb et al., 2010).

Scotland currently has no baseline measure by which to assess what 20 MN (800 m) catchment areas currently provide in urban or rural areas. This is not unusual. Gower and Grodach (2022) in their global review of 20 MN operationalisation found that the majority of cities lacked specificity and clarity in terms of measurable and well-defined planning targets or measurable policy benchmarks in relation to the 20 MN policy. As highlighted by Thornton et al. (2022), without defining or operationalising the 20 MN it will be difficult to implement, monitor and quantify the benefits of this policy.

Here we aim to define key domains of the 20 MN within the Scottish policy context. Using these data, we will provide a benchmark of the number of residential locations that have access to each domain within their local neighbourhood.

1.1. Aims and objectives of this study

1. Create 20 MN's catchment areas for health, transport, education, social and recreational domains.
2. For all Scottish residential locations, describe access to each domain within their local neighbourhood.
3. For all Scottish residential locations, examine access to all 10 domains which constitute the 20 MN together.
4. Describe variation in access to 20 MN domains for residential locations by area-level socioeconomic status and urbanicity.
5. Explore the effect of an increased accessibility catchment area for residential access to key facilities and amenities by urban/rural location and socioeconomic status.

2. Materials and methods

2.1. Setting and spatial extent

This study considered access to 20 MN domains for residential locations across the entire spatial extent of Scotland, a country and devolved administration within the UK. Scotland has a population of 5.4 million and covers an area of 77,911 km^2 (National Records of Scotland, 2021). Scotland consists of a number of large metropolitan cities, such as Glasgow and Edinburgh, remote rural areas and a number of populated islands; the majority of Scotland's population live within settlements (built-up areas which round to 500 people or more), which account for just over 2% of Scotland's area. Greater Glasgow is the largest settlement and represents over 20% of Scotland's total population (National Records of Scotland, 2018).

2.2. Defining the 20 MN domains and attributes

The 20 MN domains were drawn from the Scottish Government national planning framework (Scottish Government, 2020a), the Place Standard (Hasler, 2018), recent literature describing operationalising of the 20 MN (Calafiore et al., 2022; Thornton et al., 2022) and consultation with a group of representatives from Architecture and Design Scotland (an executive Non-Departmental Public Body), government policy, public health and third-sector organisations. The consultation comprised a series of presentations to members of these organisations, feedback on its development and recommendations for further iterations. The domains were chosen to align specifically with government policy in Scotland that stipulates community, education, health and social care and sport and leisure facilities should be easily accessible to the communities that they are intended to serve and to focus on mixed land use for communities who face more disadvantage (Scottish Government, 2020a).

Following the evidence informed co-production outlined above, ten 20 MN domains were defined: 1) healthy food retail; 2) public transport (including frequent public transport); 3) local primary health care facilities; 4) education; 5) financial; 6) community health resources; 7) accessible public open space; 8) recreational, sports pitches and facilities; 9) social and cultural; and 10) eating establishments. The details of the attributes, justification for inclusion and access measures are described within Table 1.

The domains and attributes were chosen based on facilities and amenities that individuals are likely to access daily for food, transport, health care, education, recreation, social and leisure activities. To capture eating establishments we excluded unhealthy retailers such as fast food restaurants, pubs and bars. For public transport we created two outcomes to measure the presence of a transportation stop and whether this was a high frequency route, which had five or more stops an hour

Table 1
20 min neighbourhood domains and source.

Domain	Attributes	Justification	Access measure	Source
Healthy food retail	- Large supermarket (for example, ASDA). - Medium sized supermarket chains (for example Tesco Metro, Sainsbury's Local).	Large and medium sized supermarkets provide a large range of healthy and fresh food items at a reasonable and affordable price, compared to smaller convenience stores or 'corner' shops. All large supermarkets were classified by Ordnance Survey. Medium sized national chain supermarkets (for example Tesco Metro, Morrisons Daily or Sainsbury's Local) were extracted from Ordnance Survey POI.	Binary 'Yes' if contains either a 'Supermarket' ***OR*** a 'medium sized supermarket'.	Point of interest (Dec 2021) (Ordnance Survey, 2021b)
Public Transport	- Bus stop	*Bus, light trail, tram, metro and underground stations* provide access to transport to travel for work, education and social reasons. The mix of transport stops were included to reflect the diversity of transport infrastructure across Scotland.	(1) Binary 'Yes' if contains ***any*** 'Public Transport Stop'.	Point of interest (Dec 2021) (Ordnance Survey, 2021b)
	- light rail. - tram.	*High frequency stops* are those that had five or more stops an hour. Passengers tend not to look at a timetable before arriving and are suggested as one factor for encouraging modal shift in transport methods (Government Office for Science, 2019).	(2) Binary 'Yes' if contains a high frequency public transport stops (≥5 transit movements at a stop per hour between the hours of 6am and 9pm) (Transport for London, 2020)	National public transport access node (NaPTAN) (NHS, 2021), Department for Transport for London (2020)
	- metro. - Underground stop locations..			Traveline National Dataset (TNDS), Traveline Information Lamb et al. (2010)
Primary Health Care	- General Practitioner (GP) surgery. - National Health Service (NHS) walk-in-centre.	NHS services are provided free of charge for all persons living in Scotland. The GP is usually the main point of access to medical care. 'Walk-in-centres' provide access to urgent medical attention where it is not a life-threatening situation. This includes many of the condition's individuals will visit their GP, such as a sore throat, emergency contraception, ear infection, skin condition, coughs, and colds (NHS, 2021). Therefore, both a GP and 'walk-in-centre' were included as they provide access to similar non-emergency and local primary care services.	Binary 'Yes' if contains a 'Primary care (GP)' ***OR*** a 'Walk-in-Centre'	Point of interest (Dec 2021) (Ordnance Survey, 2021b)
Community health resources	- Pharmacy.	Pharmacies in Scotland provide the dispensing of prescribed medications and a range of additional minor illness services. For example, all pharmacies that dispense NHS prescriptions provide NHS Pharmacy First Scotland services which give advice, treatment, and referrals for minor illnesses.	Binary 'Yes' if contains a 'Pharmacy'	Point of interest (Dec 2021) (Ordnance Survey, 2021b)
Education	- Primary school (Age 4–11 years).	Primary schools in Scotland are localised whereas, particularly in less urban areas, secondary school children will be expected to use motorised transport to travel to their school, which is often sited in a central location. There are 1975 primary schools in Scotland and 357 secondary schools. Although there is no specific policy of how far pupils should live from a school, there is free school transport for children living over specific distance. This differs for primary and secondary schools. For example, free transport is provided if a primary school child lives more than 1 mile (1600 m) from their school and 2 miles for secondary school children (3200 m) (Scottish Government, 2021).	Binary 'Yes' if contains 'Primary school (Age 4–11 years)'.	Point of interest (Dec 2021) (Ordnance Survey, 2021b)
Financial	- Cash machines, - Banks and building societies. - Post offices.	Bank branches, building societies, post offices and ATMs (cash machines) are all described as being methods for accessing cash and financial services in-person (House of Commons Library, 2022b). Many bank services are now available, and largely accessed, online. However, access to cash remains important, particularly for people on lower income, older people, those with certain physical and mental	Binary 'Yes' if contains either a 'Cash Machine' ***OR*** a 'Bank' ***OR*** a 'Post office'.	Point of interest (Dec 2021) (Ordnance Survey, 2021b)

