Talking about infrastructure: *eliciting public perceptions of* infrastructure

Executive Summary

Infrastructure systems must undergo transformation to avoid precipitating environmental breakdown and to support green recovery from Covid-19. That transformation will have far-reaching impacts for the public, who rely on its services and, we argue, who should have a say in how transformation happens. In this report, we identify how we might help the public to tell us what they want from future infrastructure, which we take to include energy, water, digital, and waste infrastructures, as well as flood risk management , and systems of transport. Infrastructure systems are complex and contested, but also essential to wellbeing so we argue that the public has a right to express preferences about desirable infrastructure futures. This is easy to say but eliciting public perceptions about infrastructure is very hard in practice, because of its complexity but also because there is no universal understanding of what infrastructure is or what it does. In this report, we present the findings of workshops exploring new ways to talk about infrastructure, with the aim of providing recommendations for how the public and private sectors can more effectively elicit public perceptions.

We find that framing infrastructure more carefully to include social and political systems can help the public to articulate their concerns and preferences more effectively. We also find that seeking to engage with values offers more opportunity to identify areas of agreement within publics and between the public and decision makers. Infrastructure's close relationship with wellbeing means that justice is crucial, both in terms of the outcomes of infrastructure decisions and the processes by which decisions are made. We argue that the structural inequalities that prevent participation of those who do not possess capacity to articulate perceptions on infrastructure constitutes an injustice. Building the capacity of all to express preferences is crucial to overcoming these structural inequalities.

Characteristics of Infrastructure

Infrastructure is a complex system and its structure and operation is likely to be unfamiliar to the public and inherently uncertain. We identify a series of characteristics that exacerbate these challenges of pubic engagement and which make infrastructure particularly hard to deliberate:

• It is **connective** in that it links technologies and events across places and over time and also links between infrastructure systems.

• It is **relational**; its form emerges from the interaction of different elements of the system (e.g. road networks evolve as land-use patterns, cars and shopping behaviour changes).

• It is **obdurate**; long-lasting, built on an installed base and embodying historically specific ideas about appropriate ways of living.

• It is **collective**; the services provided are for more than one person and infrastructure is frequently a precursor for a collective goal, such as economic growth or wellbeing.

• Its governance is **fragmented**; no regulator or department has overview of all aspects of infrastructure.

We argue that these characteristics must be explicitly addressed when designing engagement about infrastructure.

Workshop Design

We conducted three deliberative workshops with members of the public in Leeds, designed to examine the connective, relational, obdurate and collective nature of infrastructure systems and to build participant's capacity to talk about infrastructure. The workshops included activities to encourage discussion of infrastructure as it is now and also discussion of desirable infrastructure futures. We explicitly encouraged discussion of infrastructure governance to uncover whether the fragmented governance affected participants' perceptions or ability to engage in infrastructure decision making.

How people form and articulate perceptions of infrastructure

Framing is Important

The manner in which participants are asked to express preferences about a topic and how that topic is framed can have strong influences over their preferences. Addressing framing more explicitly during public engagement can transparently account for this influence.

Context Matters

The current layout and performance of infrastructure (the context) has a strong influence over perceptions of infrastructure. Disentangling the effect of context on perceptions can help to identify future aspirations that are less strongly influenced by the installed base and more likely to be transformative.

Interconnection with wellbeing

Many participants noted how extensively infrastructure shaped daily lives and wellbeing but found it hard to articulate *how* infrastructure did this. Providing a structure (of nine aspects of well-being) to support their analysis enabled our participants to more easily identify how infrastructure affected their wellbeing and identify how it might best be designed to maximise wellbeing.

Network interconnection

The connective nature of infrastructure is rarely reflected in public engagement and the perceived lack of connection and coherence can influence perspectives of specific projects negatively. Allowing participants to engage with the interconnection between infrastructure networks and between places can identify opportunities for exploiting this interconnection or overcoming disconnection.

