Wales Centre for Public Policy
Canolfan Polisi Cyhoeddus Cymru

# Infrastructure and long-term wellbeing - commentary

**Josh Coles-Riley and Steve Martin**

April 2022

# Our Mission

The Wales Centre for Public Policy helps to improve policy making and public services by supporting ministers and public service leaders to access and apply rigorous independent evidence about what works. It works in partnership with leading researchers and policy experts to synthesise and mobilise existing evidence and identify gaps where there is a need to generate new knowledge.

The Centre is independent of government but works closely with policy makers and practitioners to develop fresh thinking about how to address strategic challenges in health and social care, education, housing, the economy and other devolved responsibilities. It:

- Supports Welsh Government Ministers to identify, access and use authoritative evidence and independent expertise that can help inform and improve policy;
- Works with public services to access, generate, evaluate and apply evidence about what works in addressing key economic and societal challenges; and
- Draws on its work with Ministers and public services, to advance understanding of how evidence can inform and improve policy making and public services and contribute to theories of policy making and implementation.

Through secondments, PhD placements and its Research Apprenticeship programme, the Centre also helps to build capacity among researchers to engage in policy relevant research which has impact.

For further information please visit our website at [www.wcpp.org.uk](http://www.wcpp.org.uk)

## Core Funders

**Cardiff University** was founded in 1883. Located in a thriving capital city, Cardiff is an ambitious and innovative university, which is intent on building strong international relationships while demonstrating its commitment to Wales.

**Economic and Social Research Council (ESRC)** is part of UK Research and Innovation, a new organisation that brings together the UK's seven research councils, Innovate UK and Research England to maximise the contribution of each council and create the best environment for research and innovation to flourish.

**Welsh Government** is the devolved government of Wales, responsible for key areas of public life, including health, education, local government, and the environment.

# Contents

# Summary


- This report should be read in conjunction with **our evidence review of how infrastructure investments in key policy areas influence long-term wellbeing**.
- Evidence from multiple bodies of research shows that physical infrastructure plays a key role in determining long-term wellbeing.
- Wellbeing is a broad concept, which has been defined in multiple ways. Therefore, infrastructure investments may improve some dimensions of wellbeing but have negative impacts on others.
- The wellbeing impacts of infrastructure investments are often highly context-specific. What works in one place, or one section of the population may not be right for other areas or groups.
- Infrastructure systems are interconnected and interdependent. So, we need integrated, holistic approaches to infrastructure planning that take account of the synergies between projects and their cumulative economic, social and environmental impacts.
- Physical infrastructure has a long lifespan. So it is important to base investment decisions on likely future needs. Adopting iterative approaches that enable needs assessments to be updated in real time helps to build in resilience to future changes, as do flexible designs that enable adaptations in response to unexpected developments.
- How infrastructure is implemented is fundamental to its impact. It is important to combine infrastructure with other initiatives (for example investments in human capital), and to adopt transparent, inclusive, participatory processes that involve local communities in investment decisions.
- Decision-makers inevitably need to make trade-offs that involve prioritising some types of wellbeing over others. One approach is to invest in infrastructure that are known to have positive impacts across several different dimensions of wellbeing – such as nature-based solutions (for example green-blue flood defence infrastructure); insulation retrofit of homes and other buildings; active travel infrastructure; installation of broadband networks; and improvements to bus services.

# Introduction

This commentary report accompanies **a rapid review of evidence about how physical infrastructure influences long-term wellbeing**, commissioned by the Welsh Government to help inform its approach to infrastructure planning and investment.

The review summarises evidence from a wide range of research traditions and disciplines which shows how physical infrastructure has a significant influence on long-term wellbeing. It is clear from the evidence that impacts can be positive and negative depending, in part, on which of the many different dimensions of wellbeing are considered.

Our review provides a summary of evidence about some of the *potential* ways in which investment in infrastructure influences long-term wellbeing, rather than enabling detailed comparisons between different forms of infrastructure, or providing recommendations about what kinds of infrastructure to invest in to have the biggest impact.

The commentary report supplements the evidence in the review by providing additional context and detail, offering further guidance about how findings should be interpreted to inform infrastructure decision-making.

The remaining sections of the report set out:

- Why infrastructure investment matters to long-term wellbeing;
- How the relationship between infrastructure and wellbeing has been understood in different policy and research contexts;
- The implications of different approaches to defining and measuring wellbeing;
- Trade-offs involved in wellbeing approaches to infrastructure decision-making;
- How to interpret the evidence on infrastructure and wellbeing; and
- Implications for infrastructure planning and decision-making to maximise the impacts of infrastructure investment on long-term wellbeing.

# Why infrastructure matters to long-term wellbeing

The insight that physical infrastructure has considerable influence on long-term wellbeing is not a surprising one. On one level, interactions between infrastructure and wellbeing are relatively direct and fundamental (Thacker et al, 2019a). Physical infrastructures provide services which are essential to both economic prosperity and wider societal wellbeing, in particular those services and systems which enable global communications and the movement of key resources, such as energy, transport, water, waste, and information and communications technology (ICT) (Hickford et al, 2016).

It matters for wellbeing that people and communities can access the services and outcomes that physical infrastructures make possible: the supply of energy and water to households and businesses; effective management of wastes and wastewater; protection from natural hazards; the connective capabilities provided by ICT and transport systems in linking people to services, places, and each other; and the institutions and services provided by schools, community venues, hospitals, and government buildings. Individuals and communities depend on effective, well-functioning infrastructure systems for a wide range of wellbeing outcomes (Thacker et al., 2021). On the flipside, poorly planned and delivered infrastructure can have disastrous impacts on people and the environment, accelerating environmental degradation and carbon emissions, and deepening socioeconomic vulnerabilities (UNEP, 2021).

