Research Paper

Understanding how urban form enables walking

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Abstract

Health outcomes such as obesity are a priority challenge for the UK government. Increasing active travel levels is a policy goal which aims to tackle the obesity problem by encouraging people to be physically active for at least 20 minutes a day. However, walking or cycling as part of a daily life style is only possible if the built environment makes it possible. In response to this challenge, our study combines Space Syntax Integrated Urban Modelling with socio-economic datasets (including Age, Income, Household Size), to identify the characteristics where people walk to work across England's 333 Local Authorities and almost 7,000 MSOAs. Using multi-variate regression models with high degrees of explanatory power (0.88 and 0.66 R-squared at Local Authority and MSOA levels) we identify the built environment characteristics that can be shaped by planners and designers to encourage walking, specifically focussing on the network of streets, land use and density distribution.

Keywords

Walkability, 15-minute city, Evidence-based design, Spatial analysis, Health, Obesity

1. Introduction

In the UK, obesity costs the NHS over £1b per year, with further indirect costs calculated at £8.2b (DfT). Both central and local government departments and organisations including HM Treasury, Department for Transport, Department of Health and Social Care, the National Health Service and Transport for London, have all produced policies aiming to combat this. These policies consider multiple areas of intervention, from a sugar tax, to banning fast food take aways near schools, to providing better active travel infrastructure.

It is estimated by TfL that if all Londoners walk or cycle 20 minutes a day it could save the NHS £1.7b in treatment costs over 25 years (TFL). In addition to health benefits, fewer people driving delivers wider advantages in terms of reduced fossil fuel use and better air quality. However, when looking at the findings of recent reports, it is clear that the UK is not delivering places that make it possible to walk or cycle as part of an everyday lifestyle (RTPI, TfNH).

This paper summarises the findings of a series of real-world projects and internal research carried out from 2016 – 2022, to identify the physical conditions associated with places where more people walk and cycle, in order that these conditions can be put in place through planning and design. It identifies which locations at the city level are more suitable for walking and cycling, as well as how to develop these conditions at the masterplan scale.

2. Background

2.1. Health outcomes and complexity

Health outcomes are the result of complex interactions between multiple factors contributing simultaneously and creating feedback loops. These factors include genetic, socio-economic, demographic, environmental and lifestyle considerations. It is a multi-scale problem with different conditions affected by different elements of the built environment ranging from the individual dwelling (e.g. damp homes and respiratory illness), to the neighbourhood and the wider city (walkability and obesity).

Furthermore, the term health outcomes is broad, covering communicable and non-communicable disease, illness and injury, with additional complication created by research showing that some urban environment and building typology characteristics may be positively associated with certain non-communicable outcomes but negatively associated with others - density can be seen to be positive in reducing cardio vascular disease (Lai et Al 2022) but can also be associated with social isolation, especially when accommodated in apartment typologies (Lai et Al 2021).

Our work focuses on non-communicable disease, and specifically trying to encourage preventative behaviours through the design of the built environment.

There is a vast body of research on health outcomes and an increasing amount which supports the role of daily activity in the form of walking and cycling in prevention of illnesses including obesity, cardio-vascular diseases, cancers etc. This paper does not reference this deep resource in detail, the DfT Gear Change active travel policy summarises the high level benefits of a more active lifestyle to outcomes including health and wellbeing, environmental and economic.

Work by the UK Government Office for Science Foresight Group produced a systems map showing the factors that contribute to obesity. At the heart of this map is an imbalance between the energy consumed and the energy spent, with multiple genetic, non-spatial factors and individual decisions contributing. It is important to note however, that the choices made by an individual take place within a wider spatial environment and that this environment can be shaped in ways which can make different outcomes possible. A logic model emerges, where the design of the built environment affects the daily choices and activities of individuals, which over time have longer-term impacts on the individual and wider society.

Unfortunately, while the design of the built environment has the potential to make certain activities possible, it can also make them impossible. This can be seen through the emergence in UK mainstream media of anecdotal stories of new homeowners spending more of their time driving (Harrabin, Laker), data showing 83% of passenger journies made by private vehicle (Healthy Cities Commission), and an increasing amount of research on the impacts of driving on personal health (BMJ), which also have wider impacts on society and climate (Gossling et Al).

Designers and planners have a key role in making preventative daily activity possible. This requires a better understanding of the physical characteristics that makes places less car dependent and more walkable, in order that these conditions can be set in place through the design of new areas.

