what works centre for local economic growth

Rapid evidence review: Active travel infrastructure

Introduction

Active travel involves making journeys by physically active means such as walking and cycling. Investment in appropriate infrastructure – for example, pavements or cycling lanes – can help encourage active travel.

This review summarises the evaluation evidence on active travel infrastructure. Our briefing on assessing the local economic impacts of public spaces is informed by this review and a rapid evidence review that summarises the evidence on two other types of public space – public realm and green spaces.

Things to consider

Need for more evidence

- Given the increased interest in active travel, we encourage policymakers (including the Department for Transport, Active Travel England, devolved administrations, sub-national transport bodies, combined authorities and local authorities) to undertake robust impact evaluations of active travel policies and interventions.
- There is a particular need for more research into cycling and on the impact of active travel infrastructure on local economic outcomes.
- Evaluations should be conducted at the appropriate spatial scale – for example, considering displacement on to neighbouring areas – and should also consider effects on other transport modes.

Policy lessons are covered in the briefing.

Evaluation evidence

What is active travel infrastructure?

Active travel involves making journeys by physically active means such as walking and cycling. Investment in appropriate infrastructure – for example, pavements or cycling lanes – can help encourage active travel. Such investment may bring local economic benefits by improving accessibility to or from locations, or if people use the infrastructure to commute from home to work making housing near to schemes more attractive. The infrastructure may also provide amenity benefits if it results in modal shift from motor-vehicles, thus raising the attractiveness of a location.

Understanding the impact of investment in active travel infrastructure

Our evidence reviews use studies with a score of three or above on the Maryland Scientific Methods Scale (SMS), which classifies evaluations based on methodological robustness and implementation.[1] Our toolkits and rapid evidence reviews also include studies with a score of two or above when these add to the evidence base. Just over a third of the studies included in this rapid evidence review score SMS 3 or above.

Our search identified 22 evaluations. One study is SMS 4, five SMS 3, and 16 SMS 2. We give more weight to those with higher scores, and flag those scoring SMS 3 or 4. The annex provides a summary of each study.

Most of the studies look at walking, either on its own or in combination with another mode of transport. Less than a third of studies look at cycling. This is surprising given that many countries, including the UK, have a strong policy focus on installing cycling infrastructure.

Our search also identified five systematic reviews. Four of these looked at the links between the built environment and physical activity. Walking and cycling are considered in many of these reviews as either an element of the built environment (e.g. how walkable is a neighbourhood) or as an outcome (i.e. as types of physical activity). The other review looks at the associations between walking as active transportation and cardiometabolic health outcomes. As these studies provide useful insights for active travel policy, we include them in the review. However, care should be taken in interpreting the results as the reviews predominately draw on cross-sectional studies. We score cross-sectional studies at SMS 2 if adequate control variables are used but it is difficult to tell whether the studies included in the systematic reviews meet this criterion. It is not possible to score systematic reviews against the Maryland Scientific Methods Scale that we use for individual studies.

The findings are organised by outcome. Be cautious of findings based on a small number of studies.

Some notes on impacts

Costs and benefits may arise for people who do not use the active travel infrastructure. If the infrastructure improvement comes at the expense of motor-vehicle infrastructure – for example, because a cycle lane reduces road capacity – these accessibility and amenity benefits may be offset by costs for individuals who are unwilling or unable to shift from motor-vehicles to active travel modes.

Benefits and costs will tend to be localised, occurring at locations on or close to the infrastructure investment.

In principle, as active travel infrastructure investments are an addition to the transport network, they may also offer economic benefits at larger spatial scales if they improve the functioning of the whole

1 For more information on how we rank the robustness of evaluations, see our introduction to the Maryland Scientific Methods Scale.

network. For example, easier commuting or travel between businesses can improve productivity or employment. Given modal shares for active travel and the offsetting effects on motor-vehicle infrastructure, it is unlikely that these effects will be large for individual investments. They may be more significant for large network investments. Benefits that are less likely to be localised and depend on system wide adjustments will be harder to assess ex-ante and measure ex-post.

Evidence on impacts

Walking and cycling

For active travel infrastructure to have an impact on economic or other outcomes, such as health, it must first increase walking or cycling – for example, by changing perceptions of the feasibility or attractiveness of walking and cycling as an option. We found ten studies that look at these impacts using data on pedestrian or cyclist volumes or self-reported data on walking and cycling.

Six studies consider interventions that improved cycling or walking infrastructure, with all finding positive effects. Two of the studies scored SMS 3 and four SMS 2.

The two most robust studies look at the impact of segregated cycle lanes and of mini-Holland schemes to make neighbourhoods more cycle-friendly, both in London.

- AT-1 (scored as SMS 3) evaluates the impact of mini-Holland schemes to improve cycling, walking and public realm in three Outer London boroughs. Whilst there was limited evidence of change at the borough level, individuals living in or near to a mini-Holland scheme were more likely to report increased participation in cycling and walking in the past week. They also report spending more time cycling (13.3 minutes) and walking (28.5 minutes) per week.
- AT-2 (SMS 3) examines the impact of the segregated cycle lanes introduced in London between 2014 and 2019 as part of the Cycle SuperHighways programme. It finds that they increase cycling flows, without impacting on car traffic. Cycling increases by 25 percent immediately after the segregated cycle lanes open, and then grows by 20 percent per annum. The study finds little evidence of cyclist displacement (from other routes to segregated lanes), suggesting that the increase in traffic in segregated lanes is likely to result in a net increase of cycling.

The other studies also find positive effects.