Justice and fairness are key

Justice is one of the core values related to infrastructure transformation but it also affected the way that perceptions were formed. Explicitly considering procedural and recognition justice when designing engagement processes might help reduce the negative effects of these processes on perceptions. Attending to the distributional justice of proposed projects and allowing participants to discuss and debate the distribution of costs and benefits may also reduce the negative effect on perceptions.

Forming perceptions is a journey

The characteristics of infrastructure can make it hard for participants to describe what infrastructure is, or should be. Gradually introducing the five characteristics resulted in a discernible movement from individual preferences in the initial, more abstract, discussions towards a collective sense-making exercise where communal benefits were ultimately privileged over personal preferences. It is important to explicitly structure activities to enable participants to go on this journey towards forming complex and nuanced perceptions.

What people think about infrastructure

We identified a series of common aspirations for future infrastructure, which were very clearly aligned with Demski et al's (2015) public values for energy system change, with the addition of 'place' as a key value. These seven values are summarised in relation to infrastructure below with an example relevant to our workshops:

Efficient and not wasteful

Efficient systems that do not waste resources and/or produce waste products. Systems that do not waste opportunities arising from system change, and capitalise on the resources and capacities.
Using locally available resources such as a river for transport and energy generation.

Environment and nature

Systems that use and produce infrastructure services in an environmentally conscious way and do not unnecessarily interfere with, or harm, nature.
Creating a network of green spaces for leisure and transport.

Security and Stability

Systems that ensures access to infrastructure services both in terms of availability and affordability. Systems that are reliable and safe both in the production and delivery of infrastructure services.
Making the cost of public transport affordable for all.

Social justice and fairness

Systems that are developed in ways which are mindful of implications for people's abilities to live healthy lives. Systems that are fair and inclusive and where all actors are honest and transparent about their actions.
Accommodating disabled and older people in plans for car-free city centres.

Autonomy and power

Systems that are developed in ways that do not overly threaten autonomy, infringe upon freedoms, or significantly compromise abilities to control personal aspects of life.
Infrastructure owned and operated by local authorities.

Process and change

Systems that are developed with a focus on the long-term trajectories being created; that take into account system interconnections and interdependencies; and represent improvement both in terms of socio-technological advances and quality of life.
Using water assets to act as flood defence, amenity and transport.

Place

Systems that create a distinctive and attractive place that contributes to improving the quality of life of those who live there.
Attractive network of green places improving quality of life.
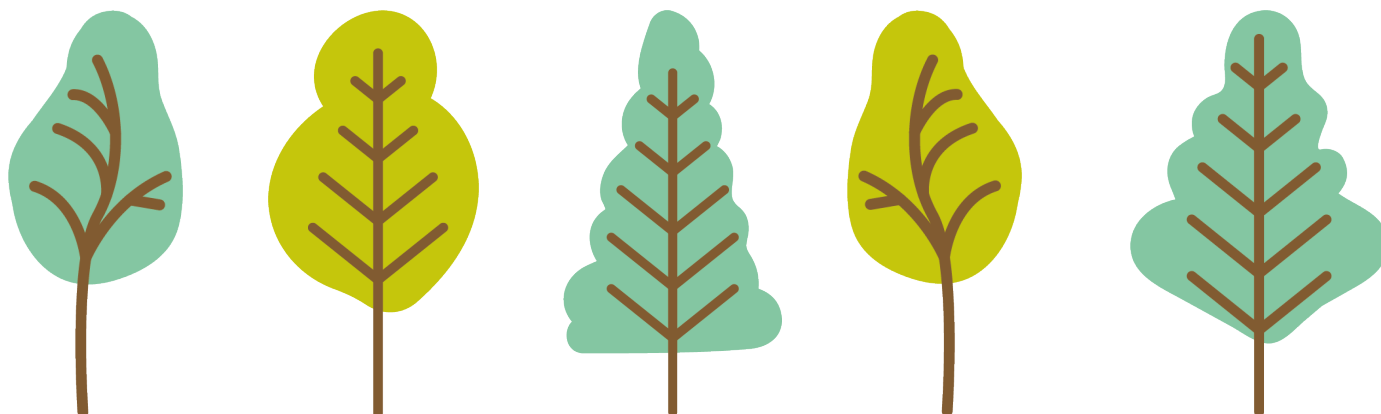
Recommendations