Furthermore, if these conditions can be identified it also means areas of risk in existing cities can be identified, and more holistic, targeted, intervention strategies can be developed to address them.

Young couples 'trapped in car dependency'

By Roger Harrabin
BBC environment analyst

24 October 2018

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TRANSPORT FOR NEW HOMES

The scramble to build new homes is producing communities where cars are the only form of transport

It must be miserable: you've saved for a newly-built home past the town's ring-road, but now you're trapped too often in a metal box with wheels.

thebmj

BMJ 2014;349:g4887 doi: 10.1136/bmj.g4887 (Published 19 August 2014)   Page 1 of 9

RESEARCH

Associations between active commuting, body fat, and body mass index: population based, cross sectional study in the United Kingdom

OPEN ACCESS

Ellen Flint *research fellow*[1], Steven Cummins *professor of population health*[1], Amanda Sacker *professor of lifecourse studies*[2]

Abstract

Introduction

The Social Cost of Automobility, Cycling and Walking in the European Union
Stefan Gössling, AndyChoi, Kaely Dekker, Daniel Metzler

Research in the EU* shows that the car represents a cost to society, on average of €0.11/pkm

Cycling and **walking** incur external benefits, at €0.18/pkm and €0.37/pkm, respectively

External cost of automobility (within the EU) is about €500 billion per year, while cy-cling and walking represent benefits of €24 billion and €66 billion

Figure 1 Left: Stories in the UK press highlight increasing awareness of links between the built environment and daily activity (Harrabin). Centre: Increasing amounts of research are being published in medical journals linking daily activity to longer-term health and well-being outcomes (Flint et Al). Right: Car dependent lifestyles not only impact on the quality of life of individuals but have wider costs to society (Gossling et Al).

2.2. Consistently describing the built environment

Until now, it has been difficult to describe the way multiple built environment systems work in combination with each other, from the point of a person.

Density provides a useful example; at a city scale, measures of density can be very helpful, but at smaller scales the same density of development can be accommodated in multiple ways, accommodated using different street layouts, public realm strategies, land use distributions and building typologies. However, each configuration produces very different urban environments and is likely to create very different patterns of daily activity.

Combining the development of technology, including open source software, more powerful hardware, with the increased prevalence of coding capabilities, and the availability of new (and open) datasets, it has become possible to make models that combine characteristics such as density with the street network, land use and public transport, and to link these to socio-economic datasets. Space Syntax have developed Integrated Urban Models (IUM) to combine these systems (Karimi et Al) and analyse their characteristics individually and in combination.

These models have been used to study health outcomes at a smaller scale; from 2017-18 Space Syntax worked with Devon and East Devon as part of the NHS Healthy New Towns and Integrated Care Excellence programmes. Through this work, Space Syntax provided the Public Health team with an IUM of Exeter, who found negative associations between obesity and the Walkability Index, that is, in more walkable urban areas there were lower levels of obesity. The model could also help explain outlier areas; it was known in Exeter that obesity tended to follow deprivation, however there were places of lower income and lower obesity. Comparing these areas with the IUM revealed that these outlier areas were more walkable (Chant et Al). IUMs have been further used over the last few years to analyse the specific urban characteristics associated with higher and lower levels of walking using a larger sample size (including the Thames Valley, and England).

Figure 2 While the same density can be accommodated in multiple different ways, when it is combined with street layout, land use, frontage, green, public and private space, it will have significantly different impacts on the way that spaces are used. As a result there are limits to the descriptive power of density to explain complicated urban conditions (diagram from Urban Task Force).

3. Methodology

Our study used multi-variate regression modelling to investigate associations between urban form and commuting behaviour including walking to work, active transport, public transport, and car ownership. We combined a selection of open and proprietary GB-wide socio-economic and demographic datasets with Space Syntax' IUM.

3.1. Space Syntax Integrated Urban Model

The Space Syntax IUM combines the street, pedestrian and cycle networks into a single network model. Each of these layers is imported into a PostgreSQL database, where data is cleaned, simplified, and given attributes to define the modes of transport that can use each segment of the network and their average speed. The land uses in each building are linked to this spatial network, with some buildings assigned multiple uses. Public transport timetable data in GTFS format is imported into the database, translated into a network, and linked at the locations of stops and stations.