- AT-3 also looks at the Cycle SuperHighways and finds an increase in cycle hire of 27 percent from London Cycle Hire docking stations within 300 metres of the cycle lanes. The increase is 73 percent when both the origin and destination of the trip are within 300 metres of the cycle lanes.
- AT-4 evaluates the impact of a new 25km guided busway in Cambridgeshire, which included a parallel path for walking and cycling. Proximity to the busway is associated with an increase in active travel mode share, with commuters living near the busway (4km) almost twice as likely as those living further away (up to 9km) to report a substantial increase in active travel mode share.
- AT-5 looks at the impact of a 2016 pilot project to install a bike lane and remove on-street parking on a 2.4 km stretch of a retail and commercial corridor in downtown Toronto. It finds that the pilot had a positive effect on cycling being chosen as the mode of transport on the day of survey, for retail trips (which includes shopping, services, and restaurants), and for shopping trips. This may be explained by another finding – that there was increase in those reporting it difficult to find car parking.
- AT-6 examines three high street improvements schemes in Lisbon. It finds they have a

positive effect on pedestrian volume and walking experience, with greater changes in walkability leading to larger changes in volumes and walking experience.

The other four studies – all scored as SMS 2 – compare neighbourhoods with different design features. All four of these studies are concerned with 'walkability'. None of these studies are particularly robust and they do not evaluate the impact of specific interventions. Three of the studies find a positive association between 'walkability' and walking (or active travel more generally). The fourth looks at perceptions, rather than behaviours, and also finds a positive effect. However, the definitions of walkability vary, often drawing on multiple factors only some of which would generally be considered active travel investments. The methodologies used in the studies also leave open questions about whether the effects of walkability on walking reflect the kind of people who choose to live in walkable neighbourhoods (i.e., people that walk more choose more walkable neighbourhoods). If this reverse causality explains the positive association between walkability and walking then we cannot be sure that investments to improve walkability would increase walking. There is also a lot of variation in terms of who walks more in these neighbourhoods and the characteristics of neighbourhoods that matter most for walkability:

- AT-7 from the US finds that neighbourhood walkability (using a score calculated specifically for this study using GIS data) has a positive effect on number of days per week older residents (aged 65-to-97) walked for at least 15 minutes at a time for three out of four groups considered.
- AT-8 from Australia finds that high walkability around home and around school is positively associated with active travel to school by children aged 5-to-12. Walkability around school is also positively associated with children accruing 20 minutes or more of physical activity through active travel per day.
- AT-9 looks at the relationship between different elements of the built environment and pedestrian volumes in a Japanese city. Across the city, five elements were positively associated with pedestrian volumes, with the largest effects observed for the number of train stations per unit area, eye-level buildings, and the number of intersections per unit area. The study finds different factors are important in different types of neighbourhood.
- AT-10 considers 'walkability' in a US city, and finds that separation from traffic, pedestrian network connectivity, parks, on-street parking, and some green street installations impact positively on perceptions of 'walkability' of street segments or blocks, whilst arterial roads and convenience stores impact negatively.

These studies form part of a wider literature on the links between the built environment and physical activity. We found four systematic reviews of this literature. The findings of these systematic reviews are more mixed than the four individual studies we considered above. For some, this might be because they include a broader range of physical activities than just walking or cycling. As with the individual studies, it is unclear whether reverse causality explains any positive associations between walkability and physical activity. And the headline findings from the reviews also echo the individual studies in terms of the diversity of findings in terms of who walks and what neighbourhood characteristics may matter:

- SR-1 finds that street and pedestrian connectivity (for example, number of intersections) and neighbourhood walkability are amongst several built environment characteristics (including land use mix and population density) that affect the physical activity of adults. Looking across the different elements of built environment and different types of physical activity (including recreational walking, transportation walking, general walking, general cycling, combined walking and cycling, and moderate to vigorous physical activity), the strongest evidence is

in relation to the built environment affecting transportation walking. Less positively, evidence on pedestrian and cycle infrastructure (for example, the installation of sidewalks, trails, and pathways) is mixed, with many studies finding no or negative effects. The review suggests that the effects of new infrastructure may depend on the attributes of scheme, extent of modification, and type of physical activity being considered.

- SR-2 looks at ten 'smart design' principles, including 'creating walkable neighbourhoods'. Just under half of studies (47 percent) reviewed found an association between walkable neighbourhoods and walking in the expected direction (i.e. that creating walkable neighbourhoods is associated with an increase in walking), with a further 3 percent finding an association in the opposite direction. This is in contrast to physical activity, with just 17 percent of studies finding an association between creating walkable neighbourhods and physical activity in the expected direction and 3 percent in the opposite direction.
- SR-3 finds through a meta-analytical approach that accounts for sample size and quality of articles that walkability has a very strong association with physical activity of older adults (aged 65 and over), and a strong association with walking by this age group. Other elements of the built environment also had associations, but the evidence on walkability was amongst the most robust.
- SR-4, by the same authors as SR3, finds that amongst older adults (aged 65 and over) walkability is one of the elements of neighbourhood environment that has the strongest positive association with walking for transportation – this is also one of the most consistent findings in the review. In contrast, the evidence on street connectivity and pedestrian-friendly features is weak, with neutral associations outweighing positive associations and a lower level of statistical significance. The review also looks at within neighbourhood walking, combined walking and cycling for transport, and cycling for transport. Some positive associations with elements of the built environment are found for each but compared to walking for transport the evidence is more limited.

Overall, while the individual studies and systematic reviews suggest some reasons for optimism that improving walkability may increase walking, they are some way from evidencing a strong causal link or providing a clear guide as to how active travel investments could change walkability, what aspects of walkability matter and for whom. The evidence on the causal links between investment in cycling infrastructure and cycling is stronger but limited.