(*continued on next page*)

Table 1 (*continued*)

Domain	Attributes	Justification	Access measure	Source
		health problems, those managing their spend, people who rely on others to buy them things and people who live in areas with poor digital connectivity (House of Commons Library, 2022a). UK Finance published a voluntary 'Access to Banking Protocol' signed by the UKs 12 largest banks, stating that from December 2021 it would commission services to meet the cash needs of the community as a whole. Highlighting the importance of bank branches, building societies, post offices and ATMs (cash machines) as being methods for accessing cash and financial services in-person.		
Accessible public open spaces	- Public Park or Garden access points. - Playing field access points. - Play space access points.	The access points for public open spaces were included. From the OS Open Greenspace spatial data layer, we selected access points for public park or gardens (areas of land designed, constructed, managed and maintained as a public park or garden), playing fields (large, flat areas of grass or specially designed surfaces, generally with marked pitches, used primarily for outdoor sports) and play spaces (a specially prepared area intended for children's play, usually linked to housing areas or parks and containing purpose-built equipment).	Binary 'Yes' if contains a 'Public Open Space Access Point'	Open Greenspace (Ordnance Survey, 2021a)
Recreational, sports pitches and facilities.	- Athletics facilities; Golf ranges, courses, and clubs; Sports grounds, stadia, and pitches; swimming pools; and tennis facilities Gymnasiums, sports halls, and leisure centres. - Athletics facilities; Golf ranges, courses, and clubs; Sports grounds, stadia, and pitches; swimming pools; and tennis facilities Athletics facilities; Golf ranges, courses, and clubs; Sports grounds, stadia, and pitches; swimming pools; and tennis facilities	The presence of a gymnasium, sports hall, leisure centre and a range of specific sports facilities and pitches were used as indicators of recreational, sports pitches and facilities. Leisure centres and swimming pools were included separately as not all leisure centres have a swimming pool and not all swimming pools are within leisure centres.	Binary 'Yes' if contains ***any*** of: 'Recreational, sports pitches and facilities'	Point of interest (Dec 2021) (Ordnance Survey, 2021b)
Social and cultural locations	- Gallery; Historic buildings; Museum; Theatre; Cinema; Social clubs; Library; and Places of worship	We provided a range of destinations that provide opportunities for social and cultural activities. This was based on evidence that better spatial access to cultural destinations such as museums and galleries is associated with increased use (Brook, 2016). We included heritage sites, such as historic buildings (including castles, forts and abbeys), as recent evidence has shown a similar relationship (L Macdonald et al., 2022). Social clubs can act as key community spaces, particularly in rural areas, where rooms may be available to rent for community activities.	Binary 'Yes' if contains ***any*** of: 'social and cultural'	Point of interest (Dec 2021) (Ordnance Survey, 2021b)
Eating establishments	- Restaurants - Cafes.	To define eating establishments, we included all non-fast food premises in the physical food environment serving food prepared out-of-home for either on or off premises consumption. This included both restaurants and cafes (POI name: café, snack bar or tea room). We excluded unhealthy retailers such as fast food restaurants, pubs and bars.	Binary 'Yes' if contains ***any*** of: 'eating establishments'.	Point of interest (Dec 2021) (Ordnance Survey, 2021b)

Note: Road and path network analysis was used to provide spatial distances between facilities and amenities. This is described within Section 2.5.1 Defining accessibility to 20 MN domains for Scottish residential location.

(Transport for London, 2020) (full method in Supplementary Table 1). High frequency stops are where passengers tend not to look at a timetable before arriving and are suggested as one factor for encouraging modal shift in transport methods (Government Office for Science, 2019). Including high frequency stops allowed us to conduct a sensitivity analysis of accessibility using a 'quality' measure of that domain from an objective nationally validated dataset.

2.3. Residential locations

Scottish residential locations were obtained from Code-Point Open, a dataset provided by the mapping agency of Great Britain (Ordnance Survey) that contains precise geographical point locations to represent all UK postal addresses (postcodes). The Scottish residential location we used is a single point for a postcode, postcodes are the smallest plotted areal unit in Scotland and on average there are 15 delivery points per postcode (range 1–100 (National Records of Scotland, 2013)). For Code-Point Open, the total number of residential dwellings within Scotland was 2.67 million with a median of 14 dwellings within a postcode point. The geocode of the unit postcode is the coordinates of the nearest delivery point to the calculated mean position of the delivery points within the postcode unit (this is the notional position of the postcode) (Ordnance Survey, 2019). In total there were 158,080 postcode points across Scotland, we excluded postcodes that did not include a residential location resulting in a total of 146,190 residential locations in Scotland included in the subsequent analysis.

2.4. Contextual information: socioeconomic status and urban/rural location

Socioeconomic status: Each residential location was assigned the income deprivation quintile of the datazone within which it was located. Datazones are small areal units used in the production of official statistics in Scotland. They contain populations of between 500 and 1000 household residents (Scottish Government, 2006). Deprivation quintile was assigned using the Income Domain of the 2020 Scottish Index of Multiple Deprivation (SIMD) (Scottish Government, 2020c). The Income Domain measures low income as indicated by the receipt of government benefits and was chosen over the full SIMD as that includes an element of geographical and facility accessibility, which may have biased our results.