The resulting model can be used for space syntax connectivity analysis, and also to identify, from the point of every building, which parts of a city (and the uses within this) can be reached within a defined journey time, by all modes of transport. A series of primary outputs of the model include the count of specific land use families within a journey time, and the distance to the closest of each of these families. From these primary outputs, a series of secondary "indices" can be calculated. These include: 1) a Walkability Index, which explains for every property in a city how many families of land use are within a 15 minute walk considering the distance to the closest, and; 2) a Car Dependence measure which looks at the advantage of having access to a car in terms of the ratio of jobs accessible within 30 minutes by car compared to by active and public transport.

SSx IUM is put together so that it can be linked to datasets held at other geographies, such as the census. This allows multiple layers of environmental, socio-economic and demographic analysis to be combined, and further risk stratification models to be applied. For example; AgeUK produces a Loneliness Map using census data to identify where a population has the characteristics associated with elderly people who are socially isolated. This model can be combined with Car Dependence, or the Walkability Index to identify if this potentially more vulnerable population live in parts of the city from which it is more difficult to access key services.

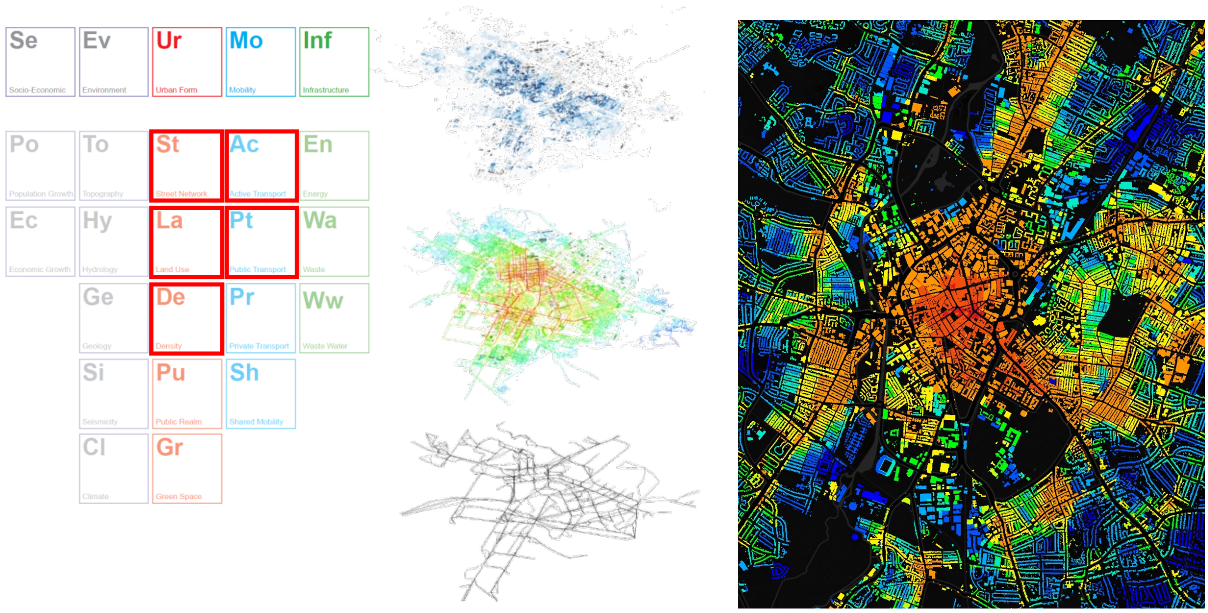

Figure 3 Space Syntax' Integrated Urban Model considers the city as a set of systems which can be grouped into families (left), Urban Form systems including Street Layout, Land Use and Density, and Mobility systems such as Public and Active Transport can be analysed individually (centre), but also in combination to produce composite measures including a Walkability Index (right).

3.2. Multi-variate regression modelling

To identify features to build the statistical model from, matrices were produced to visualise correlations between individual factors. These matrices plotted SSx IUM data including the Walkability Index (as well as access to individual land uses), socio-economic (Income), and demographic factors (Age, Household Size), individually against commuting mode share data from the census.

Explanatory multi-variate regression modelling was used to identify the features which impact on the proportion of people who walk to work (as a percentage of the total employed population within a given area). Study of individual features, spatial mapping, and testing for statistically significant mechanisms (examining coefficients and their corresponding p-values and residuals) were used to assess the statistical robustness and intuitive logic of the models.

This process was carried out to look at relationships occurring at the Local Authority level (333 areas across England), and at the MSOA level (Medium Super Output Area used to publish census data covering 6,791 areas of 5,000-15,000 population). In order to link datasets, SSx IUM data (held at the level of 7.3m individual street segments) needed to be aggregated to these different geometries with studies carried out to understand how to do this, and whether the mean, maximum, median or sum of spatial values were the most representative. Log values have been used to control for large variation (and skewness) in values at the MSOA level to help ensure linear relationships between each independent variable, the dependent variable and error terms (which is an important assumption in an ordinary least squares regression).