Local economic outcomes

Four studies consider local economic outcomes. One of the studies scored SMS 4, one SMS 3, and two SMS 2. All four of the studies look at benefits that are localised – that is, occurring at locations on or close to the infrastructure investment. In addition, none of the studies consider if there has been any displacement (i.e., whether the infrastructure has led to economic activities relocating). This means we cannot extrapolate to impacts at larger spatial scales.

Two of these studies examine the effect installing cycling infrastructure. Neither study provides a clean estimate of the impact of active travel investment as both also include other changes, such as reductions in on-street parking. The findings are mixed:

- AT-11 (SMS 3) finds that on-street bike lane improvements, alongside the removal of parking spots or a reduction or narrowing of travel lanes in four US cities (Memphis, Minneapolis, Portland, and San Francisco) had either a positive effect on employment and sales in the retail and food service sectors or no effect. In some cases, the improvements led to a shift from food to retail, or vice-versa.
- AT-12 looks at the relationship between cycling infrastructure and business sales in San

Francisco. It finds that installation of cycling infrastructure and reductions in on-street parking generally do not influence business sales. Exceptions include businesses that sell goods for the home and car-related goods and services, which experience a decline in sales when a bike lane is installed.

The other two studies look at existing infrastructure and have limitations in terms of being able to separate out the local economic impacts of specific active travel investments, with one study looking at the transport network as a whole and the other looking at walkability.

- AT-13 (SMS 4) considers transport infrastructure in Hong Kong and finds pedestrianisation 'betweenness' (a measure of how often a point is on the shortest route between a rail station and a destination) increases GVA in four service sectors.
- AT-14 finds that science and technology-related start-ups in two cities in Nebraska (US) are more likely to be located in neighbourhoods with higher walkability scores than established businesses in these sectors.

Overall, the limited evidence available, the variation in outcomes considered, and the mixed findings mean it is difficult to draw any general conclusions on whether investment in active travel infrastructure affects local economic growth.

Property prices

Seven studies examine impacts on property prices Two of the studies scored SMS 3 and five SMS 2. Five studies look at residential prices, one at residential rents, and one at commercial prices. Active travel infrastructure affects accessibility and amenity value. Studies looking at residential prices or rents will estimate the joint effect. Studies looking at commercial property prices are more likely to capture local economic benefits arising from improved accessibility, although it is possible that they capture amenity benefits for employees (e.g., due to a more pleasant commute). These studies cover a diverse range of different factors that might facilitate walking or cycling include road types, traffic calming measures, pedestrianisation, and skywalks, meaning the findings are difficult to generalise.

Four studies consider interventions that improved cycling or walking infrastructure. Two of the studies find no or limited effects.

- AT-15 (SMS-3) from the US finds that only the most effective traffic calming measures affect housing prices on traffic-calmed streets in Portland, with projects decreasing traffic by 16% increasing prices by 1%.
- AT-16 (SMS-3) from Hong Kong looks at commercial property prices, finding skywalks and pedestrian zone schemes have no effect.

The other two studies find positive effects.

- AT-17 from the US examines the effect on house prices of the shift from elevated freeways to street-level boulevards with less capacity in San Francisco following the 1989 earthquake. It finds a positive amenity effect of being close to a boulevard, in contrast to the disamenity effect of being close to a busy freeway. Analysis of traffic data suggests net positive benefits with the improvement in amenity benefits not offset by decline in transportation performance.
- AT-18 from Turkey finds distance from a pedestrian walkway on a major shopping street in a large city has a negative effect on residential rental prices.

The other three studies look at 'walkability'. Two find positive effects and one finds mixed results. As these studies scored SMS 2 and do not evaluate the impact of specific interventions, they should not be considered particularly robust.

- AT-19 finds a positive relationship between walkability and house prices in 13 of 15 housing markets studied across the US, with consumers attaching a positive value to living within easy walking distance of shopping, services, schools and parks.
- AT-20 finds a positive association between 'new urbanist' characteristics such as more interconnected street networks, more and smaller blocks, better pedestrian accessibility to commercial uses, and proximity to light rail stations and property prices. There is a 15.5 percent price premium for houses in blocks with these features.
- AT-21 finds that the relationship between street layout and property values in King County, Washington are sensitive to the way street layout is measured and the type of neighbourhood being considered. For example, there is a positive relationship between more gridiron-like street layouts and property values when one type of measurement is used but a negative relationship when an alternative measure is used. For both measures, a gridiron street layout has a negative effect when the neighbourhood is automobile-orientated.

Again, the limited evidence, the variety of different types of intervention considered, and the mixed findings mean it is not possible to draw general conclusions on whether investment in active travel infrastructure impacts property prices, although walkability does seem to be generally positively associated with increases in property prices.

Other impacts

There is an extensive literature on the links between physical activity and health, including on walking and cycling. Given what we know about the effects of health on the quantity and quality of work people can undertake, improving health is likely to have economic benefits over the longer term. We summarise some of this literature in our rapid evidence review on local green investment which suggests that cycling (as an activity) can have a positive impact on both health and mental health.

In this review, we focus on the narrower literature that looks at whether the ease with which one can walk or cycle in a place has an impact on the health outcomes of its residents. As the health literature is extensive, it is likely that our rapid review may have missed studies that look at this topic.

We found two studies, both of which scored SMS 2. Both studies focus on older populations. The caveats that apply to the walkability studies also apply here.

- AT-22 from Japan finds that the probability of five-year survival for older residents is greater for those having space near their residence for taking strolls, and parks and tree lined streets near their residence.
- In contrast, AT-7 from the US finds that neighbourhood walkability does not affect the proportion of older residents in the overweight or obese range, even though walkability does have an impact on number of self-reported walking sessions (with this later finding discussed earlier in this paper).