Take people out of the current context; give participants a creative task that seems unconnected to the current infrastructure in their locality. This can help them to see past some of the context-related constraints that shape their negative perceptions. If seeking perceptions about desirable future infrastructure, engage with the values shaping perceptions rather than participants' preferences for particular technologies. This may take more time and resource to develop and facilitate engagement activities. However, once established, these values could be used as a basis for improved dialogue and more effective decision making, resulting in more effective engagement overall.

Build capacity about how things work; provide a more structured approach to participation that seeks to build understanding of a system as well as elicit perceptions. This can result in more confident participants who feel more able to articulate their views and balance personal and collective benefits. It can also reduce systemic inequalities that mean that those with the capability to debate complex issues are empowered at the expense of others. Building capability to engage may require additional time and resource to develop materials and frameworks and to deliberate with participants. However, it could improve the quality of outputs, the experience of participating and the equality of participation.

Think carefully about framing; allow participants to examine a broader range of issues that motivate public concern, including the need for any infrastructure assets. We found that the obdurate view of what infrastructure is (large assets) and what it does (support economic growth and productivity) had a significant influence on how participants had been engaged and, importantly, negatively affected their perceptions. Allowing a broader framing of a problem can feel risky and the relationship between the outcomes of engagement and potential solutions relevant to policy makers can seem less well defined. However, there is a great deal of evidence that infrastructure is nested within social and political systems and that excluding these systems from public participation could result in disengagement and ineffective transformation strategies.

Address interconnection in participation; allow participants to explore the nature of interconnections between infrastructure systems. This allows publics to identify solutions that manage and exploit these interconnections, overcome disconnections and to consider the benefits of particular technologies in relation to others. This can reveal significantly different preferences than if technologies or systems are considered in isolation. Consulting publics about individual infrastructure systems or assets might miss these insights and underplay the complexity of public perceptions and the latent creativity of publics.

Have a more explicit focus on wellbeing; consider wellbeing and its relationship to infrastructure more explicitly and broadly when engaging publics. This allows publics to examine the many ways that infrastructure positively and negatively affects wellbeing and to debate changes that might most effectively improve wellbeing. This might also increase the weight that wellbeing is given in decision 0making processes and encourage generation of evidence to further support decisions that prioritise wellbeing.

Consider representation, procedure and distribution of benefits and impacts in the selection of participants, the design of participatory processes and the use of outcomes of these processes. This might increase the amount of time and resources required and feel like it reduces control of the topic of participation. However, explicitly addressing justice could reduce systemic inequalities of participation, improve the quality and equality of outcomes and reduce negative perceptions of projects and processes.

Introduction

There is increasing recognition that infrastructure is crucial to the functioning of the economy, society and the environment. The way we design and use infrastructure is at the root of many pressing environmental and social issues, such as the climate crisis, air pollution, biodiversity loss, unemployment, and poverty [1], [2]. Recovery from the impacts of Covid-19 restrictions presents an opportunity to transition to a sustainable society (and protect ourselves from damage already set in motion), but to do this we will have to make dramatic changes to how we prioritise, design and use infrastructure. Depending on how we go about doing this, we could exacerbate existing inequalities or create new ones, or we could significantly improve the wellbeing of people and the environment.