3.3. Limitations

While this process is extensive, and allows multiple features to be linked in a way that was not possible until relatively recently, there are still limitations that should be discussed:

First, any aggregation of data is a simplification, and there will be some loss of richness as urban characteristics described at a street-by-street level are combined into a larger area. For this reason, commuting data at MSOA level was also used. Unfortunately, nation-wide datasets that go down to the building, street or even post-code are not available and some aggregation of datasets is necessary.

Second, commute to work mode data is self-reported by the census and was collected in 2011. At the time of writing the 2021 census in the UK has not been published, but it was carried out during a Covid-19 lock down, where instruction was to record whether residents were working from home, rather than whether they would normally be travelling to another location (and the mode they would normally use to get there). Furthermore, the census only records journies to work, it doesn’t record walking as part of a public transport journey, nor how people get to school, go shopping, or walk for leisure. These trips will be missing from the datasets, and it is estimated that commuting to work represents around 20% of journies in the UK (Healthy City Commission). Despite these shortcomings, this is the only nation-wide, publicly available dataset. Through project work SSx have had access to mobile phone datasets across large regions, and while these datasets also have their specific considerations, the mode share data collected through observation rather than self-reporting is similar.

These limitations are to some extent unavoidable, but help frame the purpose of the work which is to understand which urban conditions are generally in place where more people walk to work. There will always be exceptions and outliers, but creating a model that requires continuously updated data on every resident is undesirable and unrealistic for many reasons (privacy, confidentiality, data storage, practicality of use), nor is it required; cities and towns do not constantly change to reflect their new residents, but set in place infrastructure that lasts for decades, if not centuries. The purpose of this modelling is to make sure we better understand how to set out this urban infrastructure in a way that encourages and enables most people to walk most of the time.

4. Results

The regression analysis explains 89% and 66% of the variance in walk to work data at the Local Authority and MSOA levels respectively, suggesting that models explain the majority of factors that influence walking to work across England.

The regression analysis enables an understanding of the mechanisms at play between key factors and the number of people who travel to work by foot, and include: Space Syntax Walkability Index, the settlement size and spatial network density (Node Count), Age, Households with children and Income.

Overall, the analysis finds that there are statistically significant positive effects of Walkability, Age and having children on the number of people who walk to work (significant at the 1% level). There is a statistically significant negative effect of Node Count on the number of people who walk to work (1% level).