The mixed findings from these two studies are echoed in the mixed results reported in a systematic review (SR-5) of the relationship between walking as active transportation and cardiometabolic health outcomes. Walking as active transportation is associated with smaller waist circumference and lower blood pressure but the evidence is relatively low quality. There is no or limited evidence on a relationship between walking as active transportation and high-density lipoproteins, triglycerides, fasting glucose, or cardiometabolic syndrome. In addition, the study could not establish a dose-response relationships between walking as active transportation and any of the cardiometabolic risk factors.

Overall, the evidence on the links between active travel infrastructure and health is limited and lower quality, and the findings are mixed. The reasons for the more mixed findings are unclear.

Annex: Evidence on active travel investment

For this rapid evidence review, we looked for evaluation evidence of active travel infrastructure on local economic and wider outcomes. We searched for studies relating to active travel infrastructure, using a wide range of terms including cycle paths, footpaths, pedestrianisation and traffic calming. We focused on evidence from OECD countries (or similar), published in English. We considered any study providing before-and-after comparisons or cross-sectional studies controlling for differences between areas. We also included more robust studies that compare changes in outcomes in treated areas with changes in outcomes in similar non-treated areas.

We found 22 studies. Of these, one is assessed as SMS 4, five SMS 3, and 16 as SMS 2. In summarising the evidence, we place greater emphasis on studies that used more robust methods. Four studies are from the UK, 10 from the US, two from Japan, two from Hong Kong and one each from Australia, Canada, Portugal and Turkey. This annex provides a summary of each study.

Our search also identified five systematic reviews. As these studies provide useful insights for policymaking, we include them in the review. It is not possible to score systematic reviews against the Maryland Scientific Methods Scale that we use for individual studies. Care should be taken in interpreting the results as not all studies included in a systematic review may meet our standards (SMS 2 or above).

Walking and cycling

AT-1 (SMS 3, UK) evaluates the impact of the 'mini-Holland' programme to improve cycling, walking and public realm on walking and cycling in three outer-London boroughs (Enfield, Waltham Forest and Kingston). The study uses a difference-in-differences approach, drawing on the People and Places survey. Three waves of the study were analysed, with a baseline of 3,000 respondents and 1,400 respondents in the three follow up waves. Mini-Holland boroughs and non-mini-Holland boroughs are compared, differentiating between areas within the boroughs that are 'high-dose' and 'low-dose' based on proximity to changes made to infrastructure. There is limited evidence of change at the borough level. Individuals living in or near to a mini-Holland scheme are more likely to report increased participation in cycling and walking in the past week, and to report spending more time cycling (13.3 minutes) and walking (28.5 minutes) per week. Individuals in high-dose areas are 13 percent more likely to achieve 140-minutes active travel than people in control areas in wave 3 of the survey. A similar magnitude of change in the amount of past-week walking or cycling is found across all three waves, suggesting lifestyle changes are maintained.

AT-2 (SMS 3, UK) evaluates whether the Cycle SuperHighways (CSH) programme to build segregated cycleways in London increases cycling volumes. The study uses cycling traffic flow data from the London Cycle Monitoring programme from 2014 to 2019, car traffic flow data from the Department for Transport Road Traffic Counts from 2002 to 2019, and accidents from Road Safety Data from the Department for Transport. Data on CSH was obtained from the Transport for London cycling monitoring programme. Using a difference-in-differences model, the study finds that CSH has led to a large increase in cycle traffic, with about 25 percent increase in ridership at opening, increasing by 20 percent each subsequent year. The increase is mostly due to new cyclists and increases in cycling frequency. The study does not find evidence of cyclist displacement or car traffic displacement. The study also finds a significant decrease in accidents per cyclist after a CSH opening.

AT-3 (SMS 2, UK) evaluates how Cycle SuperHighways (CSH) affect the usage of London Cycle Hire. The study covers 52 km of CSH routes and 762 cycle hire docking stations over a period of 5 years. The study identified the docking stations affected by the CSH using a 300 metre buffer and used propensity score matching to select control docking stations. The study finds CSH increases

cycle hire, with the increase 23.3 percent for trips where the destination is within the buffer area, 27.1 percent for trips where the origin is in the buffer and 73.2 percent when both the origin and destination is in the buffer. The study finds that the travel speed using cycle hires is increased by 1.79 km per hour (equivalent to a 19 percent increase).

AT-4 (SMS 2, UK) studies the effect of constructing a 25 km busway with a parallel path for walking and cycling in Cambridge on commuters' mode of travel, trip frequency and distance travelled to work. The study uses data from four waves of a survey, with the first wave undertaken pre-construction. There were 1,164 survey participants in the first wave, declining to 500 in the fourth wave. Exposure to intervention was based on distance from the survey participant's postcode to the busway and path. The study finds that proximity to the busway, after adjustment for commute and other characteristics, is associated with a large decrease in car mode share. Proximity to the busway is also associated with the likelihood of making changes in commute mode choice. In particular, there is an increase in active travel mode share, with commuters living near the busway (4km) almost twice as likely as those living further away (up to 9km) to report a substantial increase in active travel mode share.

