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Active Travel Oriented Development: Assessing the suitability of sites for new homes

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The location of new housing developments, and the provision of safe space for walking and cycling to key destinations around them, have major and long lasting impacts on travel behaviour, health, and environmental outcomes. Transit Oriented Development (TOD) is a well-recognised concept in urban planning, but systematic evidence is often lacking on the likely 'active travel performance' of new developments, making it hard for the planning process to support sustainable transport objectives. This paper articulates the concept of 'Active Travel Oriented Development' (ATOD) and describes methods for operationalising it. We demonstrate the use of a set of

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simple metrics to assess the active travel performance of new and proposed development sites. ATOD has the benefits of building on the established concept of TOD and being easy to assess. We conclude that ATOD, and tools for measuring it, are needed to ensure that transport and development policies work in harmony.

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1. Introduction

The transport sector now represents the largest single source of carbon emissions in the UK (Department for Transport 2021b), and since 1990, countries across Europe have converged towards high levels of road transport emissions (Marrero et al. 2021). When the Glasgow Climate Pact was adopted in 2021, nations agreed to work to limit anthropogenic climate change to 1.5°C above pre-industrial levels (UNFCCC 2021), requiring action across all sectors of the economy. This means stronger action is now required to reduce transport emissions (Axsen et al. 2020; Brand et al. 2020).

Transport emissions are to a large degree a product of our travel patterns and behaviours, which in turn are strongly influenced by the geography of the places where we live. For example, car dominance is often greater in rural areas (Gray et al. 2001). One of the most fundamental ways in which we shape places is through the construction of new homes and residential neighbourhoods.

1.1 Residential development and active travel

The need for residential development has risen up the political agenda in countries such as the UK, and raising housebuilding rates is a cornerstone of UK government policy (MHCLG 2017a; 2017b). Current Planning Practice Guidance on Local Housing Need (DLUHC and MHCLG 2020a) sets out a housing need in England of around 300,000 new homes per year, a 68% increase on the 178,000 homes completed in 2019 (DLUHC and MHCLG 2022). These new homes will shape the communities of the future. Decisions surrounding their location and design will have long-lasting impacts on our ability to meet policy objectives such as the UK government commitment to becoming zero carbon by 2050 (BEIS 2020). They will influence the lifestyles and choices available to future residents, including whether they are able to walk, cycle or wheel within their local neighbourhoods and on journeys to key trip attractors such as shops, schools, workplaces and public transport hubs.

In the UK, as in many countries, planning and transport policies have often been developed in isolation from one another, despite the clear linkages between them. The recently published transport decarbonisation plan includes the aim for 50% of all journeys in UK towns and cities to be walked or cycled by 2030 (Department for Transport 2021a). New cycle infrastructure design and policy guidance will help enable these changes (Department for Transport 2020a; 2020b). However, there is little recognition of the role that planning policies might have in helping or hindering these objectives (DLUHC and MHCLG 2020b).

The National Planning Policy Framework emphasises the need to put new homes in locations that allow for "limiting the need to travel" (MHCLG 2021), and policy guidance states that proximity to public transport and services can be recorded as part of site assessment in the allocation process (DLUHC and MHCLG 2019), but no set methodology nor distances are recommended. As a result, consideration of proximity, particularly of walkable distances, has taken a piecemeal approach across England (Streb, 2021). This risks exacerbating urban sprawl, travel distances, and private car usage (Oueslati et al. 2015), and could result in increasing transport emissions at a time when they need to fall rapidly.

The construction of homes in places with poor provision for active travel and public transport risks deepening inequality and transport poverty for social groups such as those on low incomes (Gates et al. 2019) and people with disabilities (Schreuer et al. 2019). It also impacts those in precarious housing or employment situations, who may have limited choice over their home and work locations. This can force into car ownership people who would otherwise be expected to find it unaffordable (Mullen et al. 2020).

For most people, acceptable journey distances for active travel are relatively low. In the UK, analysis of adults living in suburbs and satellite towns showed a steep drop in walking rates beyond 800 m (Barton et al. 2012). Internationally, the picture is largely similar. In the Netherlands, 85% of older people walked less than 2 km for grocery shopping trips (Prins et al. 2014). For daily shopping trips in Spain, 55% would walk over 15 minutes, but only 25% would walk more than 20 minutes (Arranz-López et al. 2019). When journeys are short, the vast majority of people will walk (Department for Transport 2018). This proximity can be achieved through mixed-use development, but while sites can be allocated for retail and community facilities, there is no guarantee that they will be brought forward[11]. This uncertainty emphasises the importance of proximity to existing shops and services.

Further design elements of residential developments also have important implications for active travel. Within and across a site, the connectivity, or lack thereof, can add considerable distances, particularly to short walking journeys. Direct walking and cycling routes are associated with low 'circuity' values and suggest well-connected, legible street patterns that are easy to navigate (Randall and Baetz 2001). Neighbourhoods with low circuity and where distances to non-residential destinations are low are known to be conducive to active travel (Cerin et al. 2013; Hooper et al. 2015; Saelens and Handy 2008; Stevens 2017). Evidence suggests that such active travel connectivity increases walking for transport (Bonaccorsi et al. 2020). The comparative directness of routes by foot, by bicycle and by car can also be used as an index of filtered permeability (Melia 2008). Links across site boundaries are an important component of this connectivity. Often, new developments are poorly connected with their immediate surroundings, having relatively few links that cross the 'red line' of the site boundary. This can harm prospects for active travel, causing isolation even when the geographic distance to neighbouring suburbs and community facilities is small.

1.2 The concept of Transit Oriented Development

Attempts at the integration of planning and transport have a long history. Land-use transport models (LUTMs) and the thinking underlying them date back to at least the 1960s (Ford et al. 2018; Holz-Rau and Scheiner 2019; Moeckel et al. 2018). While Transit Oriented Development (TOD) as a concept was coined in the early 1990s (Calthorpe 1993), in practice the first examples were associated with the growth of railways and trams in the mid nineteenth century (Knowles et al. 2020). In the mid-twentieth century there was in many places a move towards private car-focused transport, but at the same time a new era of planned TOD also began with Copenhagen's 1947 'Finger Plan' (Knowles 2012). We are now in a third era of TOD, which has seen a range of transit

[11] See https://eastdevonnews.co.uk/2022/01/01/east-devon-when-is-cranbrook-town-centre-coming/ and https://www.bbc.co.uk/news/uk-england-oxfordshire-60387354 for examples where new facilities are awaited.

technologies, as well as cycling and bike-sharing, used to support urban regeneration and urban expansion (Knowles et al. 2020).