Urban/rural location: Each residential location was assigned an urban or rural classification based on the datazone within which it was located. For this study, a datazone was classified as 'urban' or 'rural' using the Scottish Government core definition of rurality that classifies areas with a population of fewer than 3000 people to be rural. We used the Government's Urban Rural lookup table to create a two-fold urban rural classification; Urban: settlements of 3000 people or over and Rural: settlements of 2999 people or less (Scottish Government, 2018).

2.5. Spatial analysis

2.5.1. Defining accessibility to 20 MN domains for Scottish residential location

20 MN catchment areas were created for each of the 10 domains (two for public transport as frequent public transport was measured separately) within the Network Analyst extension (ArcGIS Pro 2.9.2) using the road and path network (Integrated Transport Network (ITN) Layer, OS MasterMap). One-way and turn restrictions on streets were removed to better model pedestrian travel. We created catchment areas surrounding the location of each domain (i.e. a public transport stop) and identified if a residential location was within that catchment area, as it was computationally more efficient and yielded the same results as opposed to creating catchment areas for each residential location.

800-m (m) network catchment areas were created surrounding the location of each individual domain location and a single 20 MN catchment area was created by domain. We also created a 1200 m catchment area to conduct a sensitivity analysis of the impact of extending the 20 MN to a 30 MN. This was because the Scottish Government policy described that the 20 MN principle could be adjusted to include allow for different geographical settings (Scottish Government, 2020a). Each residential location was then plotted within ArcGIS Pro 2.9.2 and a dichotomised (yes/no) variable was created to identify whether the residential location was within the road and path catchment area for each individual domain using 800 m and 1200 m buffers.

To illustrate access to each domain which constitute the 20-min neighbourhood all residential locations across Scotland were converted from points to a raster surface. The rasterization process was conducted for a cell size of 500m2 for a national level and 50m2 at city level. Values were assigned based on the most frequent total number of domains within 800 m of residential locations using the Point to Raster conversion tool within ArcGIS Pro v2.9.3.

2.6. Statistical analysis

2.6.1. Descriptive analysis

Summary statistics described the total number of domain features, and number and proportion of Scottish residential locations that were within an 800 m catchment area for each 20 MN domain, assessing variation by the residential locations' socioeconomic status and urban/rural classification. The analysis was at the residential location level. This determined, for each individual residential location, whether each of the 20 MN domains was within an 800 m road and path network distance. We then assigned two area-level variables to the individual residential locations to determine the Urban/Rural classification and socioeconomic status.

Using the residential dwelling count within each individual residential location, the rate per 100,000 residential dwelling with access to each domain was calculated overall and by urban/rural locations.

We explored access to each domain individually and also whether residentially locations had access to all 20 MN domains. For each residential location, the total number of domains available within 800 m was calculated. This was computed separately for public transport stops (Table 3) and high-frequency public transport stops (Supplementary Table 2).

2.6.2. Variation by socioeconomic status and urban/rural location

Logistic regression models were performed to examine the association between socioeconomic status and the likelihood of a residential location being within a 20 MN catchment area by each domain, with residential locations clustered within datazones. The total number of datazones was 6505 containing a median of 20 residential locations (range 2–183). Model-adjusted prevalence was then computed using marginal standardisation with predicted marginal probabilities (Muller and MacLehose, 2014) to compare prevalence of residential locations being within a 20 MN catchment area across deprivation quintiles. Models were run separately for each 20 MN domain and are presented in Fig. 2 with 95% Confidence Intervals (CI). A linear prediction was estimated and plotted to highlight the slope of inequality in the predicted probabilities of residential locations being located within a 20 MN for each domain. All analysis were run separately for urban and rural residential locations.

3. Results

3.1. Access to 20 MN domains within a 10-min walk of Scottish residential locations

There was variation by 20 MN domains in the number and proportion of residential locations that had access to at least one facility within a 10-min walk (Table 2). 91% (n:133,301) of residential locations had access to at least one public transport stop, this decreased by 34% (to

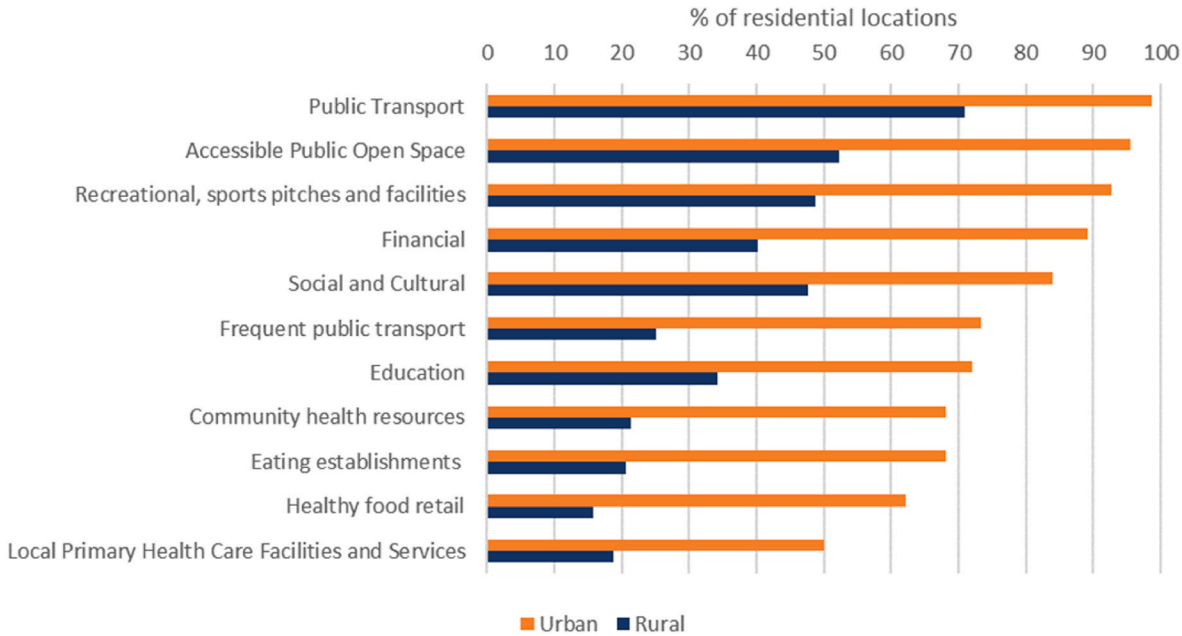

Fig. 1. Variation in access to at least one facility within a 10-min walk by Urban/Rural residential location.