AT-5 (SMS 2, Canada) measures the local economic impacts of replacing on-street parking with bike lanes in Bloor Street, Toronto. The study uses a combination of merchant surveys (to estimate customer counts), visitor surveys (to estimate customer spending and visitor frequency), and business property vacancy counts calculated through street-level fieldwork. The study uses a difference-in-differences approach, comparing the treated area (Bloor Street) to a control area (Danforth Avenue). The study finds replacing on-street parking with bike lanes has no negative economic impacts. The proportion of customers driving to the neighbourhood remains unchanged at 9 percent, whilst the proportion arriving on bicycles increases from 8 percent to 22 percent. Survey results show a positive effect of the pilot on cycling as the mode of transport on the day of survey, for retail trips (which includes shopping, services, and restaurants) and for shopping trips, with an increase in those reporting difficulties to find car parking. Overall, monthly customer spending and number of customers served by merchants increased during the pilot, visit frequency on Bloor street went up by 3 days per month, and vacancy rates remained stable. People arriving by bicycle, and those who support bike lanes, report higher monthly spending. More than 70 percent of visitors walked or took transit to Bloor Street both before and after the intervention. These visitors' journeys were mostly unaffected by the street's reconfiguration, and any changes in visiting and spending habits among most visitors were likely in response to factors unrelated to the bike lane. The study also finds that monthly customer spending was related to proximity rather than parking and locally-based visitors 2.6 times more likely to spend at least $100 per month.

AT-6 (SMS 2, Portugal) looks at effects of a street improvement intervention on pedestrian volumes and walking experience. The study analyses the Eixo central project, a large-scale street improvement project implemented in Lisbon from June 2016 to February 2017. It uses a before-and-after analysis comparing walkability and pedestrian volume data in the three intervention areas with an adjacent control area and an external control area (about one km away). Walkability data was assessed using the Indicators of Accessibility and Attractiveness of Pedestrian Environments (IAAPE) framework, which uses a weight function based on seven walkability aspects to determine a final score on a scale of zero to 100. Pedestrian flow data was collected on site on different weekdays and at different times. In addition, a post-intervention survey (802 individuals) was conducted to ask about present and past walking experience. The study finds a significant change in pedestrian volume and walking experience in the treated areas between baseline and follow-up, and a non-significant change in pedestrian volume in the control areas over the same period. In addition, the study finds that greater changes in walkability are associated with greater increases in pedestrian volumes over the same

period and have a more positive impact on the walking experience.

AT-7 (SMS 2, US) analyses the relationship between walkability in neighbourhoods and physical activity and obesity in older men and women. Data from a subset of 936 residents of King County, Washington, aged 65 to 97 years in the Adult Changes in Thought (ACT) study was combined with geographic data from the Walkable and Bikable Communities project, which provided neighbourhood walkability scores. ArcView geographic information was used to geocode each ACT participant's address and create circular buffers of 100, 500 and 1,000 metres around each resident's home to represent distances usually travelled on foot. A cross-sectional model was used to determine the associations between neighbourhood walkability and self-reported walking and body mass index. The study finds a positive association between neighbourhood walkability and self-reported weekly walking sessions in men and women living at a different address in the two years prior to assessment, and in women living at the same address for two years or more. No association is found for men living at the same address for two years or more. There is no association between higher neighbourhood walkability and the proportion of participants in the overweight or obese categories (as measured by body mass index).

AT-8 (SMS 2, Australia) analyses the impact of the built environment (for example, walkability around home and school) and household travel behaviour (i.e. whether an adult accompanies student on journey to school) on active transport to school. The study uses data on 46,562 individuals from 18,152 households from the Victorian Integrated Survey of Travel and Activity (VISTA) between 2012 and 2016. The survey was conducted in Melbourne and Geelong. The study uses a cross-sectional model. Most students (80 percent) had adult accompaniment to school, of which only 28 percent walked or cycled to school. The study finds that higher walkability around home and school, direct travel from home to school, and proximity to school are all positively associated with students engaging in active transportation. Walkability around school is also positively associated with children accruing 20 minutes or more of physical activity through active travel per day. Adult accompaniment, longer distance travelled and adult trip chains (i.e. where the journey from home to school was part of a longer journey) are all negatively associated with active transport.

AT-9 (SMS 2, Japan) looks at the influence of the built environment on pedestrian volumes in different areas in Kunamoto City. The study uses a cross-sectional model using data from a 2017 Kunamoto City Basic Survey, street-view images of Google Maps and data from the Ministry of Land, Infrastructure, Transport and Tourism. Across the city as a whole, five elements are positively associated with pedestrian volumes, with the largest effects observed for the number of train stations per unit area, eye-level buildings, and the number of intersections per unit area. In the city centre, only the number of intersections per unit area is positively associated with pedestrian volumes, whilst in 'local hub' areas (areas where essential urban functions are concentrated, such as commercial, administrative services, medical care, welfare, and education), eight elements are, with the largest effects observed for population density, eye-level roads, and the number of intersections per unit area. In 'living hub' areas (neighbourhoods that include private shops, public halls, and schools), five elements are positively associated with pedestrian volumes, with the largest effects for the number of intersections, population density, and the number of bus stops per unit area. In urban promotion areas (which are lively urbanised areas with many houses and shops) only three factors are positively associated with pedestrian volumes – the number of intersections, restaurants, and the number of bus stops per unit area. In 'urban control areas' (areas that needs to be developed or preserved), the factors with the largest positive association are the number of intersections, residential units, and the number of bus stops per unit area.

AT-10 (SMS 2, US) examines the potential benefits of green street facilities on active transportation and active ageing. Green street facilities are vegetated water catchment basins (similar to rain

gardens). The study included four mostly single-family, suburban residential areas in a neighborhood in Portland – two areas with concentrations of green street facilities and two adjacent control areas matched for socio-demographic and physical characteristics. The study uses 'walkability' data on physical characteristics for each street segment in the study area and conducted a survey to gather subjective data on the attractiveness of the study area for walking (with 748 individuals in 572 households completing the survey). The study uses a cross-sectional model to estimate the effects of roadway characteristics (being on an arterial street or having on-street parking), walking environment characteristics, and adjacent land use characteristics on street segment attractiveness scores. It finds that 'deluxe' green street installations – which have more clear and distinctive green features – are associated with higher segment attractiveness scores than more rudimentary green street facilities, which do not have an effect. Additionally, features such as the presence of parks and on-street parking, separation from vehicle traffic, and pedestrian network connectivity significantly contribute to walking environment attractiveness. By contrast, arterial streets and the presence of convenience stores have a negative effect on attractiveness for walking.