Moreover, infrastructure is critical not only to immediate wellbeing, but also to the wellbeing of future generations. The long-term nature of public infrastructure investments, such as energy, transport, and housing, means that their role in delivering wellbeing outcomes will play out over generational rather than electoral timescales. The consequence of this for infrastructure planning is that:

> **'…investments made in the current electoral cycle will determine emissions, air quality, health, resource efficiency and resilience to climate and transition risks for decades to come'.** (Agarwala and Msulwa, 2021)

The longevity of large-scale physical infrastructure creates both opportunities and risks for promoting long-term wellbeing; the long lifespan of infrastructure assets and their even longer environmental footprint means that both positive and negative impacts are locked in. This is particularly urgent in respect of climate mitigation. The

construction and operation of grey infrastructure (including buildings, transportation, and power generation) currently account for approximately 70% of global greenhouse gas emissions (Saha, 2018). The scale of investment expected in the coming decades to meet rising demand for infrastructure services, combined with the short remaining window of opportunity before unsustainable investments cause irreversible damage to the planet, mean that the consequences of infrastructure decisions made now will define our collective future (UNEP, 2021).

# Understanding the relationship between infrastructure and long-term wellbeing

Despite the defining role which infrastructure plays in influencing long-term wellbeing, investment decisions have often failed to fully address, or sometimes even consider, wellbeing impacts. Historically, they have centred on a narrower economic perspective, privileging cost-benefit analysis (CBA) approaches which seek to monetise inputs and outputs, but are unlikely to accurately represent the range of outcomes valued, or desired by infrastructure users (Adshead et al, 2019).

Studies of infrastructure decision-making highlight that measurement and assessment of the wellbeing implications is still extremely limited in practice, despite increasing efforts within research and policy circles to understand interactions between infrastructure and wellbeing (Lucas et al, 2021). And where wellbeing impacts are considered, they are generally afforded lesser importance than economic impacts within the appraisal process (Mottee et al, 2020).

In this respect, infrastructure decision-making has failed to keep pace with a dramatic rise in interest in wellbeing as a policy goal (Wallace, 2019). In Wales and elsewhere, the ‘wellbeing approach’ to policymaking has sought to go ‘beyond GDP’, and establish collective wellbeing as a core objective of public policy. This places greater focus on measures that can capture broader aspects of people’s living conditions, and the quality of their lives (Exton and Shinwell, 2018).

As the concept of wellbeing as a central aim of public policy has gained prominence internationally, there has also been increased interest in applying a wellbeing lens to prioritising, and appraising, interventions across a range of policy domains. This is reflected in a growing academic literature on the links between policy interventions and wellbeing, including interactions between infrastructure investment and wellbeing specifically. However, understanding the relationship between infrastructure and wellbeing is not a straightforward undertaking, partly because ‘wellbeing’ itself is a

complex term which is defined and measured in different ways across, and within, various research, policy, and practice contexts.

## Approaches to defining wellbeing

One approach which is gaining momentum in policy circles is to use subjective wellbeing data to measure the wellbeing effects of policy interventions. This has the advantage of enabling comparisons of effect sizes, by focusing on a single unit of measurement, such as life satisfaction, an approach which is also supported by an increased availability of high-quality survey data and the development of new methods for using subjective wellbeing evidence in policy appraisal (see e.g., HM Treasury, UK Government, 2021). However, our searches of the literature identified relatively few studies using data on subjective wellbeing to understand the wellbeing effects of infrastructure interventions specifically, though there is a more substantial literature on environmental influences, which are tangential to infrastructure, such as air pollution (e.g. Li & Managi, 2021).

The relatively few such studies that do exist suggest that the evidence is mostly correlational rather than causal. This is partly because it is rare for infrastructure interventions to coincide with the necessary experimental conditions for establishing cause and effect (Thacker et al, 2019), though a lack of understanding of how subjective wellbeing interacts with its covariates has been raised as a limitation with subjective wellbeing approaches more widely (Fabian et al, 2021). An additional limitation of studies using wellbeing data to understand the impacts of infrastructure interventions is that effect sizes tend to be relatively small. However, in the case of infrastructure interventions, relatively small effects also tend to be cumulative because infrastructure projects are usually public works affecting large numbers of people over long periods of time (Fritjers & Krekel, 2021).

A focus on subjective wellbeing may also have limited relevance to policy audiences favouring a multi-dimensional concept of wellbeing, as is the case in Wales, where the governing framework is the Well-Being of Future Generations Act (2015), which establishes collective, long-term wellbeing as the central goal of Welsh policymaking, defining this in terms of social, economic, environmental, and cultural dimensions across a long-term generational timeframe. In other words, data on subjective wellbeing may not fully capture the multi-dimensional and long-term wellbeing impacts prioritised in the Welsh policy context.

Using a multi-dimensional definition of wellbeing has the advantage of bringing into view a much more substantial evidence base on the influence of infrastructure on

wellbeing. For example, ‘a healthier Wales’, one of the seven long-term ‘wellbeing goals’ in the Act, establishes the relevance to decision-makers of the very large number of studies that focus on the health impacts of transport interventions; ‘a more equal Wales’ points to the significance of a similarly substantial literature on energy justice.

The disadvantage of this approach is that it makes it very difficult, if not impossible, to make comparisons across studies, draw conclusions about the relative effect sizes of policy decisions, or synthesise evidence which is likely to have been generated using a diverse array of models and methodologies, data types, and sources of data, according to a wide range of theoretical and methodological assumptions (Thacker et al, 2019). Even where there are standardised metrics for multi-dimensional wellbeing approaches, identifying and mapping the relationships between these is extremely challenging (Exton and Shinwell, 2018). When it comes to policy appraisal, a multi-dimensional approach to wellbeing raises the challenge that the wellbeing impacts of any given policy can therefore take on many forms, some of which are difficult to estimate with any precision (Geurs et al, 2009).

## Navigating wellbeing trade-offs

A multi-dimensional wellbeing approach also raises the (essentially political) problem of how to decide which forms of wellbeing impact should be prioritised in policy decision-making. Perceptions of the relative importance of different forms of wellbeing impact may vary widely, something which becomes problematic where there are conflicting effects (i.e., where for a given policy intervention there are both positive and negative effects across the different dimensions of wellbeing). For example, low emissions standards or charges may disproportionately impact poorer households with less efficient vehicles; at the same time, associated reductions in air pollution may have health benefits for children in densely populated urban areas.