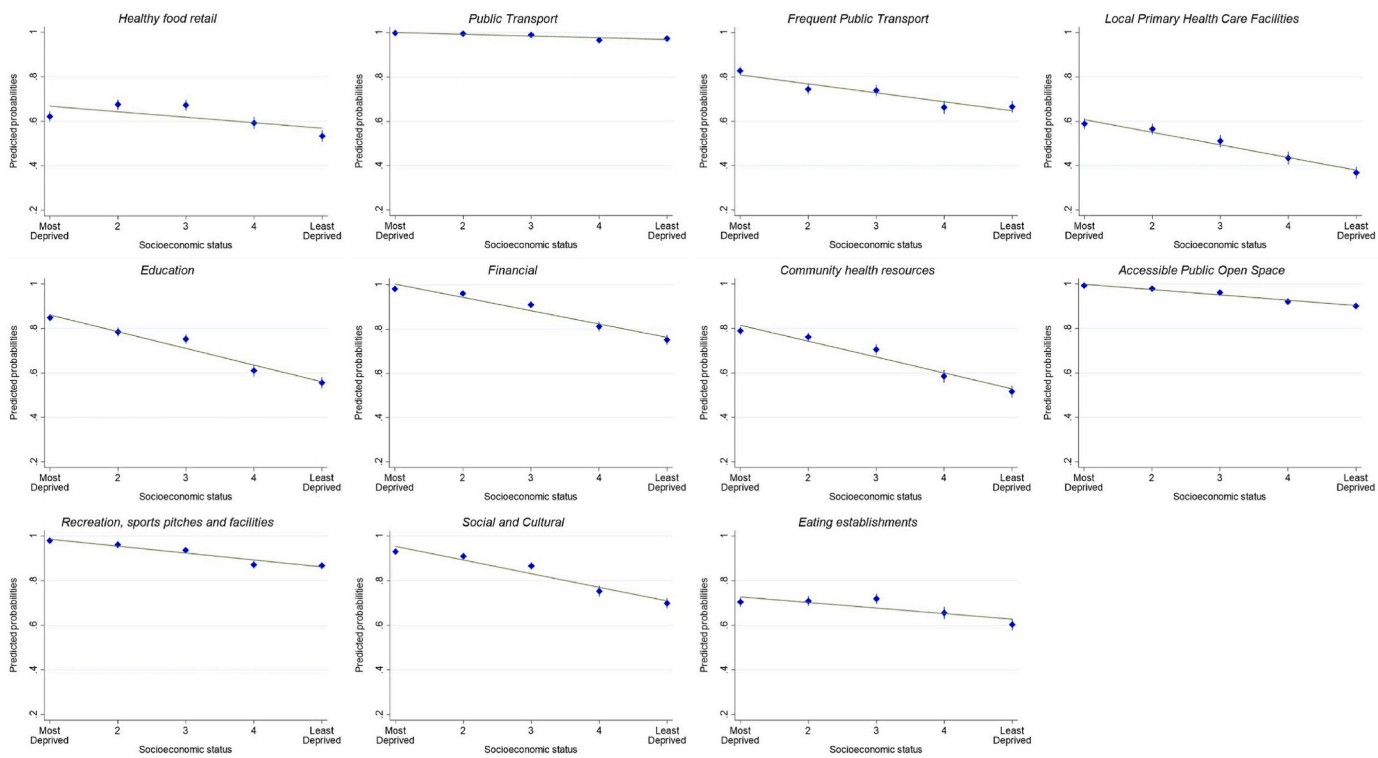

Fig. 2. Predicted prevalence of *Scottish residential locations with* access to at least one facility within a 10 min walk by socioeconomic status (Urban areas only). Note: Confidence intervals (CI) are plotted but not visible due to narrow range. Graph line presents the regression slope between predicted probabilities and socioeconomic status clustered by datazone. Figure for Rural locations only shown in Supplementary Fig. 1.

60%) for high-frequency public transport stops. Access to public open space was also high with 8 in 10 residential locations within a 10-min walk. The domains with the lowest proportion of residential locations within a 10-min walk of at least one facility were: primary care services (42%), healthy food retailers (50%), eating establishments (55%) and community health resources (56%).

3.2. Access to 20 MN domains within a 10-min walk of Scottish residential locations by urban/rural location

There was variation in access to at least one facility within a 10-min walk by the residential locations' urban/rural status (Fig. 1). For example, 62% of urban residential locations were within 10-min walk of healthy food retail, but it was just 16% of rural residential locations. Primary health care facilities showed the worst access for both urban

Table 2
Access to at least one facility within a 10-min walk of residential locations (n = 146,190) by urban and rural location.

20 MN Domain	Number of domain features			Number (%) of residential locations with access to domain			Residential dwellings with access to domain (rate per 100,000)		
	Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total
Healthy food retail	1167	166	1333	66,562 (62.2%)	6211 (15.9%)	72,773 (49.8%)	13.6	1.0	14.6
Public Transport	31,071	18,458	49,529	105,550 (98.6%)	27,751 (70.9%)	133,301 (91.2%)	21.5	4.1	25.7
Frequent public transport	6519	2278	8797	78,577 (73.4%)	9806 (25.1%)	88,383 (60.5%)	16.2	1.5	17.7
Local Primary Health Care Facilities and Services	773	283	1056	53,640 (50.1%)	7347 (18.8%)	60,987 (41.7%)	11.0	1.1	12.2
Education	1185	789	1974	77,151 (72.1%)	13,394 (34.2%)	90,545 (61.9%)	16.2	2.1	18.3
Financial	5240	1184	6424	95,401 (89.1%)	15,687 (40.1%)	111,088 (76.0%)	19.6	2.5	22.1
Community health resources	1124	198	1322	72,943 (68.1%)	8326 (21.3%)	81,269 (55.6%)	14.9	1.3	16.3
Accessible Public Open Space	14,718	5213	19,931	102,187 (95.5%)	20,453 (52.3%)	122,640 (83.9%)	21.0	3.3	24.3
Recreation, sports pitches and facilities	6940	3845	10,785	99,340 (92.8%)	19,041 (48.7%)	118,381 (81.0%)	20.3	3.0	23.3
Social and Cultural	4252	5717	9969	89,893 (84.0%)	18,658 (47.7%)	108,551 (74.3%)	18.3	2.8	21.2
Eating establishments	5174	700	5874	72,915 (68.1%)	8098 (20.7%)	81,013 (55.4%)	14.7	1.2	16.0
Total	78,163	38,831	116,994	107,058	39,132	146,190	21.2	5.1	26.7

and rural locations (51% urban; 19% rural).