When Calthorpe first outlined the concept of Transit Oriented Development (TOD), he identified the presence of a walkable environment as "*perhaps the key aspect of the concept… More walkable, integrated communities can help relieve our dependence on the auto in many ways other than just transit. Reducing trip lengths, combining destinations, carpooling, walking, and biking are all enhanced by TODs. A healthy walking environment can succeed without transit, but a transit system cannot exist without the pedestrian.*" (Calthorpe 1993). As the quote makes clear, mixed land use and the proximity of community facilities to one another and to people's homes, is a vital part of creating a walkable environment, and the built environment also has a strong impact on cycling levels (Zhao 2014).

Public transport remains a core component of integrated transport planning, but with the impact of Covid-19, there has been greater recognition of the need to support active travel and the importance of local neighbourhoods (Nurse and Dunning 2020; Considine 2020). The "15 minute neighbourhood" concept, in which key services such as schools, shops and parks are available within a 15 minute walk or cycle of people's homes (Sallis et al. 2009; Sastry et al. 2004), has emerged as a means of improving the liveability of communities. In a French context this is known as "*Ville du quart d'heure,*" as proposed by Carlos Moreno in 2016 and applied in cities such as Paris (Moreno et al. 2021). Its benefits go far beyond reducing carbon emissions, and extend to improving health and wellbeing, safety and social inclusion (Pozoukidou and Chatziyiannaki 2021; Qin et al. 2021).

1.3 Active Travel Oriented Development

In the planning and design of new residential developments, if we apply the principle that housing should be located near to people's everyday needs and in an environment that supports walking and cycling, this can enable the creation of places that are conducive to the healthy lifestyles and climate benefits which active travel confers. We term this Active Travel Oriented Development (ATOD).

To enable ATOD, infrastructure and services supporting an active travel friendly environment must be put in place. Suitable infrastructure may include safe and accessible walking routes, segregated or off-road cycleways, widespread cycle parking, workplace shower facilities and sufficient cycle storage space within new homes. Cycle infrastructure that incorporates physical protection from road traffic is preferable to purely paint-based measures. Alongside physical infrastructure, other interventions will be required such as behavioural and financial measures and favourable legislative frameworks (e.g. training schemes and loans for cycle purchase). In time, a combination of measures can lead towards Dutch-style active travel uptake. The creation of high quality infrastructure and an environment that supports active travel may to some extent reduce the ongoing need for revenue measures supporting active travel, yet incredibly some new homes in the UK are built without even pavements (Transport for New Homes 2018).

Just as Renne and Wells (2005) and Evans et al. (2007) identified the need for indices defining TOD, there is also a need for a systematic evidence base to enable the integration of transport and planning and support ATOD. Valuable indices developed so far include the spatial multi criteria assessment approach of Singh et al. (2014), and the walkability indicators of Schlossberg and Brown (2004). However, neither of these focus specifically on the active travel provision and potential of new residential developments, or on walking and cycling routes from new developments to key destinations. Tools have been developed to assess current and future levels of active travel potential, but these tend to be based on existing travel networks and are thus of limited use when designing interventions to enable walking and cycling in and around new development sites (Larsen et al. 2013; Lovelace et al. 2017; Natera Orozco et al. 2020).

Our aim is to develop widely applicable methods that can be used to assess levels of active travel around new residential developments and their potential for improvement. These include a prototype tool and an actionable index that can be used directly to assess walkability and cycleability. Although the case study development sites are all from England, the methods are applicable internationally.

1.4 Policy relevance
The research and methods presented here are particularly timely in relation to the UK policy context. Substantial reforms to English planning policy have been proposed by the Ministry of Housing Communities and Local Government (DLUHC and MHCLG 2020b). The eventual outcome of this process remains uncertain but a likely component is digitisation of the planning system based on open and accessible datasets, which this research could help to provide. We anticipate that scalable methods to systematically assess the walking and cycling potential of new residential developments will be of interest to a wide range of stakeholders working at local, regional and national levels, including researchers, developers and transport and planning officers working in local government.

1.5 The importance of intervening early in the planning process
For analysis of active travel potential to have genuine impact on both site location and design, it must occur at the earliest possible stage of the planning process. In an English context this means feeding into the selection of sites to be taken forward in the Local Plan. It is thus important to have tools and methods for assessing active travel that can be applied to any location, including sites that have not yet been built and locations where a planning application has not yet been made.

The provision of quality infrastructure or services to support active travel must also happen at an early stage in site construction. For individuals, travel behaviours are most likely to change at the onset of major life events such as moving house or starting a new job (Clark et al. 2016). Therefore, to avoid 'locking in' car dependency, it is important that the capacity for sustainable travel is built into new residential developments from the date the first homes are occupied, rather than being added on several years later. This capacity includes both infrastructure provision and proximity to everyday destinations.

However, it is also beneficial for methods to be applicable to existing sites. This can reveal how close active travel levels at a site are to their theoretical potential, and where there may be specific barriers or opportunities to improve walking and cycling access. The methods could be used longitudinally to assess changing conditions pre- and post-construction.

1.6 Objectives
Our objectives are to:

1. Assess walking and cycling provision in the vicinity of planned or proposed residential developments, and highlight barriers that could be overcome;
2. Assess walking and cycling potential associated with planned or proposed developments, regarding distance from likely destinations; and
3. Where possible, to assess the suitability for active travel of the internal layout of a site and its direct connectivity to surrounding neighbourhoods.

2. Methods

In the context of the research and policy landscape presented above, we set out to produce an evidence base that could enable planners to better account for, and support, active travel by intervening in the planning process in favour of sites that will likely boost local walking and cycling levels while preventing car dependency. Recognising that the problem is widespread and international, our aim was to develop methods that could be scaled nationally and deployed in new contexts. Building on research in the field of planning support systems (Pelzer 2017) we aimed to produce measures that are easy to visualise, understand and act on. We have provided a demonstration of these methods in the form of an open source web tool.[12]

2.1 Selection of case study sites

As case studies, we selected a sample of 38 large residential development sites, with selection criteria that the sites should be large, well known to the researchers (to ensure results matched our understanding from site visits and published documents) and diverse, representing both urban and rural sites across the whole of England. All chosen sites had >500 new homes, 84% having >1000 new homes. They represent a diverse range of development types including urban extensions, urban regeneration schemes and new settlements such as proposed Garden Villages. Most of the sites have been profiled as part of three Transport for New Homes reports (Transport for New Homes 2018; 2020; 2022), providing a wide range of background information. In most sites, construction remained in progress as of early 2021, while three were completed prior to 2021, and 12 had not yet reached the construction phase. Their locations are shown in Figure 1, reflecting the preponderance of house building in large greenfield sites beyond the Metropolitan Green Belt that surrounds London. Details of the case study sites can be found in Table 1.