This means that policy decision-makers may in practice be faced with navigating trade-offs between their different wellbeing objectives. It should be noted in the Welsh context that guidance from the Future Generations Commissioner advises policy-makers to focus their efforts on identifying ‘decisions which would have positive outcomes across all wellbeing dimensions, accepting that the benefits might be very different and small [for some dimensions] while others would be significant’ – essentially rejecting any options that entail benefits to one dimension at the expense of costs to another (Future Generations Commissioner in Fritjers & Krekel, 2021). This would also need to account for the ways in which wellbeing effects may be distributed differently across the population (and again, benefits for one group may come at the expense of costs for another). Another solution is that careful policy design to account for distributional impacts may also have the potential to make

outcomes ‘win-win’, through compensation, exemption, re-skilling, and other measures.

A further trade-off dilemma is particularly significant to Welsh policymaking, and applies to both multi-dimensional and subjective wellbeing approaches. This surfaces where there are conflicting effects across a long-term timeframe, i.e., where an intervention has immediate or shorter-term wellbeing benefits but negative long-term effects. Such trade-offs loom particularly large when it comes to the climate impacts of long-lived infrastructure assets., for example where an infrastructure intervention with benefits for jobs and prosperity (and therefore for subjective wellbeing) in the immediate term may be incompatible with the need for deep cuts in greenhouse gas emissions in order to ensure a viable global future (see e.g. Schwanen, 2021).

A recent study provides some empirical insight into this trade-off dilemma by comparing data on countries’ progress towards achieving the UN Sustainable Development Goals (SDGs) with international subjective wellbeing data, finding a positive correlation between most SDGS and wellbeing, apart from SDG12 (responsible production and consumption), and SDG13 (climate action) which are negatively correlated with wellbeing (De Neve and Sachs, 2020). This highlights how countries which perform better against SDG12 and SDG13 tend to have lower subjective wellbeing.

In the case of SDG13 (climate action), this negative correlation becomes an insignificant one when accounting for countries’ levels of economic development, suggesting that for countries that perform poorly against SDG13, higher levels of economic development drive both higher greenhouse gas emissions, and higher subjective wellbeing. However, the presence of outlier countries, with both higher subjective wellbeing and stronger relative performance against SDG12 and SDG13, also suggests that the relationship is not an inevitable one, and that policy options are available to simultaneously deliver long-term climate mitigation, and shorter-term wellbeing benefits, including economic prosperity.

As De Neve and Sachs (2020) argue, the negative correlation between subjective wellbeing and progress on climate action reflects the reliance of our current economic systems on ever-increasing, emissions-intensive consumption, and production to provide employment and support livelihoods. However, the argument is also increasingly being made for both the viability and necessity of climate-compatible economic development in the context of wider shifts in the global economy. From this perspective, investments in fossil-fuel intensive infrastructure are also short-sighted in an economic sense, as infrastructure investments that were previously assets become expensive liabilities in the transition to a low-carbon, resource efficient global economy (Zenghelis, 2021).

By the same token, there is growing evidence that investments in sustainable assets, such as clean energy infrastructure, already demonstrate improved economic returns compared to fossil fuel investments, a case which has been further strengthened by the falling costs of key technologies over the last decade (Stern et al, 2020). Other climate-compatible infrastructure investments for which there is increasingly strong evidence for economic benefits include insulation retrofits, active travel infrastructure, installing broadband networks, planting trees, and restoring wetlands (Stern et al, 2020).

## Interpreting the evidence on infrastructure and wellbeing

For our rapid review of evidence, we were asked by the Welsh Government to use a multi-dimensional definition of wellbeing, based on **the ten wellbeing objectives of the current Programme for Government**. The multi-dimensional nature of this definition meant that many different bodies of research were relevant to the review, often focusing on different forms of wellbeing impact and using different types of data and methodology. The breadth of this literature meant that we relied largely on existing systematic reviews, both to understand key messages from the literature and for judgements about the quality of the evidence available.

Overall, the evidence shows that infrastructure has considerable influence on long-term wellbeing, interacting with multiple dimensions of wellbeing in multiple ways, both positively and negatively. For the reasons set out above, we advise interpreting the review as a summary of evidence about some *potential* ways in which investment in infrastructure influences long-term wellbeing, rather than enabling detailed comparisons between different forms of infrastructure or providing recommendations about what kinds of infrastructure to invest in to have the biggest impact.

There is broad agreement in the literature that the relationship between infrastructure and wellbeing is highly context-specific and mitigated by multiple factors - including place and population characteristics, current and projected trends in demand for infrastructure services, and the complex and dynamic interdependencies that exist between infrastructure systems and between these systems, and the natural environment (Agarwala and Msulwa, 2021; Clapham, 2021; UNOPS, 2021; UNEP, 2021; Schwanen, 2021). Thus, decisions about what infrastructure investments to prioritise to best promote long-term wellbeing are dependent on a wide range of factors beyond the type of infrastructure under consideration, and beyond what evidence suggests *might be* some of the ways in which that form of infrastructure interacts with different dimensions of wellbeing over a multi-generational timeframe.

Another way of interpreting the rapid review is to view it as identifying some forms of infrastructure which hold *promise* for minimising trade-offs, and maximising synergies

across the different dimensions of long-term wellbeing. While trade-offs between costs and benefits across different dimensions of wellbeing are common features of infrastructure projects, particularly large-scale infrastructure (Hall et al., 2017, Zualanga et al., 2021), a small number of types of infrastructure investment were identified by the review as having particular promise for reducing trade-offs, and maximising co-benefits across social, economic, and environmental dimensions of wellbeing (accepting that the extent to which these benefits will be realised is dependent on the contextual factors discussed above). These include:

- nature-based solutions, for example green-blue flood defence infrastructure;
- insulation retrofit of homes and other buildings;
- active travel infrastructure;
- installation of broadband networks; and
- improvements to bus services.