3.3. Access to 20 MN domains within a 10-min walk of Scottish residential locations by area-level socioeconomic status

Fig. 2 presents the predicted prevalence of access to at least one facility within a 10-min walk to by socioeconomic status for urban residential locations only (Rural locations shown in Supplementary Fig. 1). Across all domains, prevalence of access to at least one facility was highest within the most deprived areas compared to the least deprived areas. The difference in prevalence varied by domain for urban areas; access to public transport (most deprived: 99%; least deprived: 97%) and accessible public open spaces (most deprived: 99%; least deprived: 90%) had both the greatest access and smallest prevalence difference. Community health resources (most deprived: 79%; least deprived: 52%) and primary care (most deprived: 59%, least deprived: 37%) had both the worst access and largest prevalence difference.

One in five Scottish residential locations (21%, n:31,419) had access to all 10 domains within a 10-min walk (Table 4). Fig. 3 illustrates these data for Scotland and its four largest cities (Glasgow City, City of Edinburgh, Dundee City and Aberdeen City) highlighting the variation in access to each domain between large cities and rural areas of Scotland. There was variation for residential locations having access to all 20 MN domains by urban/rural areas (Urban: 28%; Rural: 5%) and between the most and least income deprived areas (described for urban areas only, data for rural areas provided in Supplementary Table 3) (most deprived: 33%; least deprived: 18%). For urban areas, almost two thirds (65%) of residential locations had access to 8 or more domains, in contrast a quarter of rural locations had access to zero domains and half (47%) had access to less than 3 (see Table 4).

3.4. Difference in access to domains within a 30 MN

Table 5 shows that extending the 20 MN definition to a 30 MN (from a 10-min to 15-min walk) gave a 95% increase in residential locations that have access to all domains (20 MN: 21%, 30 MN: 41%). The increased catchment area provides the greatest increase in access outcome for urban areas, where the proportion of residential locations having access to all 10 domains increased from 28% to 53%. For rural areas, the proportion of residential locations having access to all domains did show a sizable increase, albeit from a very small base of 5%, to 9%.

4. Discussion

The primary aim of this study was to create 20 MN catchment areas for health, transport, education, social and recreational domains and, for all Scottish residential locations, describe access to each 20 MN domain within a 10-min walk. The secondary aims were to describe variation in access to 20 MN domains by area-level socioeconomic status and urbanicity. The final aim was to explore the effect of expanding the 20 MN catchment from 800 m to 1200 m to create a 30 MN.

Overall, 21% (n: 31,419 of 146,190) of residential locations had access to all 10 domains. This varied considerably by urban (28%) and rural (5%) location and area-level socio-economic status (most deprived: 33%; least deprived: 18%). There was variation by individual domains; less than half of residential locations were within a 10-min walk of at least one primary care facility (42%) and access was also poor for healthy food retail (50%), eating establishments (55%) and community health resources (56%). In contrast, almost 9 in 10 residential locations were within a 10-min walk of at least one public transport stop or public open space access point.

Expanding the defined access area from 800 m to 1200 m to create 30 MN s increased the proportion of residential locations that have access to all domains by 95% (20 MN: 21%; 30 MN: 41%); the increase being greater for urban areas (20 MN: 28%, 30 MN: 53%) compared to rural areas (20 MN: 5%, 30 MN: 9%). Whilst the absolute percentage increases between urban and rural areas are similar, the relative increase is greater in urban areas (Urban: 94%, Rural: 76%). The much smaller gain in rural locations is important to note because these are the areas that different definitions of access area would be seeking to benefit most.

4.1. Comparison with other literature

A number of studies have explored variation in access to a range of facilities and amenities within mostly urban settings (Gower and Grodach, 2022). Boakye-Dankwa et al. (2019) compared perceived accessibility to a number of services or facilities within a 10-min walk from home for residents in Brisbane and Hong Kong. Their finding that approximately 9 in 10 residents within both cities reported a public transport stop within a 10-min walk was similar to our study and others from Australia (Thornton et al., 2022). Approximately three quarters of the Hong Kong (73%) and Brisbane (77%) residents also reported residing within a 10-min walk to a public park. This was similar to objectively measured proximity to public open space in Melbourne (73.2%) and Adelaide (76.1%) (Thornton et al., 2022). In Scotland, we found that 96% of urban and 84% of all residential locations were within a 10-min walk of the more broadly defined '*any publicly accessible open space*'. The objective measure of proximity to open space here also echoes national survey data from Scotland in which 87% of residents reported living within a 10-min walk of greenspace (Olsen et al., 2022). Although these figures are all broadly similar, context specific variation in accessibility to facilities and amenities is highly likely and should be assessed when operationalising the 20 MN.

We found that the most deprived areas of Scotland had better access to all ten 20 MN domains compared to the least deprived areas. This

Table 3
Access to at least one facility within a 10-min walk of residential locations (n = 146,190) by socioeconomic status.