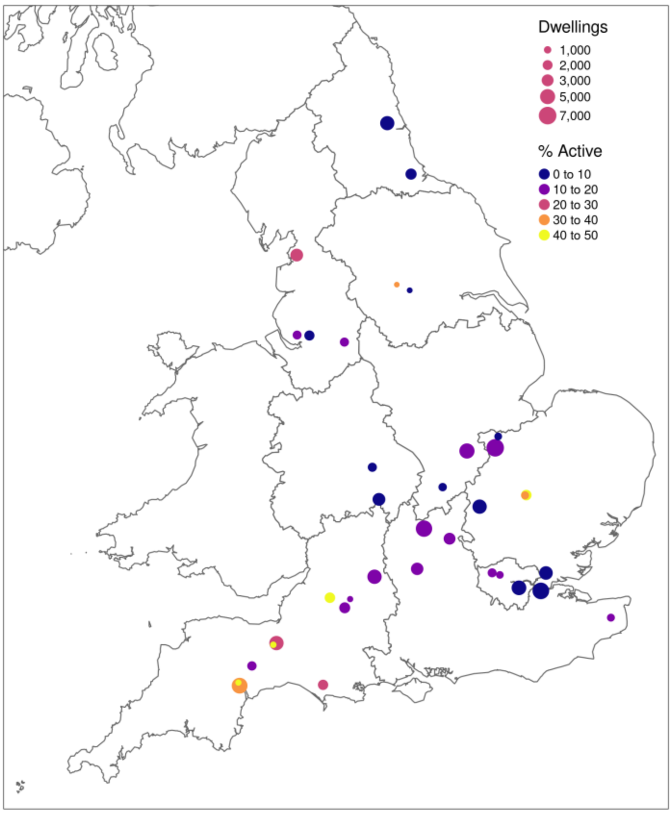

Figure 1. *The geographic distribution of case study sites across England, with symbol size proportional to the number of dwellings when complete and colour showing the proportion of existing commuter journeys made by active travel in the area surrounding each site.*

[12] https://actdev.cyipt.bike/

Table 1. List of case study sites with key metadata.

Full name	Main Local Authority	Type of development	Construction started before 2021?	Construction complete by 2021?	Dwellings when complete	Lat/long
Allerton Bywater Millennium Community	Leeds	Semi-rural brownfield	Yes	No	562	-1.362, 53.745
Ashton Park, Trowbridge	Wiltshire	Urban extension	No	No	2500	-2.189, 51.306
Berryfields, Aylesbury Garden Town	Aylesbury Vale	Expanded town	Yes	No	3000	-0.855, 51.837
Aylesham Garden Village	Dover	Rural village extension	Yes	No	1200	1.198, 51.230
Bailrigg Garden Village	Lancaster	Urban extension	No	No	3500	-2.799, 54.016
Bath Western Riverside	Bath and North East Somerset	Urban redevelopment	Yes	No	2280	-2.377, 51.383
North West Bicester Eco-Town	Cherwell	Expanded town	Yes	No	6000	-1.180, 51.914
Castle Mead, Trowbridge	Wiltshire	Urban extension	Yes	Yes	650	-2.182, 51.318
Chapelford Urban Village	Warrington	Suburban brownfield	Yes	Yes	2110	-2.638, 53.398
Clackers Brook, Melksham	Wiltshire	Urban extension	Yes	Yes	670	-2.120, 51.373
Cricklewood	Barnet	Urban redevelopment	No	No	1100	-0.215, 51.559
Culm Garden Village	Mid Devon	Expanded town	No	No	1750	-3.369, 50.859
Dickens Heath	Solihull	New satellite town	Yes	No	1672	-1.838, 52.386
Great Western Park, Didcot Garden Town	South Oxfordshire	Expanded town	Yes	No	3300	-1.267, 51.605
Dunton Hills Garden Village	Thurrock	New satellite town	No	No	4000	0.372, 51.573
Whitecliffe, Ebbsfleet Garden City	Dartford	New / extended settlement	Yes	No	6200	0.306, 51.435

Exeter Red Cow Village (Liveable Exeter)	Exeter	Urban redevelopment	No	No	664	-3.541, 50.731
Great Kneighton	Cambridge	Urban extension	Yes	No	2300	0.121, 52.172
Halsnead Garden Village	Knowsley	Urban extension	No	No	1589	-2.794, 53.402
Hampton	Peterborough	Urban extension	Yes	No	6900	-0.274, 52.535
Handforth Garden Village	Cheshire East	Urban extension	No	No	1650	-2.193, 53.347
Kidbrooke Village	Greenwich	Urban redevelopment	Yes	No	4763	0.028, 51.459
Leeds Climate Innovation District	Leeds	Urban redevelopment	Yes	No	520	-1.526, 53.789
Long Marston Garden Village	Stratford-on-Avon	New rural settlement	No	No	3500	-1.753, 52.139
Marsh Barton (Liveable Exeter)	Exeter	Suburban brownfield	No	No	5544	-3.526, 50.707
Newborough Road	Peterborough	Urban extension	No	No	1130	-0.236, 52.623
Newcastle Great Park	Newcastle upon Tyne	Urban extension	Yes	No	4400	-1.648, 55.029
Northwick Park Brent	Brent	Urban redevelopment	No	No	1600	-0.313, 51.575
Poundbury	Dorset	Urban extension	Yes	No	2200	-2.464, 50.714
Priors Hall	Corby	Urban extension	Yes	No	5095	-0.634, 52.511
Taunton Firepool	Somerset West and Taunton	Urban redevelopment	Yes	No	747	-3.097, 51.022
Monkton Heathfield Garden Community	Somerset West and Taunton	Urban extension	Yes	No	4500	-3.057, 51.035
Trumpington Meadows	Cambridge	Urban extension	Yes	No	1200	0.105, 52.170
Upton	Northampton	Urban extension	Yes	No	1382	-0.943, 52.233
Water Lane (Liveable Exeter)	Exeter	Urban redevelopment	No	No	1567	-3.528, 50.713
Wichelstowe	Swindon	Urban extension	Yes	No	4500	-1.810, 51.545

Wixams	Bedford	New satellite town	Yes	No	4500	-0.473, 52.083
Wynyard	Hartlepool	New semi-rural settlement	Yes	No	2600	-1.345, 54.638

2.2 *Planning data*

UK PlanIt[13] is a national database of planning applications based on scraping and aggregating data from the websites of more than 400 planning authorities. The UK has no centralised government dataset of planning applications; the PlanIt dataset enables the methods presented in this paper to be deployed nationwide. Planning applications relate to a wide range of activity and there is no official standardised indication of the type or size of development which is being planned. We used the 38 case study sites to improve the classification of planning application size within PlanIt.