In a briefing written to inform this commentary, Zenghelis (2021) points out that there are wellbeing benefits to regional investments that attract low-carbon, resource-efficient industries, which are well placed to take advantage of growing markets in the future. Building supply networks and knowledge and production clusters for these industries can be regarded as a sensible risk-opportunity based investment, likely to support future prosperity and wellbeing, with far less long-term risk than alternatives which involve locking into high carbon infrastructure and behaviours.

In addition to this there are infrastructure investments which are likely to involve some shorter-term wellbeing trade-offs, but which may play an essential part in meeting climate mitigation targets, particularly the different forms of infrastructure investment associated with decarbonising transport, and energy systems. The problem this presents for policymakers is how to reduce and mitigate these trade-offs to acceptable levels – for example, in the case of equity impacts, this is most often discussed in terms of the need for policies to support a just transition (for a review, see Wang & Lo, 2021).

## Maximising the potential of infrastructure to promote long-term wellbeing

While it is possible to draw conclusions from the evidence about which forms of infrastructure investment are likely to hold particular promise for maximising co-benefits and minimising trade-offs across multiple dimensions of wellbeing, studies of infrastructure decision-making also strongly caution against an isolated approach which focuses infrastructure decisions at the level of individual projects (Agarwala and Msulwa, 2021), and fails to account for the interdependencies between

infrastructure systems (Hall et al, 2017; UNEP, 2021; Kanmouh et al, 2021). Indeed, studies are consistent in identifying some specific features of infrastructure and infrastructure systems which need to be considered and addressed in infrastructure decision-making, in order to realise the potential of infrastructure investments to promote long-term wellbeing:

1. **Infrastructure decisions are context-specific.** Making the right choices about infrastructure depends on in-depth knowledge of both the systems that are to be provided, and the context in which they will operate. Context-specific spatial and geographic considerations should be addressed at the planning stage, in order to harness local features, resources and conditions, and minimise negative socioeconomic or environmental impacts (Agarwala and Msuwla, 2021; Clapham, 2021; Schwanen, 2021; UNOPS, 2021; UNEP, 2021)
2. ***How* infrastructure is implemented is fundamental to wellbeing outcomes**. In many contexts, a single infrastructure intervention will be insufficient to realise wellbeing benefits, unless combined with other policy interventions and (non-capital) spending. For example, evidence suggests that local economic benefits of infrastructure investment may only fully emerge when accompanied by complementary policies and investments in human capital (Thacker et al, 2019). Similarly, evidence on green-space interventions indicates that these are significantly more effective in delivering wellbeing benefits where changes to the physical environment are accompanied by measures to raise awareness and promote community use (Hunter et al, 2019). Infrastructure experts also highlight the importance to the relationship between infrastructure and wellbeing of involving people and communities in investment decisions that directly affect them, with transparent, inclusive, and participatory decision-making and inclusive and meaningful stakeholder consultation at a local level (Agarwala and Msulwa, 2021; Clapham, 2021; Schwanen, 2021; UNOPS, 2021).
3. **Infrastructure systems are interconnected.** Many interdependencies exist between different infrastructure systems and sectors, for example where demand for one infrastructure service is highly correlated with demand for another, or when one infrastructure system has the potential to consume a significant proportion of the capacity of another. This highlights the need for an integrated, holistic approach to infrastructure planning and decision-making, as opposed to approaches which focus decision-making at the level of individual projects, failing to account for synergies and interdependencies between infrastructure systems or their cumulative social and environmental impacts. By contrast, viewing infrastructure as a 'system of systems' allows trade-offs and synergies between different projects and sectors to be balanced against one another, enabling more efficient use of infrastructure investment to deliver services and promote long-

term wellbeing. Moreover, failure to account for the interactions between different systems across the lifecycle threatens the long-term viability of these systems, and can have broader social and environmental ramifications (Hall et al, 2017; UNEP, 2021; Kanmouh et al, 2021; UNOPS, 2021; Thacker et al, 2019).

4 **Infrastructure has a long lifespan.** As previously discussed, the longevity of infrastructure assets introduces high potential for lock-in of both positive and negative impacts (Thacker et al, 2019) and vulnerability to economic dislocation (Coyle et al, 2020). The long lifespan of infrastructure assets also means that infrastructure planning must contend with a wide range of future uncertainties associated with demographic, economic, environmental, political, and technological changes, all of which are likely to have significant effects on the demands and requirements of infrastructure systems (Hifckford et al, 2016). This means that evidence about 'what has worked' previously may have limited relevance in a context where the global conditions for infrastructure services are changing so rapidly (Zenghelis, 2021). On a more practical note, technology that increases the future flexibility of infrastructure assets can help reduce the risks of uncertainty and increase resilience to shocks (UNOPS, 2021). For example, planning for modular capacity growth can promote solutions that are adaptive to uncertain future scenarios (Adshead et al, 2019). Beyond this, there is a need for accurate modelling of future demand and capacity to inform infrastructure planning, with the ability to assess a wide range of future conditions and policy interventions (Blainey & Preston, 2019). Another option is to use iterative infrastructure assessments that are updated and informed in real-time by the most recent data, better enabling decision-makers to plan infrastructure interventions in the context of uncertainty (Adshead et al, 2019).

5 **The construction of infrastructure is expensive and uses vast amounts of natural resources.** In addition, infrastructure assets contribute to other types of air, ground, and water pollution during construction, operation, and decommissioning and are responsible for a large volume of solid waste. From this perspective, minimising the negative long-term impacts of infrastructure systems means seeking in the first instance to minimise the amount of new infrastructure that is constructed. This can be achieved by using integrated, service-needs-based approaches, informed by detailed and accurate data and modelling about demand and capacity. Planners should prioritise options to reduce demand where possible, invest in nature-based solutions, and upgrade or repurpose existing infrastructure before considering the construction of new infrastructure assets (UNOPS, 2021).