The tight coupling between infrastructure and social and environmental wellbeing implies that public perceptions of infrastructure should be better understood and that these perceptions should more strongly influence decisions about infrastructure system transformation [3]–[5]. This is easy to say but difficult to do in practice. There is no universal understanding of what infrastructure is, or what it does, on which to base public engagement activities. The networks of assets, services and actors that make up infrastructure have characteristics that make it even harder to talk about. In this report, we explain why it is so hard to uncover public perceptions of current and future infrastructure and present work that explores how this might be done better. We conclude with a series of recommendations for eliciting public perceptions of infrastructure.

What is infrastructure?

When you ask what infrastructure is, people often refer to large structures, like pylons and bridges, or to networks, like transmissions cables and roads. This focus on physical structures and networks is common, but overlooks the services it provides and the organisations and people that shape its operation. Infrastructure services, for example, the energy we use to heat our home, or the bus service connecting us (or not) to work, school, health or leisure facilities provide a much clearer link between infrastructure and our wellbeing. Infrastructure services are shaped by physical assets but also by the way those assets are used or operated, so we need to think about all elements of this system.

It is common to differentiate 'economic' infrastructure, which ostensibly keeps the economy going, from 'social' infrastructure, which keeps society going. The UK's National Infrastructure Commission (NIC) specifies that economic infrastructure includes; transport, energy, water and sewerage, flood risk, digital and waste. Social infrastructure frequently refers to a range of services and facilities that meet local and strategic needs and contribute towards a good quality of life. It includes health provision, education, community, play, youth, recreation, sports, faith, and emergency facilities (Greater London Authority 2017). This division is problematic because many economic infrastructures are essential to societal wellbeing (for example, energy keeps homes warm and reduces ill health) and vice versa.

In this report, we focus on what the NIC calls economic infrastructure systems because it is these that have the most significant impact on environmental breakdown and are affected most extensively by proposals for a green recovery from Covid-19. However, we recognise that they have economic and social benefits. We define infrastructure as more than a collection of structures and networks. These structures and networks interact with each other, with the policy and regulation that shape investment and operational regimes, and with the practices and wellbeing of its users. Therefore, all of these aspects should be considered when we talk about infrastructure.

Why is infrastructure so hard to talk about?

The interactions between structures, networks, operations, policy and users make infrastructure a very complex system. This gives rise to several unique characteristics of infrastructure [6], [7]: It is **connective** in that it links technologies and events across places and over time and also links between infrastructure systems. It is **relational**; its form emerges from the interaction of different elements of the system (e.g. road networks evolve as land-use patterns, car ownership and shopping behaviour changes). It is **obdurate**; long-lasting, built on an installed base and embodying historically specific ideas about appropriate ways of living. And it is **collective**; the services provided are for more than one person and infrastructure is frequently a precursor to a collective goal, such as economic growth or wellbeing. A final, yet crucial, characteristic of infrastructure is the **fragmented governance** of the system; no organisation or department has overview of all aspects of infrastructure.

In this section, we describe why these characteristics make infrastructure so hard to talk about.

Connective

The **connectivity** of infrastructure makes it hard to draw a boundary around the system we want people to talk about. The physical connectivity of infrastructure has received a lot of attention in academia and in policy making, such as the use of water in energy generation [8]–[11]. However, some argue that infrastructure is also deeply connected through the way we use it, for example using roads for both driving to work and cycling for pleasure or using gas to heat water for a shower. Connections don't just occur in a place but also between places, for example the road network connecting places together, or electricity networks connecting sites of generation with sites of production. Infrastructure can also create a lack of connection, for example; inner city areas could be spatially close to city centre facilities but poorly connected, which might create or aggravate inequalities. Having to consider this connectivity can make the depth and scale of public engagement challenging – simple enquiry about preferred options is not possible when the implications and trade-offs are so complicated.