2.3 *Demographic and travel data*

In the UK, the best available travel data at high geographic resolution are the 2011 Census travel to work origin-destination (OD) data, which formed a foundation of the analysis. We used data aggregated to Middle Layer Super Output Area (MSOA) zones; these have a mean population of around 7800.[14] Converting the OD data to desire lines, we used their Euclidean distances and flow data to demarcate a study area around each site, incorporating all desire lines with length ≤ 20 km where the number of journeys by foot, bicycle and car/van drivers met a threshold value. The threshold value was set as $t = \frac{d}{250}$, where t is the threshold value and d is the number of dwellings the site will contain at completion.

2.4 *Journey routing and road characteristics*

For all desire lines within the study area, we generated walking and cycle routes for journeys to work, and for journeys to the nearest town centre using the English Town Centres 2004 dataset published by MHCLG.[15] All journeys originate from the centre of the site polygon. For commutes, the destination is the population-weighted centroid of the appropriate MSOA. Walking routes were generated as long as the destination was within 6 km of the site. We used these 6 km and 20 km thresholds, not to suggest that they are acceptable maximum distances for walking and cycle journeys respectively, but to ensure that all potential journeys were captured, in particular for journeys to large rural MSOAs where the actual destination may be closer than the population-weighted MSOA centroid. Even with this generous cut-off, at two sites (Wynyard and Long Marston) there were no modelled journeys <6 km in length.

Journeys on foot were routed using the Open Source Routing Machine[16] (OSRM) routing engine. For cycle journeys, we used the CycleStreets.net 'fastest route' algorithm, which aims to emulate a likely route option a knowledgeable cyclist might take, by minimising journey time. The cycleability of cycle route segments was estimated using factors including road type, cycle path width and surface quality, speed limits, barriers and obstructions, signage, and route legibility. It is lowest on routes with a high degree of traffic stress, where traffic volumes and collision risk are likely to be high.[17] A similar 'walkability' measure, including factors such as pavement provision and dropped kerbs, would be useful but has not yet been developed. We calculated walking and cycle route circuity as the ratio of total route distance to Euclidean distance.

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[13] https://www.planit.org.uk PlanIt provides an open API, but use beyond the rate limit requires registration, potentially involving a commercial arrangement.
[14] https://data.gov.uk/dataset/2cf1f346-2f74-4c06-bd4b-30d7e4df5ae7/middle-layer-super-output-area-msoa-boundaries
[15] https://data.gov.uk/dataset/ed07b21f-0a33-49e2-9578-83ccbc6a20db/english-town-centres-2004
[16] http://project-osrm.org/
[17] https://www.cyclestreets.net/api/v1/journey/

2.5 Mode shift scenarios

For each site, we generated two scenarios, as illustrated in Figure 2. For the Baseline scenario, we used the 2011 Census data, adjusted to represent the estimated population, at completion, of the chosen residential development site, rather than the population of the MSOA(s) that the site lies within. For any given OD pair and mode:

$$T_b = \frac{T_m * d * hs}{P_m} \quad (1)$$

where T_b is the number of trips in the baseline scenario; T_m is the number of trips from the MSOA(s) the site lies within, according to the 2011 Census; P_m is the total population in 2011 of the MSOA(s) the site lies within; d is the number of dwellings the site will contain at completion; and hs is the mean UK household size.

The Go Active scenario represents the potential for increased uptake of walking and cycling, in the presence of high quality infrastructure and sustained investment. We calculated this uptake purely as a switch from car/van driving to walking or cycling. Other modes of travel were kept constant, and no change was made to journeys that already took place by foot or bicycle. We assumed that the journey destinations and total volume of travel remain identical to the Baseline scenario, and we did not attempt to account for the impacts of factors such as road traffic volumes, collision rates, typical weather conditions or seasonality.

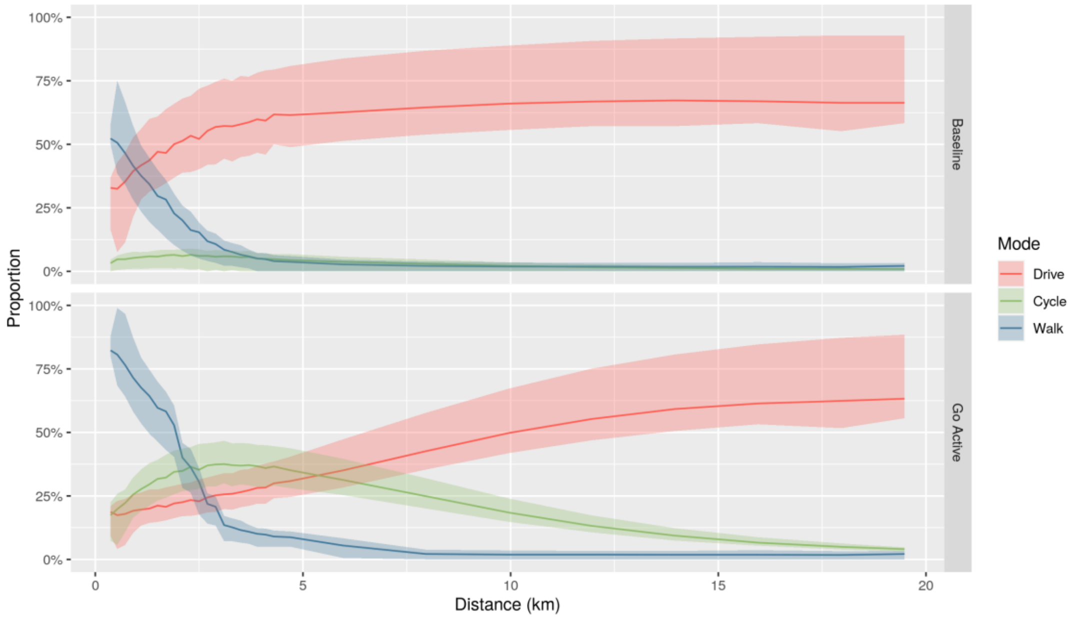

Figure 2. Commute mode shares by distance for the Baseline and Go Active scenarios, showing uplift in walking and cycling and a reduction in car/van driving under Go Active.

To generate the increased cycle uptake in Go Active, we used the 'Go Dutch' uptake function from the Propensity to Cycle Tool[18] (Goodman et al. 2019; Lovelace et al. 2017). This represents the proportion of journeys that would be undertaken by bicycle if cycle mode share corresponded with average cycling levels in the Netherlands, controlling for route length and mean route gradient. To generate the increased walking uptake in Go Active, we used a set of simple estimations to approximate a distance decay curve. For journeys ≤ 2.0 km in length we assumed a 30% increase

[18] https://www.pct.bike/

in walking mode share; for journeys of 2.0 - 2.5 km, walking mode share was increased by 20%; for 2.5 - 3.0 km by 10%; and for 3.0 - 6.0 km by 5%.