SR-1 analyses the relationship between the built environment and physical activity among adults. This systematic review considered studies published in English from across a range of health, leisure, transportation, social sciences and geographical databases. Through keyword and phrase searches and data cleaning, 33 articles were identified that met the study criteria. Most studies in the review find that the relationship between the built environment and physical activity is either positive or there is no association. The study finds street and pedestrian connectivity (for example, number of intersections) and neighbourhood walkability have a positive effect on the physical activity of adults. These are amongst a number of different elements of the built environment that had an effect. Having looked at a range of different types of physical activity (including recreational walking, transportation walking, general walking, general cycling, combined walking and cycling, and moderate to vigorous physical activity), the strongest evidence relates to the effect of the built environment on transportation walking. The study finds mixed evidence on the effect of new pedestrian and cycle infrastructure, such as the installation of sidewalks, trails, and pathways, on physical activity, with many studies finding no or negative effects, and suggest that these may depend on the attributes of scheme, extent of modification, and type of physical activity.

SR-2 consider whether factors considered as part of 'smart growth planning' are associated with physical activity and body mass. 'Smart growth planning' is defined as the range of housing opportunities and choices, walkable neighbourhoods, distinctive communities with a strong sense of place, mixed land use, open space and critical environmental areas, variety of transportation choices, development directed toward existing communities, and compact building design. Only articles which included at least four elements of smart growth planning were included. The review includes 44 studies. Few studies report significant associations between smart growth principles and physical activity or body mass. There is an association between walkable neighbourhoods and walking in half of the reviewed studies, with this being in the expected direction (i.e. that creating walkable neighbourhoods is associated with an increase in walking) in 47 percent of studies, and in the opposite direction in 3 percent of studies. For physical activity, there is an association between creating walkable neighbourhoods and physical activity in the expected direction in 17 percent of studies, and in the opposite direction in 3 percent of studies.

SR-3 reviews on the association between the built environment and physical activity of older adults (aged 65 and over). This systematic review identified 1,571 potential articles, but after checking and filtering articles, only six articles met the review criteria and were included. The review finds positive correlations between physical activities and a range of environmental attributes, including walkability, safety from crime, access to destinations and services, recreational facilities, parks and public open

spaces, shops and commercial destinations, greenery and aesthetically pleasing scenery, walk-friendly infrastructure, and access to public transport. The strength of associations varies across different environmental attributes, with the evidence on walkability amongst the most robust.

SR-4 assesses the association between neighbourhood physical environment and active travel in older adults (aged 65 and over). The review focuses on five active travel outcomes – total walking for transport, within-neighbourhood walking for transport, combined walking and cycling for transport, cycling for transport, and all active travel combined. The review identified 19,005 studies, with 42 quantitative studies meeting the selection criteria and included in the review. The studies covered seven categories of neighbourhood physical environment – residential density and urbanisation, walkability, street connectivity, access to and availability of service and destinations, pedestrian and cycling infrastructure, aesthetics, cleanliness and order, and safety and traffic. Most studies (35 out of 42) find a positive association between 'total walking for transport' and residential density and urbanisation, walkability, street connectivity, overall access to destinations, and services. Amongst older adults, walkability is one of the elements that has the strongest positive association with walking for transportation. This is also one of the most consistent findings in the review. The review also finds a positive association between neighbourhood physical environment and older adults walking and cycling. Some positive associations are found between elements of the built environment and within neighbourhood walking, combined walking and cycling for transport, and cycling for transport but the evidence is more limited than for walking for transport. The review highlights the cross-sectional nature of the evidence as its main weakness, meaning causality cannot be established. Only four out of 42 studies reviewed addressed the issue of self-selection.

Local economic outcomes

AT-11 (SMS 3, US) investigates whether and how street improvements impact the economic vitality and business performance in surrounding areas. The study uses aggregated trend analysis, difference-in-difference, interrupted time series analysis, and distributional analysis, to examine seven corridors installed between 2008 and 2013, within four selected study cities across the U.S. – Portland, San Francisco, Minneapolis, and Memphis. The study uses employment data from the Longitudinal Employer-Household Dynamics study for the period 2002 to 2015, employment and wage data from the Quarterly Census of Employment and Wages for 2004 to 2015, employment and sales data from the National Establishment Time Series for 1990 to 2015, and retail sales tax data (no period specified). Overall, street improvements either have positive impacts on employment and sales, or no effect. In some cases, the study finds that infrastructure improvements contribute to a shift in industry, from food services to retail establishments or vice-versa.

AT-12 (SMS 2, US) studies the relationship between bicycle infrastructure and business performance in San Francisco. Bicycle infrastructure data was obtained from the San Francisco Municipal Transportation Agency (SFMTA) Bike Network dataset, business performance data was measured from the National Establishment Time Series from 1996 to 2014, and on-street parking data was gathered from Google Street View imagery covering 2007 to 2018. The study used a cross-sectional model of the change in sales over time, isolating the effect of bicycle infrastructure while controlling for characteristics of the business, corridor, and surrounding neighbourhood. Overall, the results suggest that bicycle infrastructure and changes in on-street parking supply generally do not have a significant effect on sales, but effects are mixed among type of businesses – sellers of goods for the home or auto-related goods and services experience a decline in sales when located on corridors with bike lanes, whilst new and existing businesses generally have similar sales, and new restaurants and grocery stores have significantly higher sales than their existing counterparts.