To maximise the potential of infrastructure investments to promote long-term wellbeing, a wide range of different sources of insight need to be obtained and incorporated into infrastructure planning and decision-making. There is broad

agreement that decisions about infrastructure investment should not be taken in isolation at the level of individual projects. Instead, infrastructure decisions should reflect the outcome of an integrated, holistic, and long-term strategy for the sustainable delivery of infrastructure services, based on comprehensive data and forecasting about demand and capacity, including analysis of infrastructure system interdependencies, and regular monitoring of system performance and impacts, combined with detailed knowledge of the contexts in which infrastructure will operate, and consideration of local geographic, spatial, and socioeconomic conditions.

While the task is a complex one, a range of tools, strategies, and guidance are available to decision-makers - including strategic foresight, scenario analysis and computer-based modelling (Thacker et al, 2019; UNOPS, 2021). In the Welsh policy context, there is a need to combine such approaches with a process for understanding the effects of infrastructure interventions on multiple dimensions of wellbeing, across a range of spatial scales and a multi-generational timeframe (for one approach to accounting for multiple forms of wellbeing impact in policy prioritisation, see HM Treasury, UK Government, 2021). The relevance of the evidence included in our rapid review is that it indicates some potential ways in which different forms of infrastructure investment might influence the different dimensions of wellbeing of interest to Welsh policymakers. Given the defining role of infrastructure in long-term social, economic, and environmental wellbeing, understanding both general and local interactions between physical infrastructure and wellbeing is of considerable importance to decision-makers.

# References


Adshead, D., Thacker, S., Fuldauer, L. I. & Hall, J. W. (2019). **Delivering on the Sustainable Development Goals through long-term infrastructure planning.** Global Environmental Change, 59.

Agarwala, M. & Msulwa, R. (2021). Infrastructure, Wellbeing, and the Wealth Economy. [Unpublished briefing note]

Alves, A., Vojinovic, Z., Kapelan, Z., Sanchez, A. & Gersonius, B. (2020). **Exploring trade-offs among the multiple benefits of green-blue-grey infrastructure for urban flood mitigation.** Science of the Total Environment, 10, 239-254.

Alves, A., Patino Gomez, J., Vojinovic, Z., Sanchez, A. & Weesakul, S. (2018). **Combining co-benefits and stakeholders' perceptions into green infrastructure selection for flood risk reduction.** Environments, 5, 29-51.

Ashley, R., Gersonius, B., Digman, C., Horton, B., Smith, B. & Shaffer, P. (2018). **Including uncertainty in valuing blue and green infrastructure for stormwater management.** Ecosystem Services, 33, 237-246.

Baars, S., Schellings, G., Krishnamurthy, S. & Joore, P. (2021). **A framework for exploration of relationship between the psychosocial and physical learning environment.** Learning Environment Research, 24, 43–69.

Bagnall, A., South, J., Di Martino, S., Southby, K., Pilkington, G., Mitchell, B., Pennington, A. & Corcoran, R. (2018). **A systematic review of interventions to boost social relations through improvements in community infrastructure (places and spaces).** Retrieved from: **Places-spaces-people-wellbeing-full-report-MAY2018-1_0119755600.pdf (whatworkswellbeing.org)**

Baker, E., Lester, L. H., Bentley, R. & Beer, A. (2016). **Poor housing quality: prevalence and health effects.** Journal of Prevention and Intervention, 44, 219-232.

Barrett, P. (2015). **The impact of classroom design on pupils' learning: Final results of a holistic, multi-level analysis.** Building and Environment, 89, 118-133.

Beer, A., Baker, E., Wood, G. & Raftery, P. (2011). **Housing policy, housing assistance, and the wellbeing dividend: developing an evidence base for post-GFC economies.** Housing Studies, 26, 1171-1192.

Berry, P. M., Brown, S., Chen, M., Kontogianni, A., Rowlands, O., Simpson, G. & Skourtos, M. (2015). **Cross-sectoral interactions of adaptation and mitigation measures.** Climactic Change, 128, 381-393.

Blainey, S. P. & Preston, J. M. (2019). **Predict or prophesy? Issues and trade-offs in modelling long-term infrastructure demand and capacity.** Transport Policy, 74,165-173.

Bowen, K. & Lynch, Y. (2017). **The public health benefits of green infrastructure: The potential of economic framing for enhanced decision-making.** Current Opinion in Environmental Sustainability, 25, 90-95.

Brand, C., Anable, J., Ketsopoulou, I. & Watson, J. (2020). **Road to zero or road to nowhere? Disrupting transport and energy in a zero carbon world.** Energy Policy, 139.

Burgess, G. & Holmes, H. (2021). **New horizons: digital exclusion and the importance of getting online.** Retrieved from: **https://www.cchpr.landecon.cam.ac.uk/files/media/new_horizons_digital_exclusion_report_final.pdf**

Calvillo, C.F. & Turner, K. (2020). **Analysing the impacts of large-scale EV rollout in the UK - how can we better inform climate and environmental policy?** Energy Strategy Reviews, 30.

Cairns, J., Warren, J., Garthwaite, K., Greig, G. & Bambra, C. (2015). **Go slow: an umbrella review of the effects of 20 mph zones and limits on health and health inequalities.** Journal of Public Health, 37, 3, 515-520.

Carmona, M. (2019). **Place value: place quality and its impact on health, social, economic, and environmental outcomes.** Journal of Urban Design, 24, 1-48.

Centre for Ageing Better (2020). **Homes, health, and Covid-19.** Retrieved from: **https://ageing-better.org.uk/sites/default/files/2021-08/Homes-health-and-COV19-poor-quality-homes.pdf**

Centre for Cities (2020). **Getting moving: where can transport investment level up growth?** Retrieved from: **https://www.centreforcities.org/wp-content/uploads/2020/03/Getting-moving-transport-infrastructure-in-cities-2020.pdf**

Chambers, D., Cantrell, A., Preston, L., Peasgood, T., Paisley, S. & Clowes, M. (2018). **Housing for vulnerable people: systematic review of the evidence on**

**housing interventions for 'housing vulnerable' adults and its relationship to wellbeing.** Retrieved from: **https://eprints.whiterose.ac.uk/131241/1/Housing-evidence-review-may-2018.pdf**

Chatterjee, K., Clark, B., Nguyen, A., Wishart, R., Gallop, K., Smith, N. & Tipping, S. (2019). **Access to transport and life opportunities.** Retrieved from: **https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/831766/access_to_transport_report.pdf**

Choi, C., Berry, P. & Smith, A. (2021). **The climate benefits, co-benefits, and trade-offs of green infrastructure: a systematic literature review**. Journal of Environmental Management, 291.