2.6 Within-site metrics

For sites that were at least partially occupied and therefore contained internal road networks in Open Street Map (OSM), we assessed mean in-site circuity of walking, cycle and driving routes by creating 20 origin-destination pairs with random start and end points within each site. We generated driving routes for journeys between each pair of points, then reset the point locations based on these results, constraining the points to be directly on the road network. We then generated walking and cycle routes between each pair of points. For comparability, all journeys were routed using OSRM. To assess links across site boundaries, we calculated the number of unique access points where cycle routes crossed the boundary of each site.

3. Results

We use a set of simple metrics (see Table 2) to assess the suitability of sites for Active Travel Oriented Development, providing data on existing travel patterns and the future potential for active travel in the local vicinity, as well as (where data on internal road networks are available) provision for active travel within the site itself. These results are also visualised on a site-by-site basis in our prototype web tool. The list of metrics is not exhaustive but can be added to if more data are available, for example representing access to public transport nodes, which would provide valuable additional insights.

Table 2. Metrics of Active Travel Oriented Development. The within-site metrics were calculated only for the 26 sites at which construction had begun as of early 2021. The other metrics were calculated for all sites, except circuity of walking routes, which could not be assessed at Wynyard and Long Marston since no walking routes <6 km in length were identified here. Results that suggest good active travel provision/potential are highlighted in green, these bad are highlighted in red.

Metrics			Min	First quartile	Median	Third quartile	Max
Existing active travel provision in vicinity of site	Existing commute modes (%)	Active	4	9	13	24.25	47
		Walk	3	5.25	10	15	39
		Cycle	1	2	3	5	31
		Drive car/van	27	53	67.5	73.75	83
	Quality of walk and cycle routes	Circuity of cycle routes	1.13	1.3	1.36	1.54	1.86
		Circuity of walking routes	1.16	1.27	1.32	1.47	1.98
		Cycleability of cycle routes	1.46	2.67	3.69	4.24	6.38
Potential for active travel in vicinity of site	Distances to destinations (km)	Median commute	1.7	3.83	6.75	9.75	16
		Town centre	1	2.2	2.95	4.75	11.9
	Potential commute modes (%)	Active	10	25	31.5	45.5	64
		Walk	0	6.5	12	18.75	50
		Cycle	2	12.5	18.5	24	40
		Drive car/van	19	27.5	49	57.75	79

Within-site active travel provision	Quality of routes within and across border of the site	Circuity of walking routes	1.28	1.39	1.48	1.73	2.79
		Circuity of cycle routes	1.31	1.45	1.62	1.83	3.02
		Circuity of driving routes	1.44	1.72	2.38	3.09	4.93
		Access points	2	3	4	5	10

3.1 Existing active travel provision in the vicinity of the sites

To assess existing active travel provision, we have chosen metrics representing existing commute mode shares and the quality of walking and cycling routes in the vicinity of the site. Baseline travel patterns are derived using 2011 Census commuting data. Although some of the sites were partially complete by that date, these data reflect travel patterns for the wider vicinity of a site, rather than solely for the site itself, because we used data aggregated at the MSOA level. Therefore, even for sites which were partially occupied in 2011, this baseline data is derived from a wider zone which stretches beyond the site boundaries. This method has the benefit that it can be applied to sites which do not yet exist, or are not yet occupied.

Unsurprisingly, existing commuting patterns in the vicinity of these sites vary greatly. Baseline walking mode share as a percentage of all commuter journeys varies from 3% at Upton, Newborough Road (both urban fringe sites) and Dickens Heath (a satellite town) to 39% at Bath Western Riverside (an urban core redevelopment scheme), with a median of 10%. Cycling mode share is as low as 1% at eight, mainly rural, sites, though this group also includes Northwick Park Hospital in Brent, London. Driving mode share is > 80% at five sites, four of which (Dickens Heath, Chapelford, Wynyard and Upton) are sites in which some of the homes are known to have been occupied prior to 2011. Only at eight sites is driving mode share < 50%. These are all urban sites; three of them are in London.

Provision of safe, direct, high quality active travel infrastructure is a key determinant of people's travel behaviour. To quantify this, we assessed the circuity of walking and cycling routes and the cycleability of the cycle routes. Cycleability and circuity varied greatly, even between sites that had similar levels of walking/cycling potential based on proximity to key destinations. This is illustrated in Figure 3, which shows walking and cycling routes to workplaces (aggregated by MSOA) and to the nearest town centre.

Circuity must be interpreted in combination with commute distances, since it typically falls with greater journey distance (Cubukcu 2021). Cycle route circuity was highest in isolated sites such as Wynyard and Dunton Hills, where there are very few cycleable links between the site and surrounding areas, and is lowest in Cricklewood in North London. Circuity of walking routes shows similar results, being lowest in well-connected sites.

Low scores are best in the metric used for cycleability. Unsurprisingly, the results are lowest in the two Cambridge sites; a city with the highest quality cycle infrastructure in England. Results are highest where cycle routes tend to follow major roads, such as at Priors Hall, separated from Corby by a large industrial estate, or Halsnead Garden Village, the site of which lies adjacent to the M62 / M57 motorway interchange.