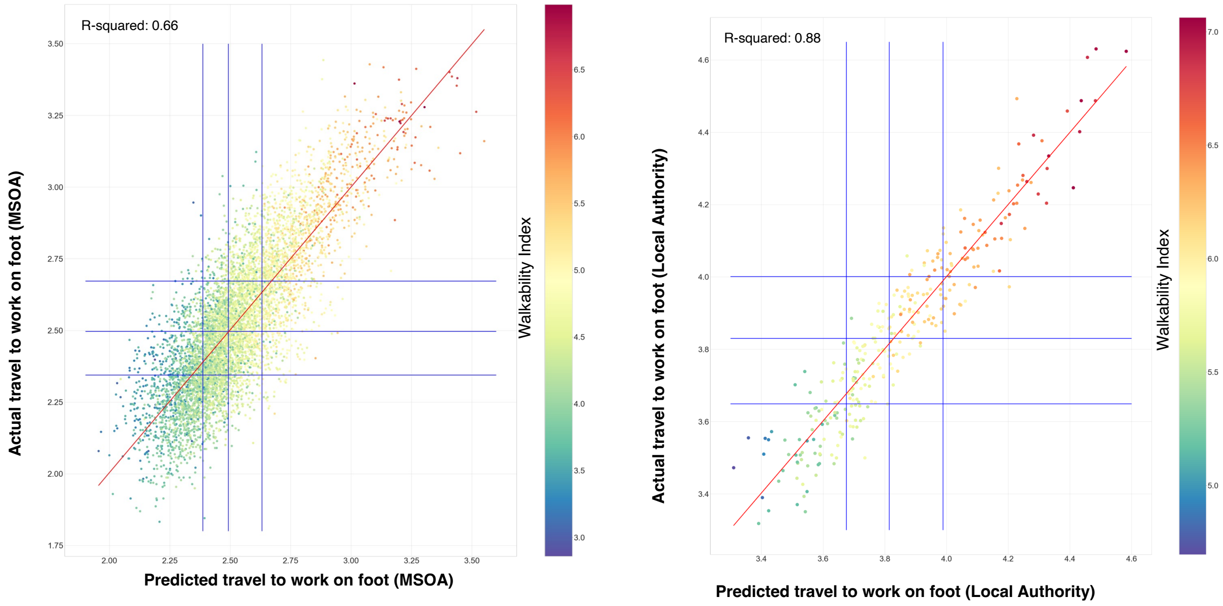

Figure 4 Multi-variate regression models showing actual levels of walking to work (y-axis) versus predicted levels (x-axis). At MSOA level (left) the model describes 66% of the distribution of actual walking, while at Local Authority level (right) the model describes 88%.

These findings are robust at the MSOA-level and Local Authority level of analysis. The analysis finds that mean income does not have a statistically significant effect on the number of people who walk to work at the MSOA level, but that there is a statistically significant negative effect at the Local Authority level (it is possible that this is the result of the scale of data aggregation and the definition of administrative boundaries).

Both MSOA and Local Authority models are statistically significant (prob F-stat = 0.00 for both models), meaning that the coefficients on our regressor terms are jointly significant, allowing us to conclude that our model has explanatory power for where people walk to work.

4.1. Findings

Study of coefficient data for each feature of the model indicates that:

- Increasing the Walkability by 1%, that is creating better connected street networks with a wider mix of uses, is associated with increasing the number of people walking to work by 0.27% (MSOA level) and 0.32% (Local Authority level).
- Increasing the number of people aged 18 to 29 by 1% is associated with increasing the number of people walking to work (0.58% MSOA, 0.63% Local Authority).
- Increasing the number of households with no children by 1% is associated with increasing the number of people walking to work (0.5% MSOA, 1.5% Local Authority).
- Increasing the income of households by 1 unit is associated with a decrease in the number of people walking to work, but only at Local Authority level (0.5%).

- Increasing the 10km Node Count, that is larger cities with more dense, well connected street grids, is associated with reducing the number of people walking to work (-0.29% MSOA, -0.63% Local Authority).

4.2 Analysis

These results indicate that the spatial characteristics of an urban area (at city scale and the smaller 15-minute walk scale) are important, but so too are Age and Household Size. Places with a younger population and fewer children are associated with more people walking to work, and there are likely to be multiple reasons for this beyond the built environment: as people progress through their career their income increases, many start families and move to more expensive larger properties. Childcare requirements mean people have less time to drop/collect children at/from school and then walk to work, and in the UK prices for family sized houses in (more walkable) city centre locations tend to be very high, meaning many families move to less central locations on the premise of more space for the money (but at the cost of fewer local services and less land uses within walking distance).

In analysis of individual datasets it could be seen that there were outlier areas which were unwalkable but which had higher than average numbers of people walking, and often these could be explained by the presence of a younger population. However, it should be noted that as these younger populations age or have children, they may be less likely to continue walking to work unless the physical environment is improved. The wider findings indicate that where people can walk to work, when they live close enough, in a walkable environment, then they do. If a city is severed by large highways or other infrastructure which is difficult to cross, unpleasant to be near, and which increases the distances between places then fewer people walk.

Cities, Municipalities and Local Authorities may not be able to change the age or family sizes of their inhabitants, but what they can control is their built environment, and this can be done through city level policy (e.g. in allocating housing land), and through the approval and adoption of masterplans that enable and encourage walking.

One finding worth expanding is the relationship between Node Count at 10km and lower levels of walking to work. It seems contradictory that areas which are embedded in large, continuously connected networks record lower levels of walking. Areas with high Node Counts at this scale tend to be part of a very large city, with more jobs, such as London. As a result there are more jobs to get to centrally and more areas between the edge and the centre which in practice may be too far to walk from. In settlements with high Node Counts at 10km, strong associations were found with people commuting to work by public transport (0.81), people commuting by active modes, but not walking, i.e. cycling (0.76) and lower levels of car ownership (-0.65). Therefore, large cities may record fewer people walking to work, but there are positive trends associated with them in terms of reduced car use.

5.0 Discussion: How to make use of these findings

By linking spatial, socio-economic and demographic datasets this research enables a better understanding of the conditions present where more people walk. It shows that these places, aside from having good street connectivity, also have many other characteristics in common. For example, the combination of multiple, mixed land uses and connected street and pedestrian networks (all measured by the Walkability Index) means that, within a 15 minute walk, residents may easily access many kinds of different uses (shops, schools, places of work and leisure).