Clapham, D. (2021). **The impact of housing investment on wellbeing**. [Unpublished briefing note]

Clapham, D., Foye, C. & Christian, J. (2018). **The concept of subjective well-being in housing studies.** Housing, Theory and Society, 261-80.

Cooper, E., Gates, S., Grollman, C., Mayer, M., Davis, B., Bankiewicz, U., & Khambhaita, P. (2019). **Transport, health, and wellbeing: an evidence review for the Department of Transport.** Retrieved from: **https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/847884/Transport__health_and_wellbeing.pdf**

Cowell, R., Ellis, R., Sherry-Brennan, F., Strachan, P. A. & Toke, D. (2017). **Sub-national government and pathways to sustainable energy.** Environment and Planning C, 35, 1139-1155.

Coyle, D., Zenghelis, D., Agarwala, M., Felici, M., Lu, S. & Wdowin, J. (2020). **Valuing wealth, building prosperity: Wealth Economy project on natural and social capital first year report to Letter One.** Retrieved from: **https://www.bennettinstitute.cam.ac.uk/media/uploads/files/WER_layout_March_2020_ONLINE_FINAL_Pdf_1.pdf**

DCMS (2018). **Evaluation of the economic impact and public value of the Superfast Broadband Programme: final report.** Retrieved from: **https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/734855/Superfast_Integrated_Report.pdf**

De Neve, J. & Sachs, J. D. (2020). **The SDGs and human well-being: a global analysis of synergies, trade-offs, and regional differences.** Nature Research Scientific Reports, 10.

Department for Transport (2015). **Transport accessibility: rapid evidence review.** Retrieved from: **https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/939955/rapid-evidence-review.pdf**

Department for Transport (2021). **Switching to sustainable transport: a rapid evidence assessment.** Retrieved from: **https://www.gov.uk/government/publications/switching-to-sustainable-transport-a-rapid-evidence-assessment**

Education Endowment Foundation (2021). **Education evidence: early years toolkit.** Retrieved from: **https://educationendowmentfoundation.org.uk/education-evidence/early-years-toolkit**

Elvik, R. (2017). **Road safety effects of roundabouts: a meta-analysis.** Accident Analysis and Prevention, 364-371.

Evans, G., Yoo, M. J. & Sipple, J. (2010) .**The ecological context of student achievement.** Journal of Environmental Psychology, 30, 239-244.

Extin, C. & Shinwell, M. (2018). **Policy use of wellbeing metrics: describing countries' experiences.** Retrieved from: **https://www.oecd-ilibrary.org/economics/policy-use-of-well-being-metrics_d98eb8ed-en**

Fabian, M., Agarwala, M., Alexandrova, A., Coyle, D. & Felici, M. (2021). **Wellbeing public policy needs more theory.** Retrieved from: **https://www.bennettinstitute.cam.ac.uk/media/uploads/files/WPP_needs_more_theory_working_paper.pdf**

Freeman, R. & Ekins, P. (2021). **Decarbonising energy and the energy transition.** Retrieved from: **https://www.ucl.ac.uk/bartlett/news/2021/apr/decarbonising-energy-and-energy-transition**

Flanagan, K. et al. (2019). **A conceptual analysis of social housing as infrastructure.** Retrieved from: **https://www.ahuri.edu.au/research/final-reports/309**

Frijters, P. & Krekel, C. (2021). **A handbook for wellbeing policy-making**. Oxford: Oxford University Press.

Geurs, K. T., Boon, W. & Van Wee, B. (2009). **Social impacts of transport: literature review and the state of the practice of transport appraisal in the Netherlands and the United Kingdom.** Transport Reviews, 29, 1, 69-90.

Geels, F., Schwanen, T., Sorrel, S., Henkins, K. & Sovacool, B. J. (2018). **Reducing energy demand through low carbon innovation: a sociotechnical transitions perspective and thirteen research debates.** Energy Research and Social Science, 40, 23-45.

Gibb, K., Lawson, L., Williams, J. & McLaughlin, M. (2020). **The impact of social housing: economic, social, health and wellbeing.** Retrieved from: **https://www.sfha.co.uk/mediaLibrary/other/english/66627.pdf**

Gossling, S., Nicolosi, J. & Litman, T. (2021). **The health cost of transport in cities.** Current Environmental Health Reports, 8, 196-201.

Grey, C. N. B., Jiang, S., Nascimento, C., Rodgers, S. E., Johnson, R., Lyons, R. A. & Poortinga, W. (2017). **The short-term health and psychosocial impacts of domestic energy efficiency investments in low-income areas: a controlled before and after study.** BMC Public Health, 17.

Hall, J. W., Thacker, S., Ives, M. C., Cao, Y., Chaudry, M., Blainey, S. P. & Oughton, E. J. (2017). **Strategic analysis of the future of national infrastructure.** *Civil Engineering* 170, 39-47.

Henderson, D. (2017). **Assessing the impact of business broadband use on the Welsh economy.** Welsh Economic Review, 28-36.

Hepburn, C., O' Callaghan, B., Stern, N., Stiglitz, J. & Zenghelis, D. (2020). **Will Covid-19 fiscal recovery packages accelerate or retard progress on climate change?** Oxford Review of Economic Policy, 36.

Horne, R. (2018). **Housing sustainability in low carbon cities.** London: Routledge.

Hickford, A. J., Nicholls, R. J., Otto, A., Hall, J. W., Blainey, S. P., Tran, M. & Baruah, P. (2016). **Creating an ensemble of future strategies for future infrastructure provision.** Futures, 66, 13-24.