20 MN Domain	Number of domain features						Number (%) of residential locations with access to domain						Residential dwellings with access to domain (rate per 100,000)					
	Most deprived	2	3	4	Least deprived	Total	Most deprived	2	3	4	Least deprived	Total	Most deprived	2	3	4	Least deprived	Total
Healthy food retail	183	268	279	298	305	1333	15,411 (61.1%)	17,140 (62.3%)	15,608 (51.1%)	12,569 (36.7%)	12,045 (42.1%)	72,773 (49.8%)	3.4	3.4	3.0	2.4	2.2	14.6
Public Transport	6534	6559	10,211	13,508	12,717	49,529	25,159 (99.8%)	26,986 (98.0%)	27,909 (91.4%)	28,007 (81.67%)	25,240 (88.2%)	133,301 (91.18%)	5.6	5.4	5.2	4.9	4.5	25.7
Frequent public transport	1463	1319	1572	1893	2550	8797	20,481 (81.24%)	19,346 (70.28%)	17,759 (58.14%)	15,205 (44.3%)	15,592 (54.5%)	88,383 (60.5%)	4.6	3.9	3.5	2.8	2.9	17.7
Local Primary Health Care Facilities and Services	215	187	266	245	143	1056	14,806 (58.7%)	15,124 (54.9%)	12,856 (42.1%)	9890 (28.8%)	8311 (29.0%)	60,987 (41.7%)	3.3	3.0	2.5	1.9	1.5	12.2
Education	294	337	429	523	391	1974	21,234 (84.2%)	21,034 (76.4%)	19,419 (63.6%)	15,501 (45.2%)	13,357 (46.7%)	90,545 (61.9%)	4.8	4.3	3.8	2.9	2.5	18.3
Financial	1328	1355	1376	1300	1065	6424	24,679 (97.9%)	25,581 (92.9%)	23,451 (76.8%)	19,735 (57.6%)	17,642 (61.7%)	111,088 (76.0%)	5.5	5.2	4.5	3.7	3.3	22.1
Community health resources	276	297	269	255	225	1322	19,733 (78.3%)	19,915 (72.3%)	16,873 (55.2%)	13,063 (38.1%)	11,685 (40.8%)	81,269 (55.6%)	4.4	4.0	3.3	2.4	2.1	16.3
Accessible Public Open Space	2662	3173	3865	4691	5540	19,931	24,991 (99.1%)	26,320 (95.6%)	25,556 (83.7%)	23,680 (69.1%)	22,093 (77.2%)	122,640 (83.9%)	5.6	5.3	4.9	4.4	4.1	24.3
Recreation, sports pitches and facilities	1136	1634	2091	2985	2939	10,785	24,617 (97.7%)	25,687 (93.3%)	24,715 (80.9%)	22,251 (64.9%)	21,111 (73.8%)	118,381 (81.0%)	5.5	5.2	4.7	4.0	3.8	23.3
Social and Cultural	819	1140	2433	3471	2106	9969	23,343 (92.6%)	24,441 (88.8%)	23,434 (76.7%)	20,291 (59.2%)	17,042 (59.6%)	108,551 (74.3%)	5.2	4.9	4.4	3.6	3.0	21.2
Eating establishments	666	940	1280	1602	1386	5874	17,349 (68.8%)	18,227 (66.2%)	17,203 (56.3%)	14,594 (42.6%)	13,640 (47.7%)	81,013 (55.4%)	3.9	3.6	3.3	2.7	2.5	16.0
Total	15,576	17,209	24,071	30,771	29,367	116,994	25,209	27,528	30,544	34,291	28,618	146,190	5.6	5.4	5.4	5.4	4.8	26.7

Table 4
Access to 20 MN domains for Scottish residential locations by urbanicity and socioeconomic status.

Number of domains within 800 m of residential locations	All Scottish residential locations (n = 146,190)		Urban (n = 107,058)		Rural (n = 39,132)		1 (most deprived)* (n = 24,401)		2 (n = 24,070)		3 (n = 20,230)		4 (n = 17,764)		5 (least deprived) (n = 20,593)	
	n	%	N	%	n	%	n	%	n	%	n	%	n	%	n	%
0 domains	10,079	6.9	938	0.9	9141	23.4	21	0.1	76	0.3	138	0.7	392	2.2	311	1.5
1 domain	7029	4.8	1089	1.0	5940	15.2	38	0.2	98	0.4	191	0.9	391	2.2	371	1.8
2 domains	5041	3.5	1671	1.6	3370	8.6	34	0.1	119	0.5	237	1.2	507	2.9	774	3.8
3 domains	5241	3.6	2774	2.6	2467	6.3	109	0.5	204	0.9	402	2.0	775	4.4	1284	6.2
4 domains	6982	4.8	4501	4.2	2481	6.3	374	1.5	496	2.1	684	3.4	1106	6.2	1841	8.9
5 domains	8516	5.8	5922	5.5	2594	6.6	739	3.0	901	3.7	1101	5.4	1321	7.4	1860	9.0
6 domains	12,233	8.4	9034	8.4	3199	8.2	1947	8.0	1866	7.8	1540	7.6	1529	8.6	2152	10.5
7 domains	14,189	9.7	11,213	10.5	2976	7.6	2661	10.9	2551	10.6	1821	9.0	1756	9.9	2424	11.8
8 domains	18,854	12.9	16,229	15.2	2625	6.7	4280	17.5	3995	16.6	3069	15.2	2256	12.7	2629	12.8
9 domains	26,607	18.2	24,182	22.6	2425	6.2	6246	25.6	6212	25.8	4759	23.5	3633	20.5	3332	16.2
10 domains (All 20 MN domains)	**31,419**	**21.5**	**29,505**	**27.6**	**1914**	**4.9**	**7952**	**32.6**	**7552**	**31.4**	**6288**	**31.1**	**4098**	**23.1**	**3615**	**17.6**

Note: *Urban residential locations only (n = 107,058), data for rural residential locations provided in Supplementary Table 3.