Areas which score highly on the Walkability Index tend to have significantly more people walking to work. In other words, if it's not physically possible to walk to work people won't – there aren't many highly walkable areas where few people walk to work, nor less walkable areas where many people walk (see scatter below). There may be places where a younger, healthier population, with more time, overcome the constraints of the built environment and walk to work, but these are exceptions.

As this paper is aimed at a planning and design practitioners, we focus the discussion on what this means for the built environment under their influence.

5.1 What does this mean for Strategic Planning Policy?

Our research can support strategic decision making at city scale, specifically in relation to the allocation of population or housing to potential sites where the underlying locational characteristics should be considered. This applies at multiple scales, for example at the regional scale there is an argument that growth should be allocated where the larger scale conditions are in place to enable more active, less carbon intensive lifestyles – these are the larger cities with more dense spatial networks identified by the characteristic of Node Count at 10km.

Within these cities, data such as the Walkability Index can be used to identify development sites in locations which are inherently more walkable (this can also be used at the masterplan scale as set out later), and where regeneration of brownfield land should be prioritised over greenfield development of peripheral areas. While this land is often more expensive to buy and may require remedial action, the public sector can benefit from the potential health care savings associated with more active lives.

Alongside decision making on allocation of growth, a further element is to consider the supply of housing proposed, and whether there is adequate supply of (market, affordable and social) family size units in more walkable, more central locations.

5.2 What does this mean for masterplanners and urban designers?

For practitioners working at the masterplan scale, this research gives a more precise description of how to design the elements a Planner, Urban Designer or Architect has control over. First is the layout of streets, and a key consideration of more active places is that these areas don't just provide a locally walkable neighbourhood, they integrate and overlap with well-connected parts of the wider city. This is identified through the components of Node Count and the Walkability Index, and builds on earlier work by Bill Hillier who identified the characteristic of "multi-scale spatial accessibility" (Hillier).

Detailed analysis of the spatial networks in places with higher levels of walking, and in the top quartile of Walkability, show that these areas are made up of urban blocks which are smaller, and easier to walk around. Typically, the length of these street segments is between 50m and 100m, arranged in more continuously connected networks which offer between four and six routes in and out of them, while also connecting locally important streets with those which are important to the wider city. More walkable areas not only have street networks that are easier to move around, they are populated with a wider mix of uses that give more reasons for people to walk.

These findings are particularly relevant to the 15-minute city conversation. This terminology is very powerful, being intuitive to members of the public as well as designers and policy makers, however where it needs careful application is in the translation in to a set of (potentially over-simplified) design principles. The risk is that it focuses designers to look only at the very local scale – the neighbourhood or 15 minute area.

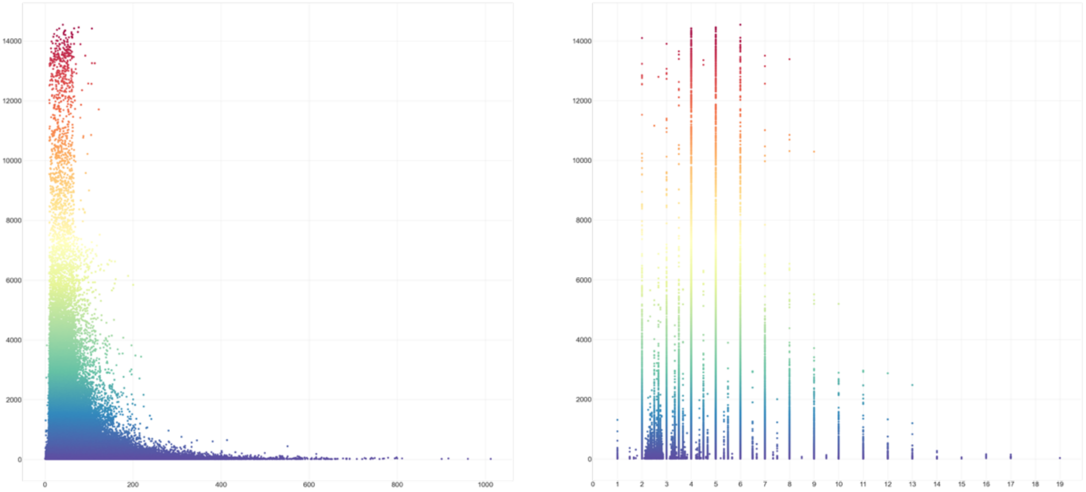

Figure 5 Left: Scattergram showing Walkability Index (y-axis) against street segment length, or the distance between junctions, (y-axis). Places with highest levels of Walkability have street segments in the range of 50-100m, indicating they typically take less than one minute to reach a point which offers new connections. Right: Scattergram showing Walkability Index (y-axis) against connectivity, or the number of connections each street segment offers (y-axis). Street segments in places with the highest levels of Walkability have between four to six potential connections to them, indicating that they are part of larger, continuously connected, networks. This combination of factors means that they are human scale, and offer multiple routes between places which effectively reduces distance for pedestrians.