HM Treasury (2021). **Wellbeing guidance for appraisal: supplementary Green Book guidance.** Retrieved from: **https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1005388/Wellbeing_guidance_for_appraisal_-_supplementary_Green_Book_guidance.pdf**

Hunter, R. F., Cleland, C., Cleary, A., Droomers, M., Wheeler, B. W., Sinnet, D., Nieuwenhuijsen, M. J. & Braubach, M. (2019). **Environmental, health, wellbeing, social and equity effects of urban green space interventions: A meta-narrative evidence synthesis**. Environment International, 130.

Hunter, R.F., Christian, H., Veitch, J., Astell-Burt, T., Hipp, A. & Schipperijn, J. (2015). **The impact of interventions to promote physical activity in urban green space: a systematic review and recommendations for future research.** Social Science & Medicine, 124, 246-256.

Kamal, A., Al-Ghamdi, S. G. & Koc, M. (2019). **Revaluing the costs and benefits of energy efficiency: a systematic review.** Energy Research and Social Science, 54, 68-84.

Kanmouh, O., Nogal, M., Binnekamp, R. & Wolfert, R. (2021). **Multi-system intervention optimization for interdependent infrastructure.** Automation in Construction, 127, 1-11.

Katris, A., Turner, K. & Stewart, J. (2021). **Meeting the UK's energy efficiency goals: securing greater wider economy benefits through longer term programmes.** Retrieved from: **https://strathprints.strath.ac.uk/77545/1/Katris_etal_CEP_2021_Meeting_the_UKs_energy_efficiency_goals_securing_greater_wider_economy_benefits.pdf**

King's Fund (2016). **The economics of housing and health: the role of housing associations.** Retrieved from: **https://www.kingsfund.org.uk/sites/default/files/field/field_publication_file/Economics_housing_and_health_Kings_Fund_Sep_2016.pdf**

Krekel, C & Zerrahn, A. (2017). **Does the presence of wind turbines have negative externalities for people in their surroundings? Evidence from well-being data.** Journal of Environmental Economics and Management, 82, 221-238.

Lucas, K., Philips, I. & Verlinghieri, E. (2021). **A mixed methods approach to the social assessment of transport infrastructure projects.** Transportation.

Lucas, K. (2019). **A new evolution for transport-related social exclusion research?** Journal of Transport Geography, 81.

Li, Y. & Managi, S. (2021). **Spatial variability of the relationship between air pollution and well-being.** Sustainable Cities and Society, 76.

Maclennan, D., Randolph, B., Crommelin, L., Witte, E., Klestov, P., Scealy, B. & Brown, S. (2019). **Strengthening economic cases for housing policies.** Retrieved from: **https://cityfutures.ada.unsw.edu.au//research/projects/strengthening-economic-cases-housing-productivity-gains-better-housing-outcomes/**

Mackett, R. L. (2021). **Policy interventions to facilitate travel by people with mental health conditions.** Transport Policy,110, 306-313.

Maidment, C., Jones, C. R., Webb, T. L., Hathway, E. A. & Gilbertson, J. M. (2014). **The impact of household energy efficiency measures on health: a meta-analysis.** Energy Policy, 65, 583-593.

Marsden, G., Anable, J., Chatterton, T., Docherty, I., Faulcobridge, J., Murray, L., Roby, H. & Shires, J. (2020). **Studying disruptive elements: innovations in behaviour, opportunities for lower carbon transport policy?** Transport Policy, 94, 89-101.

Martorell, P., Stange, K. & McFarlin, I. (2016). **Investing in schools: capital spending, facility conditions, and student achievement**. Journal of Public Economics, 140, 13-29.

Mottee, L. K. (2020). **Reflecting on how social impacts are considered in transport infrastructure project planning: looking beyond the claimed success of Sydney's South West Rail Link.** Urban Policy and Research, 38, 3, 185-198.

National Infrastructure Commission (2018). **National infrastructure assessment.** Retrieved from: **https://nic.org.uk/app/uploads/CCS001_CCS0618917350-001_NIC-NIA_Accessible-1.pdf**

Nellthorp, J. & Ojeda-Cabral, M. (2021). **Residual values and appraisal period in multimodal transport appraisal.** Retrieved from: **https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/984207/rvs-and-appraisal-period.pdf**

Nelson, S. & Allwood, J. M. (2021). **Technology or behaviour? Balanced disruption in the race to net zero emissions.** Energy Research and Social Science, 78.

Nygaard, C. (2019). **Social and affordable housing as social infrastructure.** Retrieved from: **https://www.communityhousing.com.au/wp-content/uploads/2019/11/Social-and-affordable-housing-as-social-infrastructure-FINAL.pdf?x12261**

O' Donnell, E. & Thorne, C. R. (2020). ‘Urban flood risk management: the Blue-Green advantage.', in Thorne, C. R. ed. (2020) **Blue-Green cities: integrating urban flood risk management with green infrastructure.** ICE Publishing.

Ojeda-Cabral, M., Dekker, T., Batley, R. & Matthews, B. (2020). **Valuation and appraisal of accessibility in rail: an appraisal framework for improvements in accessibility for all – final report.** Retrieved from: https://www.sparkrail.org/Lists/Records/DispForm.aspx?ID=26839.

Palmas, C., Rode, C. & Lovett, A. A. (2019). 'Renewable energy production capacities and goods' in Albert, C. ed. (2019). **Landscape planning with ecosystem services: Theories and methods for application in Europe.** Springer Netherlands.

Park, J. & Chowdhury, S. (2018). **Investigating the barriers in a typical journey by public transport users with disabilities.** Journal of Transport & Health, 10, 361-368.

Quality of Life Foundation (2019). **Literature review of quality of life in the built environment.** Retrieved from: **https://www.qolf.org/literature-review/**

Saha, D. (2018). **Low-carbon infrastructure: an essential solution to climate change?** Retrieved from: **https://blogs.worldbank.org/ppps/low-carbon-infrastructure-essential-solution-climate-change**

Schwanen, T. (2021). **Infrastructure and wellbeing in Wales.** [Unpublished briefing note]

Sharifi, A., Pathak, M., Joshi, C. & Bao-Jie, H. (2021). **A systematic review of the health co-benefits of urban climate change adaptation.** Sustainable Cities and Society, 74.