AT-13 (SMS 4, Hong Kong) looks at the wider economic impacts on productivity from rail, road

and walking transport networks. Using historical transport plans from 1994 as instrument for current (2016) transport network infrastructure, the study employs a cross-sectional model and an instrumental variable approach to identify the causal effect of transport network centralities (i.e. local transport accessibility) on productivity. The study uses network science centrality, which is defined as the extent to which locations are connected to other locations through transport networks. The centrality indices used in this study account for features of network design and travel behaviours, and include the full urban rail, road, and pedestrian network. The analysis is conducted at Tertiary Planning Unit-level (TPU, the city's smallest planning unit), and focuses on four key services sectors (financial services, trading and logistics, tourism, and professional and producer services), reflecting Hong Kong's specialism in service sectors. The study finds that a one percent increase in pedestrian betweenness (a measure of how often a point is on the shortest route between a rail station and a destination) is associated with an increase in Gross Value Added (GVA, a measure of economic output) in four service sectors by 0.437 percent.

AT-14 (SMS 2, US) looks at the relationship between neighbourhood walkability and firm location of science and technology-related firms in Lincoln and Omaha in the US state of Nebraska. The study uses data on start-up firms from Crunchbase.com, data on established firms from the online business database ReferenceUSA, and a walkability index from the online service Walk Score. The final sample consists of 88 technology start-ups and 138 established technology firms in Omaha and Lincoln as well as 100 randomly selected firms (all sizes and industries) and 100 randomly selected start-up firms. The study employs a cross-sectional model to assess whether start-up technology firms (founded between 2009 and 2018 and having fewer than 50 employees in 2018) are more likely to locate in walkable urban locations relative to larger, well-established firms and firms in other industries. The study controls for confounding variables such as firms' distance to the central business district and the proportion of start-up or technology firms within a 2 km radius. The study finds that start-up firms are associated with significantly higher walkability scores than established technology firms, and start-up firms have a stronger tendency to cluster.

Property prices

AT-15 (SMS 3, US) looks at the effect of traffic calming interventions on housing prices in urban residential neighbourhoods in Portland. The study uses geo-referenced data on the installation of 1,187 traffic calming devices and implements a hedonic estimation method using difference-in-differences to estimate buyers' marginal willingness to pay for living in homes located on calmed streets compared to those located on adjacent streets. The hedonic price method uses information on house prices along with characteristics of the house and the surrounding land to infer values of the traffic calming. The study uses data on housing and property characteristics from the Multnomah County division of Assessment and Taxation, addresses from the city's open data resources and data on calming devices from the GIS division of the Bureau of Transportation. Properties are included if they are situated on the treated street portion and if a transaction has occurred within three years of installation of a calming device. The study controls for house characteristics and time-fixed effects. Overall, the study finds no effect of traffic calming interventions on house prices. There is, however, an impact where the traffic calming has a significant impact on traffic volume, with calming interventions that decrease traffic by 16 percent raising house prices on treated streets by one percent.

AT-16 (SMS 3, Hong Kong) examines the effect of skywalk networks and pedestrian zone schemes on property prices in office towers and retail streets. The study applies a hedonic regression in a difference-in-differences framework to estimate the net capitalisation effects of pedestrianisation on commercial properties within two comparable areas on Hong Kong Island (skywalk networks) and three comparable areas in Kowloon (pedestrian zone schemes). The study uses data on office

and retail transaction records for the periods 1994 to 1996 and 2005 to 2007 (pre-expansion and post-expansion of skywalk network schemes) for Hong Kong Island, and retail transaction records for 1997 to 1999 and 2010 to 2012 (pre-implementation and post-implementation of pedestrian zone schemes) for Kowloon. The study controls for district, year, and quarter fixed effects. With the exception of office units connected by footbridges for rail accessibility, the study finds no effect of the skywalk networks on office and retail property prices (across four different variables). Similarly, pedestrian zone schemes do not have an effect on retail property prices in Kowloon. The study highlights an important limitation – the treatment period chosen for the study coincides with the SARS epidemic, which was a severe economic shock to Hong Kong.

AT-17 (SMS 2, US) looks at the effect of replacing elevated freeways with surface-street boulevards on housing prices. The analysis considers properties within a two-mile radius of two separate corridors in San Francisco, California – the Embarcadero Freeway and the Central Freeway. Both were severely damaged by the 1989 Loma Prieta earthquake, and both freeways were replaced by boulevards opening in 2000 and 2006 respectively. The study combines property sales data from the Metroscan database and data on property location and neighbourhood characteristics from the Association of Bay Area Governments. The final dataset included 9,573 sales transactions between 1986 and 2005 for the Embarcadero corridor and 10,237 sales transactions between 1987 and 2007 for the Central Freeway corridor. Using a difference-in-differences framework to estimate the causal effect of the freeway replacement on housing prices (i.e. hedonic price method), the study finds a positive amenity effect of being located close to the boulevard on housing prices in both cases. This contrasts with the disamenity effect of proximity to a busy freeway prior to the construction of the boulevard. The study finds a net positive benefit, with analysis of traffic data finding that the improvements in amenity benefits are not offset by decline in transportation performance.