It is possible to frame much late 20th century, car dependent development as 15-minute cities, and this can be seen using examples of UK New Towns. Milton Keynes, for example, has a large super grid designed for cars which defines a series of smaller, discrete areas of city. These discrete areas have many of the required local facilities, such as schools, local shops or a park which can be identified in the Walkability Index. However, because they have been designed in isolation from each other, these areas operate individually which effectively reduces the choice of services and uses residents have access to. Mode separated networks are provided for car, pedestrians and cyclists, and despite many new towns having very high cycle network provision, they are not well used. Stevenage, for example, has some of the highest amount of cycle route per person, but the lowest cycling mode shares (Guardian 2017). There are multiple reasons for this; active transport routes are often out of view from surrounding users, poorly lit, poorly maintained, and rarely integrated with the most important parts of the city where people are more likely to want to get to.

Comparing Milton Keynes with an example of “muti-scale” urbanism (in this case part of North London), it can be seen how the local and wider scale spatial networks align and integrate with each other. This allows many smaller neighbourhoods to interact with each other to create larger, more accessible centres, and offering access to a wider range of services. The Walkability Index shows that while in Milton Keynes it may be possible for many people to access one local centre, in North London, even in the most isolated places it is possible to reach multiple, larger, centres within 15 minutes. This overlap between users creates opportunities to access and support a wider range of social and economic opportunities.

Comparing these different characteristics of Walkability against travel behaviour further underlines the risk of pursuing the 15-minute city as a set of discrete, localised areas. In Milton Keynes, Car Ownership is higher, Commuting by Car is higher while Commuting by Active and Public modes is lower. Not only do these types of development increase the risk of poor health outcomes, but they also worsen climate issues including use of fossil fuel/finite resource, poorer air quality, noise pollution, and congestion.

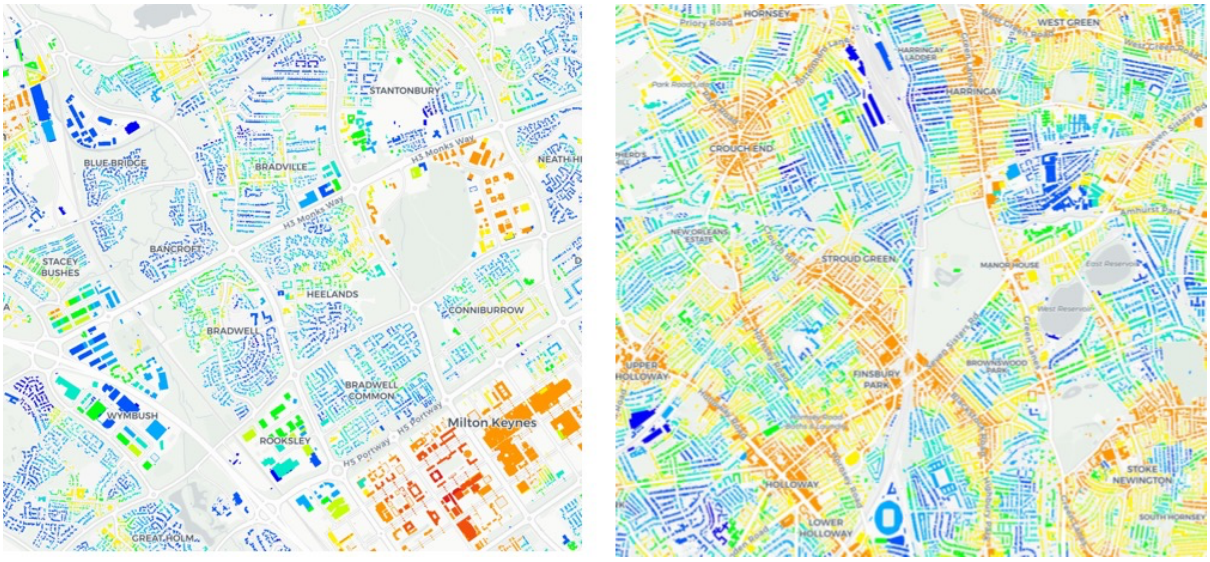

Figure 6 Walkability Index, red is higher, blue is lower. The Walkability Index shows that in North London (right), because the local and city-wide street networks overlap with each other, the mix of uses within walking distance is greater than in settlements such as Milton Keynes (left) where the movement networks have been designed to be separate from each other.