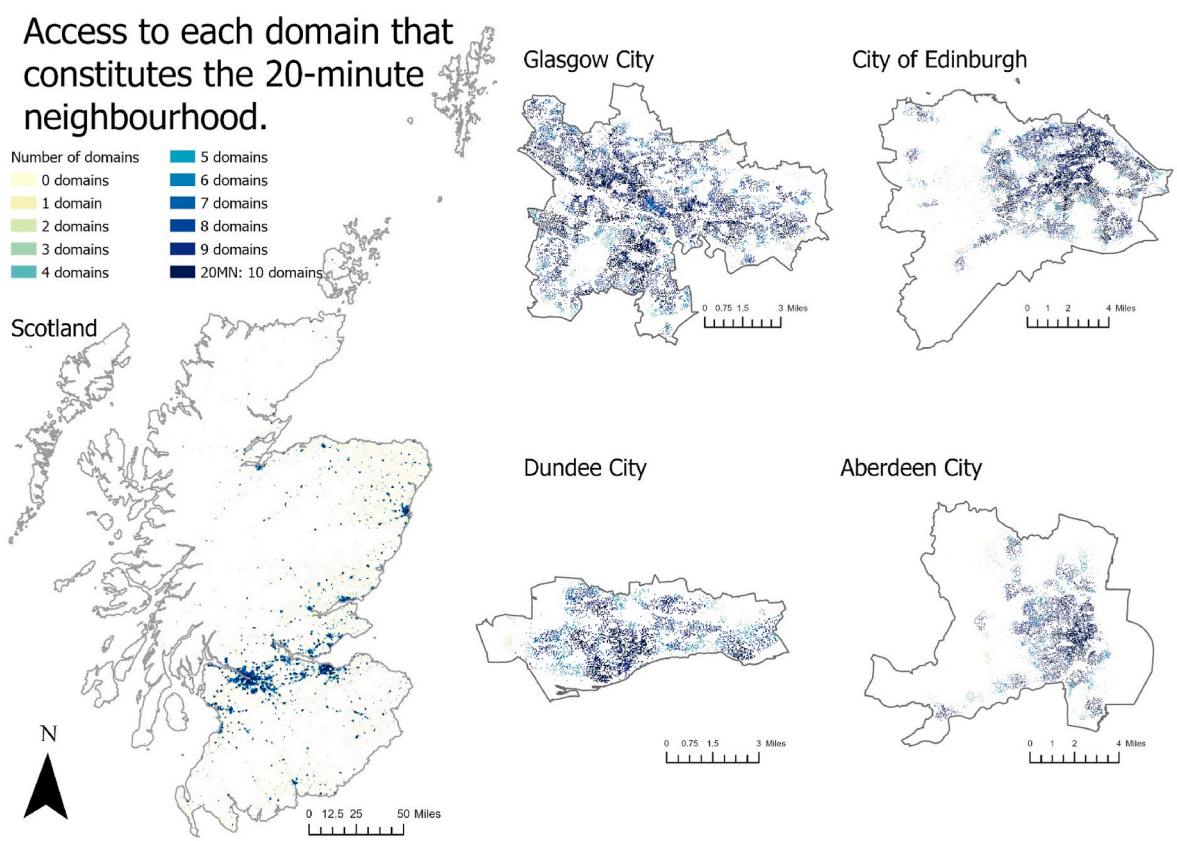

Fig. 3. Access to each domain and the 20-min neighbourhood, Scotland and the four largest cities: Glasgow City, City of Edinburgh, Dundee City and Aberdeen City.

gradient is unusual in epidemiological studies which tend to report poorer outcomes for those residing in the most deprived areas (Marmot, 2020). One simplistic interpretation of the findings would be that 20 MN policy should focus on improving access to a facilities and amenities within the *least* deprived areas. However, this has the potential to *increase* health inequalities by making improvements for populations who already have better health outcomes. Our findings do suggest that careful consideration of the potential of 20 MN s to reduce health inequalities is required. Service environment is just one component of the wider determinants of health, and both causal pathways and mechanisms of intervention must also be considered (Kriznik et al., 2018). Recent studies have highlighted that a complex and wide range of social and lifestyle factors are associated with disproportionate harm in deprived populations (Foster et al., 2018).

This study shows that, in Scotland, more deprived areas have better access to services and facilities that may promote or support healthy living. However, these areas are also more likely to have a greater density of retail outlets that can adversely affect health. An examination of the socio-spatial patterning of retail outlets selling potentially health-damaging goods/services (labelled environmental 'bads') found a social gradient with more unhealthy product retailers being present in the most deprived places (Macdonald et al., 2018). Research in New Zealand also showed that environmental 'goods' and 'bads' often co-occurred in the same space and are patterned by area-level deprivation (Pearce

Table 5
Percentage of Scottish residential locations within a 20 MN and 30 MN by urban/rural location.

Number of domains	All Scottish residential locations		Urban Areas		Rural Areas	
	20 MN	30 MN	20 MN	30 MN	20 MN	30 MN
	%	%	%	%	%	%
0 domains	6.9	5.4	0.9	0.5	23.4	16.2
1 domain	4.8	3.4	1.0	0.5	15.2	14.5
2 domains	3.5	2.4	1.6	0.6	8.6	8.8
3 domains	3.6	2.1	2.6	0.7	6.3	5.8
4 domains	4.8	2.1	4.2	1.2	6.3	5.6
5 domains	5.8	2.3	5.5	1.8	6.6	6.0
6 domains	8.4	3.1	8.4	2.8	8.2	8.8
7 domains	9.7	4.8	10.5	5.3	7.6	8.9
8 domains	12.9	5.9	15.2	9.2	6.7	8.4
9 domains	18.2	8.5	22.6	24.1	6.2	8.5
All 10 domains	**21.5**	**41.1**	**27.6**	**53.3**	**4.9**	**8.6**

et al., 2006a, 2006b); the most deprived areas often had the most convenience stores, gaming venues, takeaway, fast-food and alcohol outlets (Marek et al., 2021). Future studies should explore the co-location of unhealthy commodity retailers within 20 MN s. Perhaps a more nuanced approach to the policy is required, ensuring access to salutogenic services and facilities, but limiting access to pathogenic ones.

Dunning et al. (2021) argue that binary 'present/not present' measures should not be used when defining access to individual domains within a 20 MN. Instead, they propose quality weighting should be applied. However, robust and objective measures of facility or service quality can be very difficult to create or obtain, particularly when aspects of quality are subjective and might vary from user to user. Here, we tried to measure quality for one domain, public transport. This was achieved by calculating whether each individual stop location had a high frequency of transit visits per hour. Imposing this marker of quality decreased the number of residential locations meeting the 20 MN criteria for public transport by over 50,000. Access to high frequency transport stops is important; qualitative research in Scotland found that individuals wanted public transport that was '*more accessible, and more affordable, with a reliable and frequent service*' (Brown and Anable, 2021), highlighting that spatial access to facilities alone may not be a suitable indicator of a liveable and healthy neighbourhood.

Further assessment of the qualities of individual 20 MN domains should be explored. This could include cost-related barriers as well as service performance. The Place Standard includes a number of place making qualities that quantitative assessments may not be able to capture easily, such as care and maintenance, and the influence on user/community identity, belonging, and social contact which a service or facility might promote (Hasler, 2018). Local qualitative assessments of place may benefit the understanding its quality.