AT-18 (SMS 2, Turkey) looks at the impact of a pedestrian walkway on residential rents and the factors affecting this impact. The analysis examines the approximately 500-metre-long Forbes pedestrian walkway, which was established as a pedestrian zone in 1996 and is part of the 1.5 km Forbes Street in Izmir. The study employs cross-sectional analysis to estimate the causal effect of housing characteristics (distance to pedestrian way) and socio-demographic household characteristics (perceived overall quality level of pedestrian way) on the rental price of the property (hedonic price method). The study combines questionnaire survey data on price and structural characteristics of housing and pedestrian way attributes with information from municipal maps. The survey, conducted from April to June 2007, divided the study area into four zones (defined by the distance of properties from the pedestrian walkway), with a final sample size of 140 households across the study area. The study finds a negative relationship between distance to the pedestrian walkway and rental prices and between overall perceived quality of the pedestrian walkway and rental prices.

AT-19 (SMS 2, US) looks at the effect of walkability on house prices in 15 housing markets across the US. The study uses data on 93,725 recent housing transactions from 'ZipRealty', while the walkability score was generated by 'Front Seat' based on the property addresses included in 'ZipRealty'. The walkability score is generated by the Walk Score algorithm, which measures the number of typical consumer destinations (13 different categories ranging from grocery stores to parks and hardware stores) located within a short distance of each property. The study uses a hedonic regression and a cross-sectional model to estimate how much market value homebuyers implicitly attach to houses with higher walkability scores. The hedonic regression decomposes the contribution of each of a house's attritubes to its market price. The study controls for house characteristics like size and age and neighbourhood characteristics such as distance to central business district, proximity to employment opportunities, and neighbourhood income level. The study finds a positive correlation

between walkability and house prices in 13 of the 15 studied markets. The study finds that consumers attach a positive value to living within easy walking distance of shopping, services, schools and parks. Holding all other factors constant, a one-point increase in average walkability is associated with a $700 to $3,000 increase in value for a typical house. The property value premium for walkability seems to be higher in more populous urban areas and those with extensive transit.

AT-20 (SMS 2, US) looks at the effect of neighbourhood attributes associated with 'new urbanism' on housing prices. The study is conducted at the block-group level, with Washington County (Oregon) divided into 186 block groups. The dataset consists of 48,070 real estate sales transactions from January 1990 to December 2000. The study uses a cross-sectional model to determine the causal effect of urban form on property values using a hedonic pricing model. To identify the price premium associated with new urbanism, a hypothetical neighbourhood is compared with an exemplary new urbanism neighbourhood. The study finds statistically significant correlations between housing prices and new urbanist characteristics such as more interconnected street networks, more and smaller blocks, more street miles, better pedestrian accessibility to commercial uses and proximity to operating light rail stations. The study finds a 15.5 percent price premium for houses in blocks with these features.

AT-21 (SMS 2, US) looks at the effect of street layout and retail proximity on property values. The study uses regression analysis in a hedonic price model to analyse data from 38 different census tracts (i.e., neighbourhoods) in King County, Washington. The final dataset includes 25,825 residential sales transactions from January 1989 to October 2003, obtained from the King County Tax Assessor Database, the Seattle Times web page, and the King County GIS map. The study uses two alternative measures to index the street layout of neighbourhoods – a space syntax that measures the design properties of street patterns and an alternative measure based on the ratio of street intersections to street segments. The study finds that neighbourhood street layout has an effect on property values, but the effects are sensitive to the way street layout is measured. A more gridiron-like street layout increases property values using the space syntax model but decreases them when using the 'ratio of intersections to segments' measure. In automobile-oriented neighbourhoods, a more gridiron-like street layout reduces property values when using either measure. Neighbourhood design systematically alters the marginal effects of both travel distance and straight-line distance between residential and retail sites on house prices. In pedestrian-oriented neighbourhoods with highly connected streets, proximity to retail increases property values, while proximity to retail reduces property values in pedestrian-oriented neighbourhoods with less connected streets. In automobile-oriented neighbourhoods, proximity to retail has no effect on property values.

Other impacts

AT-22 (SMS 2, Japan) examines the association between walkable public areas in residential areas and the longevity (five-year survival) of older people (aged 71 and over) in the Tokyo metropolitan area. The study uses data from a 1992 follow-up survey of 3,144 residents of the Tokyo metropolitan area born in 1903, 1908, 1913, and 1918 that were selected in 1989 for the baseline. The study uses data on nine characteristics of the participant's residential environment characteristics captured in the 1992 survey – space near the residence for taking a stroll, presence of a park and tree-lined streets near the residence, noise from automobiles and factories near the residence, the level of crime in the community, hours of sunlight at the residence, existence of a garden at the residence, whether the residence faced a road with a regular bus service, active communication among neighbouring residents, and preference to continue to live in the current community. The study uses cross-sectional analysis to establish associations between each of the residential-environmental factors and five-year survival. The study finds that the probability of five-year survival of older people was greater

for subjects having either a space near their residence for taking strolls or parks and tree lined streets near their residence, as well as among those who preferred to continue to live in their current community. Other findings include a higher probability of survival amongst men who were not subject to noise from automobiles and factories near their residence or who enjoyed sunlight at their residence and a higher probability of survival amongst women who claimed to have active communication with their neighbours and those who preferred to continue to live in their current community.

SR-5 is a systematic review of the relationship between walking for active transportation and adult (aged 18 and over) cardiometabolic health. The researchers found 13 studies (covering 86,193 participants) that met their eligibility criteria. One of the studies was a randomised control trial, four were cohort studies and eight were cross-sectional studies. The most common covariates were age (12 studies), other physical activity (11 studies) and smoking (11 studies). The review finds an association between walking for active transportation and smaller waist circumference or risk of abdominal obesity, and lower blood pressure or hypertension prevalence, but no effect on cardiometabolic risk factor. There is no or limited evidence on a relationship between walking as active transportation and high-density lipoproteins, triglycerides, fasting glucose, or cardiometabolic syndrome.The review recognises that there are a range of measurement issues that affect the robustness of the findings.

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