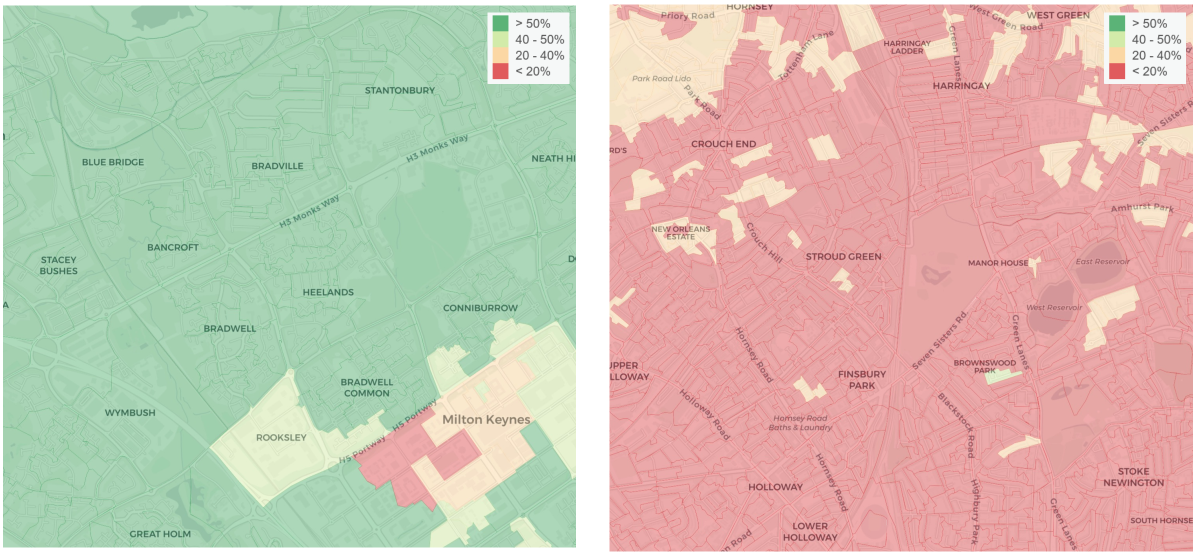

Figure 7 Private Car mode share, green is higher, red is lower. In Milton Keynes (left) car use in most areas is above 50%, while in North London (right) car use in most areas is below 20%. The fragmented spatial networks of Milton Keynes create a set of isolated areas that work individually, effectively increasing the walking distances between places. This presents a fundamental spatial problem which is difficult to correct. In North London, the overlap between local and wider areas reduces the distances between uses, and while this makes it easier for people to move by active modes, the (less fundamental) challenge is to accommodate multiple modes of transport safely and pleasantly in the same space.

6. Conclusion

This research shows how outcomes such as health are complex, and while multiple factors interact to contribute to longer term outcomes, a better understanding of the role of the built environment in enabling and encouraging active daily lifestyles, such as walking to work, can make positive outcomes possible.

It should be noted that while research is leading to a better understanding of the specific characteristics of the built environment to set in place, positive outcomes require individuals to make certain choices. Good urban policy, planning and design can encourage these choices, by making it possible to walk or cycle, however it can't guarantee that people will do this. As such, it is useful to caveat the potential impact that design can have, and while it may not be possible to guarantee a positive outcome, it can make it possible. Unfortunately, and as illustrated by the recent press stories and examples of car dependent housing in the UK, it can also make it almost impossible.

For practitioners, key learnings from this research are that a more walkable urban environment needs to work across multiple scales, it needs to create smaller, more permeable urban blocks, that are at the scale of a person. Blocks should be populated with a mix of uses and structured in a way that creates local areas that are integrated with, and part of, a much larger whole. The multiple urban systems in a city, specifically the movement and infrastructure network need to be shaped around people, multi-modal, mixed-use, slow speed streets should be used to integrate and connect areas and to avoid at all costs creating fragmented, discrete areas.

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