Smith, M., Hosking, J., Woodward, A., Witten, K., MacMillian, A., Field, A., Baas, P. & Mackie, H. (2017). **Systematic review of built environment effects on physical acivity and active transport.** International Journal of Behavioural Nutrition and Physical Activity, 14.

Spray, J., Witten, K., Wiles, J., Anderson, A., Paul, D., Wade, J. & Ameratunga, S. (2020). **Inequitable mobilities: Intersections of diversity with urban infrastructure influence mobility, health and wellbeing.** Cities & Health.

Steer, J. (2020). **Transport across the UK - the required revolution.** Town and Country Planning, 89, 404-9.

Stern, N., Unsworth, S., Valero, A., Zenghelis, D., Rydge, J. & Robins, N. (2020). **Strategy, investment and policy for a strong and sustainable recovery: an action plan.** Retrieved from: **https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2020/07/Strategy-investment-and-policy-for-a-strong-and-sustainable-recovery.pdf**

Thacker, S., Adshead, D., Fay, M., Hallegatte, S., Harvey, M., Meller, H., O'Regan, N., Rozenberg, J., Watkins, G. & Hall, J. W. (2019a). **Infrastructure for sustainable development.** Nature Sustainability, 2, 324-331.

Thacker, S., Adshead, D., Crosskey, S., Bajpai, A., Ceppi, P, Hall, J. W. & O' Regan, N. (2019b) **Infrastructure: underpinning sustainable development.** Retrieved from: **https://content.unops.org/publications/Infrastructure_underpining_sustainable_development_EN.pdf**

Thacker, S., Adshead, D., Fantini, C., Palmer, R., Ghosal, R., Adeoti, T., Morgan, G. & Stratton-Short, S. (2021). **Infrastructure for climate action.** Retrieved from: **https://content.unops.org/publications/Infrastructure-for-climate-action_EN.pdf**

Twohig-Bennett, C. & Jones, A. (2018). **The health benefits of the great outdoors: a systematic review and meta-analysis of greenspace exposure and health outcomes.** Environmental Research, 166, 628-637.

UK Committee on Climate Change (2019). **UK housing – fit for the future?** Retrieved from: **https://www.theccc.org.uk/publication/uk-housing-fit-for-the-future/**

UK Committee on Climate Change (2020). **The Sixth Carbon Budget: the UK's path to net zero.** Retrieved from: **https://www.theccc.org.uk/wp-content/uploads/2020/12/The-Sixth-Carbon-Budget-The-UKs-path-to-Net-Zero.pdf**

UNEP (2021). **International good practice principles for sustainable infrastructure: integrated, systems-level approaches for policymakers.** Retrieved from: **https://www.unep.org/resources/publication/international-good-practice-principles-sustainable-infrastructure**

Verlinghieri, E. & Schwanen, T. (2020. **Transport and mobility justice: evolving discussions.** Journal of Transport Geography, 87.

Wallace, J. (2019). **Wellbeing and devolution: reframing the role of government in Scotland, Wales and Northern Ireland.** Palgrave Macmillan.

Wang, L., Xue, X., Zhao, Z. & Wang, Z. (2018). **The impacts of transportation infrastructure on sustainable development: emerging trends and challenges.** International Journal of Environmental Research and Public Health, 15, 6.

Wang, X & Lo, K. (2021). **Just transition: a conceptual review.** Energy Research & Social Science, 82.

WERU (2019). **Digital maturity economic impact report.** Retrieved from: **https://www.cardiff.ac.uk/superfast-broadband-project/economic-impact-research**

What Works Centre for Local Economic Growth (2015). **Evidence review: broadband.** Retrieved from: **https://whatworksgrowth.org/public/files/Policy_Reviews/15-03-10-Broadband-Full-Review.pdf**

What Works Centre for Local Economic Growth (2015). **Evidence summary: transport.** Retrieved from: **https://whatworksgrowth.org/public/files/Policy_Reviews/15-06-25_Transport_Review.pdf**

What Works Centre for Wellbeing (2021). **Covid-19 and wellbeing inequalities: housing.** Retrieved from: **https://whatworkswellbeing.org/wp-content/uploads/2021/07/www-b15-WIRED-housing-FINAL.pdf**

Windermer, R. & Cowell, R. (2021). **Are the impacts of wind energy reversible? Critically reviewing the research literature, the governance challenges and presenting an agenda for social science.** Energy Research and Social Science, 79.

Zenghelis, D. (2021). **Infrastructure requirements for Wales' transition.** [Unpublished briefing note]

Zualanga, S., Karney, B. W. & Saxe, S. (2021). **The concept of value in sustainable infrastructure systems: a literature review.** Environmental Research Infrastructure and Sustainability 1, 2.

# Acknowledgements

We would like to thank all the experts who attended and presented their work at roundtable events, prepared discussion papers, and peer reviewed this commentary paper and the evidence summary. We are grateful for the contributions of Nancy Hey, What Works Centre for Wellbeing; Professor Tim Schwanen, Transport Studies Unit, University of Oxford; Dr Manuel Ojeda Cabral, Institute for Transport Studies, University of Leeds; Professor David Clapham, UK Collaborative Centre for Housing Evidence, University of Glasgow; Dr Matthew Agarwala and Dr Rehema Msulwa, Bennett Institute for Public Policy, University of Cambridge; Dr Scott Thacker, United Nations Office for Project Services; Professor Paul Ekins, Institute for Sustainable Resources, UCL; and Dimitri Zenghelis, Grantham Research Institute on Climate Change and the Environment, LSE. Except where cited, views expressed in the report are the authors' own.

## Author Details

**Josh Coles-Riley** is Research Associate at the Wales Centre for Public Policy.

**Steve Martin** is Director of the Wales Centre for Public Policy and Professor of Public Policy & Management at Cardiff University.

For further information please contact:
**Josh Coles-Riley**
Wales Centre for Public Policy
+44 (0) 29 2251 0876
**josh.coles-riley@wcpp.org.uk**



Wales Centre
for Public Policy
Canolfan Polisi
Cyhoeddus Cymru