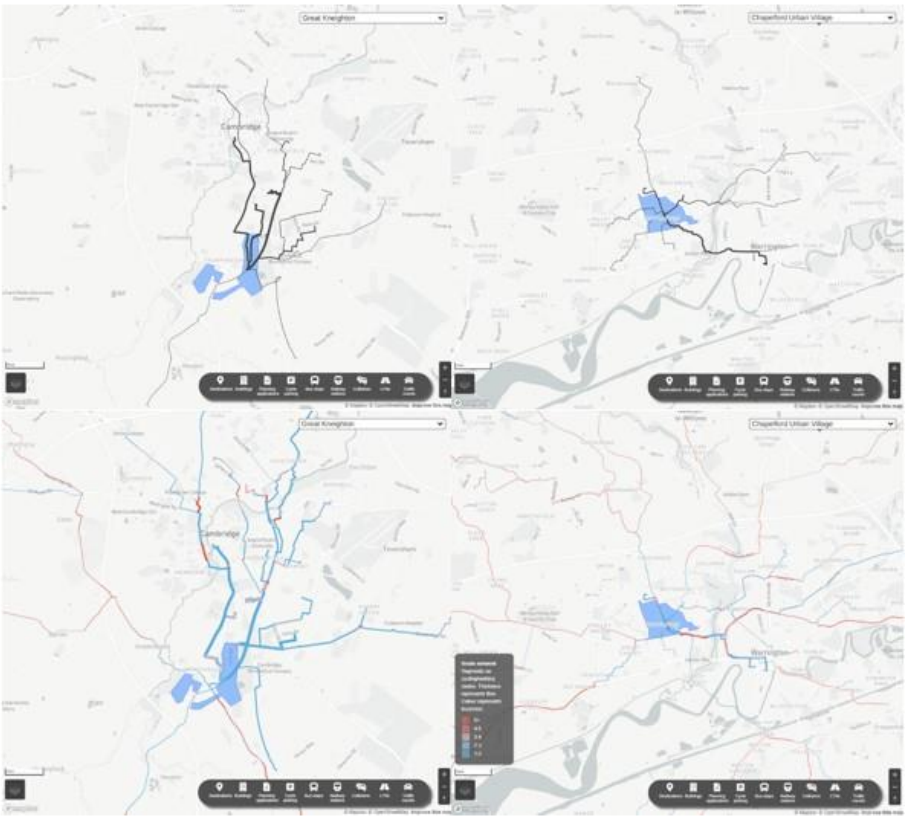

Figure 3. Web tool screenshots showing route networks for walking (top) and cycling (bottom) in Great Kneighton (left) and Chapelford (right). For the cycle routes, note the predominance of blue (high cycleability) route segments at Great Kneighton compared with the higher prevalence of red (low cycleability) segments at Chapelford, indicating the relatively busy, and potentially unsafe, nature of routes to key destinations surrounding Chapelford.

3.2 *Potential to increase active travel in the vicinity of the sites*

The potential to increase active travel in the vicinity of each site is assessed using metrics representing median distances to key destinations and potential future commute mode shares under a high active travel uptake scenario. Median commute distances range from 1.7 km at Taunton Firepool to 16.0 km at Culm Garden Village, with a median of 6.75 km. By comparison, the median distance from a site to the nearest town centre is 2.95 km.

Using a standardised set of distance bands, as shown in Figure 4 for two contrasting sites, we further investigated the relationship between commute distance and existing mode of travel. At Chapelford the median commute distance is higher than at Great Kneighton, and active modes also comprise a smaller proportion of the short journeys. We could have broken down the first distance band into journeys of 0-1 km and 1-3 km, but since these represent distances to MSOA centroids, many sites had very few journeys in the 0-1 km band.

Assuming workplace locations remain unchanged, the Go Active scenario uses commute distances and mean gradients to estimate how many of these journeys could theoretically switch from car/van driving to walking or cycling. The proportion of commutes by foot under our Go Active scenario ranges from 0% to 50%, median 12%. At Wynyard and Long Marston - isolated rural sites where new settlements have been proposed or constructed - the proportion is 0% because in these places our input data contained no trips shorter in length than our 6 km maximum threshold distance for walking, which is far beyond what research shows most people are willing to walk for everyday destinations. In contrast, five dense urban sites - Bath Western Riverside, Exeter Red Cow Village, Taunton Firepool, Leeds Climate Innovation District and Poundbury - see at least 40% of commutes by foot in this scenario.

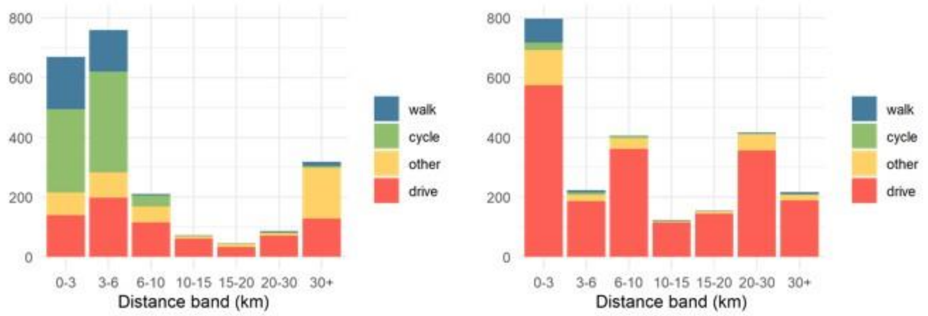

Figure 4. Baseline scenario commute modes and distances at Great Kneighton (left) and Chapelford (right).

Uptake of cycle commuting in the Go Active scenario is low in some urban sites with short median commute distances because there are relatively few existing commuters who drive, and the majority of these journeys have been assumed to be walked instead, with walking being chosen in preference to cycling in the uptake model. Low uptake of cycle commuting is also found in the more remote rural sites with long median commute distances. Total active travel uptake (measuring walking and cycling combined) is highest at Poundbury and in centrally located urban redevelopment sites in smaller cities or large towns. The proportion of commutes by car/van drivers is typically lower in Go Active than in the Baseline scenario, ranging from 19% at Kidbrooke Village to 79% at Wynyard and Long Marston.

Comparing the Baseline and Go Active scenarios we can see where proximity to employment sites creates potential for substantially increased walking and cycling uptake. Of the 38 sites, the greatest proportional increase in walking mode share is at Chapelford, where it increases 150%, from 4% to 10%. This suggests that in 2011, the proportion of journeys on foot at Chapelford was considerably below potential. Proportional increases in cycling to work are much greater. At Dickens Heath, cycling mode share increases 1900%, from 1% to 20% (Figure 5). By contrast, the proportional increase in cycling is just 29% at Great Kneighton in Cambridge, where cycling is already close to Dutch levels.

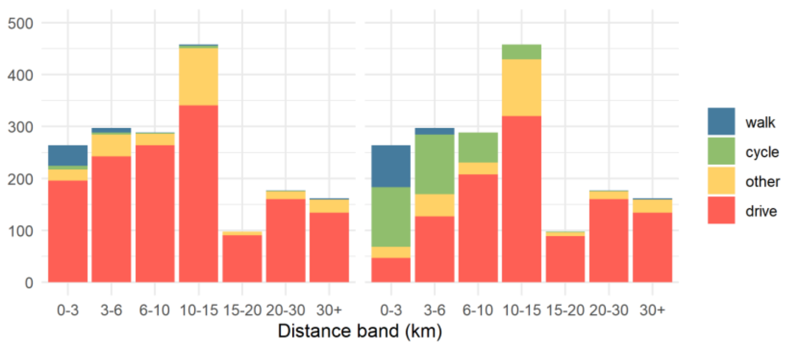

Figure 5. Baseline (left) and Go Active (right) scenarios for [Dickens Heath](#).

3.3 Travel in and around the sites themselves

Where data are available on the actual or proposed internal layout of a development site, it is beneficial to include this in assessments of active travel potential. We have selected as metrics the circuity of the walking, cycling and driving routes within a site, and the number of unique locations at which cycle routes from the site cross the site boundary.