4.2. Implications for 20 min neighbourhood policy

Pursuing a policy that aims to establish 20 MN s across a nation is ambitious. In their review of international 20 MN planning documents, Gower and Grodach (2022) found that only 2 of 18 cities had clear and measurable benchmarks to help implement or assess the 20 MN concept. The absence of measurable benchmarks and/or statutory weight identified in policy led the authors to question whether the implementation of 20 MN would lead to sustainable city planning or whether it was predominately a branding exercise for these cities (Gower and Grodach, 2022). Gower and Grodach (2022) recommend a statutory-backed document that outlines measurable targets, quality and quantity metrics, and rights and responsibilities is required to properly implement 20 MN. However, it is important to acknowledge that many of the 20 MN principles may be included within other government policies and performance frameworks. For example, Scotland's National Performance Framework indicator measures and monitors the proportion of the population who live within a 5-min walk of a natural space (Scottish Government, 2020a).

The Scottish Government policy states that the 20 MN principle could be adjusted to include varying geographical scales from cities and urban environments, to rural and island communities (Scottish Government, 2020a). We used the same domain and access definitions for all areas of Scotland and found they may not be appropriate for all geographical settings. Further, our results showed that expanding the geographical catchment areas of 20 MN from 800 m to 1200 m has greatest benefit for urban areas but little substantial benefit in rural locations. A recent European-wide study found that context-specific, multi-layered approaches were required to tackle rural accessibility challenges whilst still ensuring a reduced environmental impact (Vitale Brovarone and Cotella, 2020). In many developed nations, supermarket food can be delivered to the home (at cost) and many pharmacies provide a free delivery service. If systems like these can ensure access to services, perhaps the fixed distance/time model of accessibility is redundant. Healthcare has also seen substantial developments in this regard. Many governments are making efforts to maximise the use of information technology and digital connectivity in the provision of remote and rural primary care (Scottish Government, 2020d) and the digital transformation of healthcare services was accelerated during the COVID-19 pandemic where face-to-face consultations were limited and many barriers to change were overcome. Despite this, investment is still required to modernise infrastructure and support patients with worse health and poorer digital literacy levels (Neves et al., 2021). Although access to online delivery services may also be a driver for increasing health inequalities as recent evidence shows that access to online fast-food home delivery is greatest in more deprived areas of England (Keeble et al., 2021). Providing services digitally for rural communities would require a transformation in infrastructure and it is often the elderly and most deprived who are at a digital disadvantage and least likely to be able to navigate these services (Velaga et al., 2012). This highlights the requirement for a health inequalities impact assessment of the implementation of the 20 MN physically and/or remotely.

4.3. Strengths and limitations

Our study had a number of strengths. We were able to identify 146,190 residential locations in Scotland and assess their accessibility to a facilities and amenities within boundaries relating to a 10-min and 15-min walk. We drew on robust national datasets. We used a road and path network buffer to create catchment areas, which provides greater spatial accuracy compared to circular and elliptical buffers. We were also able to assess the quality of the public transport domain by calculating the frequency of transit visits per hour for all locations.

However, the study had limitations and these prompt suggestions for future and improved research. We did not include the *number* of facilities within a 10-min walk of a residential location, our outcome measured a binary yes/no presence of at least one. Future studies could incorporate the number of facilities and amenities within a 20 MN as this could enhance the assessment and better reflect the range of destinations. We were unable to assess the quality of facilities and amenities for most domains. There was either no agreed or available measure of quality. Our study did not include measures of active travel infrastructure and there were two reasons for this. Firstly, they are poorly recorded in national spatial datasets in terms of the infrastructure type or quality (i.e., a segregated cycle lane or solely part of a national cycle route, that does not infer quality). Secondly, the 20 MN policy in Scotland, and elsewhere, infers that the policy will create neighbourhoods that promote walking and cycling rather than investing in infrastructure. Finally, the context for this study is that the 20 MN concept plausibly improves health, reduces inequalities and makes living more sustainable. The study did not explore any of these outcomes. Future work

might, for example, examine the health and sustainability of communities with similar levels of income deprivation but different performance on the 20 MN criteria. This would determine whether good local access to services and facilities is associated with better health and more sustainable living. If so, in the longer-term, evaluation of interventions to improve adherence to 20 MN criteria could establish causality.

There are a number of facilities that may provide important community uses that we excluded from our dataset. For example, pubs can act as community hubs in rural communities to provide services such as cinemas, digital hubs and community meeting spaces (Government of Ireland, 2022). We recommend the creation of national community asset registers to ensure these community resources are located for future studies. For open spaces, we only included access to areas of land designed, constructed, managed and maintained as a public park or garden. Rural areas in particular have access to large areas of natural spaces outside of this definition. We did not include these spaces as we were unable to determine the accessibility of these spaces. We were able to provide the rate per 100,000 residential dwellings with access to domain (total: 2.67 million dwellings). The number of dwellings is higher than the total number of households (2.51 million) in Scotland as 88,300 dwellings (3%) were vacant and 24,000 (1%) were second homes (National Records of Scotland, 2022). The definition of café's included snack bars, which could not be removed, and they could provide unhealthy food produce.

5. Conclusions

The 20 MN concept is receiving policy interest and its implementation has rapidly increased around the world in recent years. Despite this, there have been few national baseline assessments of current inequalities in access to facilities and amenities for residential locations. Our nationwide baseline assessment of 20 MN accessibility for residential locations in Scotland found variation in access by individual domains; good access to public open space and public transport locations and poor access to primary health care facilities and healthy food retailers. Our results highlight that further research is required to establish both the association and causal relationship between sustainable behaviours and health.

Residential locations within the most deprived areas had better access across all 20 MN domains when compared to the least deprived areas and a policy focusing solely on improving access to key facilities and amenities for deprived areas may therefore be ineffective in reducing health inequalities. Future studies should assess the quality of facilities and co-location with health damaging facilities, particularly within more deprived areas. There was little benefit in increasing the 10-min walking distance to 15-min for improving access to a range of facilities and amenities in rural areas. A more nuanced and community-led approach may be required for rural communities that ensures a focus on on-demand service and transport delivered as well as tackling digital deprivation and digital literacy levels. Digital access to- and provision -of many services has increased during the past decade and it is important that this provision of daily needs is incorporated in future studies. We suggest this should be reflected in future research where the fixed spatial measure of a neighbourhood service area should be updated to incorporate digital service access, such as home delivery service areas for supermarkets and broadband speed maps.

Credit author statement

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Data availability

The authors do not have permission to share data.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.socscimed.2022.115502.

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