For all sites that are at least partially occupied, we find median within-site circuity of 1.48 for walking networks (meaning walking routes are on average 48% longer than the Euclidean distance), 1.62 for cycling networks, and 2.38 for driving networks. When comparing different modes for the same site, the mean ratio of walking to driving route circuity is 0.71 and the mean cycling to driving route circuity ratio is 0.78. By comparison, in Lisbon, Costa et al. (2021) found a median circuity for 0-2 km trips of around 1.3-1.5 for walking, 1.5-1.9 for cycling, and 1.6-2.2 for driving. Conventional post-war North American suburbs, with curvilinear street patterns and cul-de-sacs, typically have higher circuity values for pedestrians of around 1.6 - 1.9 (Randall and Baetz 2001). At sites where construction remains in progress, circuity will be subject to change as new links are created within the site.

Where circuity is relatively high for all modes, such as at Clackers Brook, Melksham, this suggests unintuitive, winding street patterns, often dominated by cul-de-sacs, encouraging car dependency. Where circuity is higher for driving than for other modes, this suggests a degree of filtered permeability, benefitting active travel. For example Wichelstowe has a walking:driving circuity ratio of 0.32 and a cycling:driving circuity ratio of 0.35. Here, the road that passes through the centre of the East Wichel development contains a bus gate which prevents through traffic in the residential area. In other situations, cut-throughs may reduce the circuity of cul-de-sac street patterns for walkers and cyclists. However, quality of active travel provision is also an important factor. Alleys and cut-throughs that are poorly lit or surfaced, narrow and/or not overlooked by neighbouring houses, may be avoided by residents due to factors such as fear of crime. These quality issues are not measured in the ActDev tool.

Where circuity is low for all three modes, this suggests intuitive street patterns and layouts that are easy to navigate for both residents and visitors, as long as the street design puts the needs of non-motorised modes first. For example Poundbury (Figure 6) has within-site circuity of 1.30 for walking, 1.37 for cycling, and 1.49 for driving. Finally at Wynyard the site contains two distinct zones between which there are no safe walking or cycling routes. It is simply not possible to cross the dual carriageway that separates these two zones, so for many residents there is no viable way to reach local shops and services on foot or by bicycle.

The number of locations in which cycle routes cross the site boundary ranges from two to ten, with a median of four. Apart from the urban site of Taunton Firepool, the next highest site has six access points.

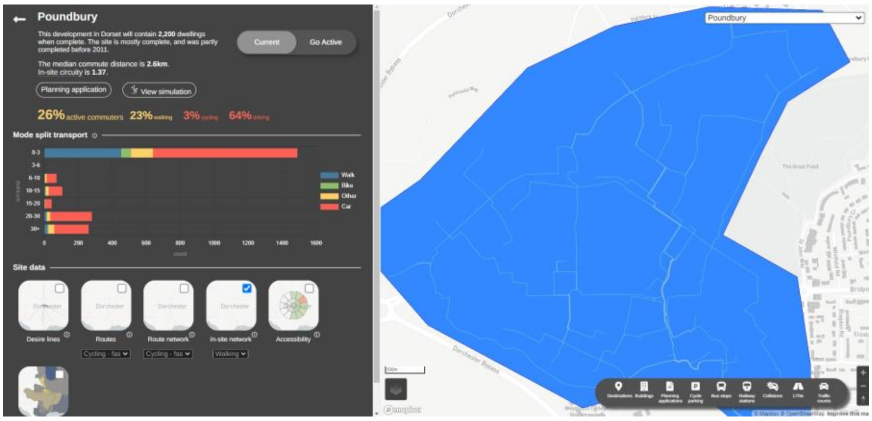

Figure 6. *Web tool screenshot showing the internal walking route network at Poundbury; routes are shown between 20 randomly selected OD pairs within the site.*

4. Discussion

To support Active Travel Oriented Development, it is clear from previous research that location, the provision of infrastructure leading to key destinations, and site design are key. This paper proposes an approach to making this knowledge actionable, by rating developments (existing and proposed) in terms of several elements that impact current and potential levels of walking and cycling.

We have chosen a set of metrics relating to well-understood factors influencing active travel, which make use of widely available data and can thus be used in the greatest possible range of circumstances. For example, people walk more when they have easy access to everyday destinations, including shops, schools, and workplaces. The metrics we have identified can be used as an index of ATOD, supporting assessment of new developments from an active travel perspective. We focus on active travel because there is already a good understanding of the public transport requirements for Transit Oriented Development (Singh et al. 2014), even though these principles are often not followed in development planning (Knowles 2021).

The proposed metrics highlight three key factors influencing walking and cycling provision and potential: quality of surrounding walking and cycling routes, proximity to trip attractors, and provision of direct active travel routes within and across the site itself. Commute mode shares and distances in our Baseline scenario approximate existing conditions in the local area, while the Go Active scenario represents the potential for greater walking and cycling given high quality infrastructure and investment. The difference between these two scenarios highlights the extent to which new infrastructure could lead to more walking and cycling. In-site circuity metrics for people on foot, cycling and driving provide an indication of the connectivity of the internal street layout and the existence of filtered permeability measures.

Results from these metrics must be interpreted in the context of the local situation. High walking and cycling mode shares under the Go Active scenario do not indicate that a site currently has good accessibility for active modes. They suggest there is potential for high levels of active travel, but this potential can only be realised with a very high quality of support. As this scenario was created based on cycling levels in the Netherlands, we expect this would include a Dutch-style standard of infrastructure, as well as non-infrastructure measures. If site metrics continue to show low levels of active travel even in the Go Active scenario, this suggests that typical journey distances are so long that switching mode from driving to walking or cycling is not feasible for these journeys. Conversely, if existing walking and cycling levels around a site are far below their estimated Go Active potential, this suggests there may be particular barriers in the local area that need further investigation.

The metrics of existing active travel levels should also be applied with care, since they are derived at MSOA level. Many MSOAs cover a large area, and a development site in a given MSOA may have very different characteristics to the localities containing the bulk of its existing housing stock. Therefore, the travel behaviour of development site residents may be expected to differ from typical travel behaviour for existing homes within the same MSOA. This is especially pertinent for greenfield sites that lie far from existing homes, and must be taken into account when interpreting results for both existing and potential commute mode shares. In addition, the size of MSOAs means journey destinations may be distant from a given MSOA centroid. These effects could be ameliorated by using Lower Super Output Area (LSOA) data rather than MSOA data, although the smaller average population size of LSOAs would result in a smaller set of modelled commute destinations. We could also model a wider range of destinations, rather than routing all journeys to zone centroids.

We have developed a prototype web tool which allows these methods to be used by interested parties such as planners, policy-makers and researchers. This tool is open source and free to use, with a user-friendly interface. Currently it contains data for 38 case study sites, but we hope to extend this much more widely in future. The tool has already received interest from stakeholders involved in the development planning process.

The need for such research is highlighted by the limitations of existing travel data in England. We have used 2011 Census data, which means that recent changes in work and travel patterns may be missed. However, the fact that in England the highest quality data of this type is greater than ten years old and only covers commuting journeys highlights the continuing need for studies that can update our understanding of travel patterns and potential. To compound the situation, the 2021 Census was conducted during a period when Covid-19 response measures meant many people were working from home.

There are important aspects of ATOD that we have not yet been able to implement in our proposed metrics and web tool. We used a simple uptake model to represent ambitious scenarios of increased active travel, illustrated in Figure 2. The model only represents modal shift from driving to walking and cycling. A significant area not yet covered is integration between transport modes. By combining the speed and spatial reach of public transport with the flexibility of active modes, such integration enables a much wider range of journeys than either transit or active modes alone. These journeys are central to the success of Transit Oriented Development, especially in less densely-populated contexts (Nigro et al. 2019). In the Netherlands, 47% of rail users access the station by bicycle (Kager et al. 2016). To overcome this limitation, we would need to create new uptake models that go beyond those currently developed as part of the Propensity to Cycle Tool (Lovelace et al. 2017), which incorporate multimodal, multi-stage journeys. These could use the widely recognised 800 m threshold walking distance to rail stations (Mitchell and Bendixson 2015). Our online webtool already includes layers showing rail station and bus stop locations, but does not yet include light rail / metro stations. To properly represent multimodal journeys, GTFS public transport timetable data should be used, since the presence of a bus or rail stop does not necessarily indicate that a useful service exists connecting to destinations of interest.

Some of the key factors influencing active travel behaviour, such as speed limits and the presence of cycle infrastructure (Mertens et al. 2017), are accounted for as part of our cycleability metric. Other relevant factors may include traffic volumes and collision rates, but these are less well understood at the road segment level, especially for roads within and around newly constructed neighbourhoods, so it would be harder for them to be included in a universally applicable manner. Seasonality and weather conditions are important in the UK, but we do not consider these because apart from providing covered shelters or cycle stands they cannot realistically be influenced by the designers of new residential developments.

Currently, our methodology involves the assumption that destinations and trip attractors are fixed. In reality, developments can include a range of community facilities within them. Land use policies promoting mixed use development can support this, thereby increasing residents' physical activity (Saelens and Handy 2008). By highlighting where journey distances are beyond those that people would realistically walk or cycle, our proposed metrics can support such policies either in selecting suitable development sites or strengthening the case for amenities within the development site, phased to support active travel from initial occupancy. In future, inclusion of 'destination switching' and broadening our coverage of different destination types could further improve the ability to support effective land use policies.

This brings us to a further limitation which is our focus on commuting as the journey purpose; chosen because of the availability of comprehensive open data, albeit with the caveats noted above. Travel to work accounted for around 20% of total travel in England by distance before the Covid-19 pandemic.[19] The average commuting trip distance is longer than most other trip purposes, suggesting it may indicate the upper limits of how far people will walk or cycle, although this may differ from people's willingness to walk or cycle to other everyday destinations. We included travel to the nearest town centre as a proxy for other trip purposes such as shopping, leisure, education and personal business, but a more complete journey purpose coverage would better capture these trips. This could be based on OSM location data for destinations such as schools, shops and leisure facilities.

Coverage of non-commuter journeys is particularly important as during the pandemic, working from home levels increased from around 5% to 30% of the workforce.[20] Housing market trends have shown reduced demand for homes close to centres of employment (Liu and Su 2021). The

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[19] https://www.gov.uk/government/statistical-data-sets/nts04-purpose-of-trips

[20] https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/conditionsanddiseases/bulletins/coronavirustheukeconomyandsocietyfasterindicators/22april2021

lasting impact of these changes on travel behaviour is still unknown. A shift towards more flexible, hybrid working patterns would have further trip chaining impacts and could mean journeys are more easily managed by car (Chatterjee and Crawford 2021). However, people working from home may be more likely to use active modes (Elldér 2020). Footfall in local centres recovered faster than in city centres (Mumford et al. 2021), perhaps suggesting that people wish to stay local for everyday services. This emphasises the need for proximity to community facilities and safe active travel networks so people feel able to walk and cycle to local shops and services.

Travel behaviour in existing journeys can provide a valuable depiction of the quality of existing active travel provision. Our focus on a limited set of quantitative measures will undoubtedly miss some aspects relating to active travel provision and potential, such as the perceived quality of the journey and infrastructure. Additional assessment metrics could be added to broaden the scope of the analysis, or practitioners could use other infrastructure assessment tools alongside this tool. This could for example include more measures that directly relate to the design of the residential development sites themselves, or to the integration of active travel with public transport.

As the above limitations make clear, the metrics presented in this paper cannot provide a definitive account of a residential development's active travel provision and potential. However, they provide a standardised and easily usable index, able to fill a gap in the planning process which is often overlooked (Chang et al. 2019). Further work can lead to improvements in particular metrics with the ability to support the principle of Active Travel Oriented Development.

5. Conclusion

Active Travel Oriented Development is suggested as a means of creating liveable communities in which jobs and services are within easy reach of people's homes, and residents do not need to rely on private vehicles to go about their daily lives. This can help to alleviate the many problems associated with high levels of motor traffic, such as carbon emissions, air pollution, noise pollution and lack of physical activity. Transit Oriented Development also addresses many of these issues, but we believe it can be complemented by perspectives that focus directly on active travel within local communities.

The methods presented in this paper have great potential to support ATOD. Specifically, they can generate the actionable evidence that is needed for planners to decide between sites from the perspectives of sustainable and active travel. Climate change and health objectives are increasingly included in Local Plans, but often the planning processes to achieve these are overlooked. Results generated by the methods we have presented can influence two main types of decision in the planning process:

1. Early in the planning process, the decision of whether to approve potential development sites, based on consideration of the feasibility of future residents walking and cycling to key destinations, including town centres and workplaces.
2. For sites that are taken forward, the results can inform planners about potential site layouts, road space reallocation options, and opportunities to bridge gaps in walking and cycling networks to increase walkability and cycleability, revealing how planning gains associated with the development could be invested to improve sustainability.

In tandem, these changes have great potential to ensure that new housing developments meet not only the needs of the future residents, but also steer society away from car-dependency and towards the zero carbon and physically active society that is necessary for a sustainable, healthy and liveable future.

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