Relational

The different elements of infrastructure only become an infrastructure system when those elements interact. For example, a culture of consumption and expansion of the automotive industry has increased car ownership, which prompts an increase in provision of car infrastructure, which enables car owners to travel further to shop or work, which encourages urban sprawl and results in a road system that prioritises cars [12]. This can make it difficult to distinguish the many different parts of infrastructure, rendering it invisible to some users . This invisibility makes it hard to engage the public in discussion of infrastructure, because people do not recognise how it influences their daily life [13]. It is only when infrastructure breaks down and obstructs daily life that we really notice it, and then it is usually in a negative light [7]. This negative association could have a significant influence on perceptions of current infrastructure and shape perceptions of future proposals.

Obdurate

Infrastructure is generally made from durable materials and its construction involves major investment and significant sunk costs. Therefore, it is very long-lasting and built on top of the installed base, rather than creating new infrastructure from scratch. This **obduracy** can make it hard to re-imagine either infrastructure itself or how it might shape our lives [14]. Obduracy also manifests itself in a specific understanding of what infrastructure is (large assets) and what it does (support economic growth), which is driven by historical and political ideals. Despite this, infrastructure is discussed in terms of scientific impartiality and the political ideology guiding infrastructure strategy and projects is rarely made explicit [15]. The public rarely gets an opportunity to debate the ideals and ideology underpinning infrastructure planning, but it clearly shapes both how the public is engaged and could shape their perceptions. Disentangling perceptions of desirable infrastructure futures from a predetermined understanding of infrastructure presents a real challenge for public engagement.

Collective

The **collective** nature of infrastructure means that structures and networks provide services to a multitude of people that contribute to collective goals. The diverse activities and interests of these people makes it hard (and often undesirable) to identify a unified public perception of specific proposals. Infrastructure also acts as a public good; users should not be excluded because infrastructure delivers desirable outcomes such as wellbeing [16], [17] and economic growth [18]. This collective provision is not universal, for example, prioritisation of broadband roll out in profitable areas and high speed trains; services are prioritised for profitable customers or only available to those who can afford them. The crucial importance of infrastructure to societal outcomes mean it is important to understand who has a say in implementing change and who sets the objectives [19]. However, it also makes it hard to determine the object of engagement – it is not necessarily the asset that is important, but what that asset does for people [17].

Fragmented Governance

Infrastructure is the responsibility of a number of different organisations and regulators and is split across the public and private sector. It is also the responsibility of organisations at different geographic scales (for example Highways England are responsible for national roads and Local Authorities are responsible for local roads). This fragmentation of governance distributes responsibility for infrastructure transformation across multiple organisations operating at different scales and within different regulatory regimes [20]. This leads to complex governance arrangements that cannot fully address the connective nature of infrastructure across sectors and places [21]. It is rare for an organisation or department to have an overview of the infrastructure system and the capacity to engage the public in this system. Some countries have started to recognise the impact of this fragmentation of governance and have developed advisory bodes at the national scale, such as the National Infrastructure Commission in the UK and Infrastructure Australia. Nevertheless the focus of these bodies is at the national scale, which overlooks the significant role of local government and the concentration of infrastructure in urban centres [22].

What did we do to get people to talk about infrastructure?

To try to address these challenges we ran a series of workshops with members of the public to discuss their understanding of infrastructure and their aspirations for future infrastructure. Three workshops were held, each with 8-10 people from West Yorkshire. The workshops were designed to examine the connective, relational, obdurate and collective nature of infrastructure and to build participant's capacity to talk about infrastructure. We explicitly encouraged discussion of infrastructure governance to uncover whether the fragmented governance affected perceptions or participants' ability to engage in infrastructure decision making.

Specific details of the participants who attended, and the data collection and analysis are included in Appendix A but activities are summarised below to provide context for subsequent discussion.

Defining infrastructure: whole group discussion to elicit participants' initial understanding of what infrastructure is, followed by a presentation by the project team.

Visualising infrastructure: small group discussion of a pre-prepared map highlighting location of key infrastructure assets in the vicinity of the workshop location, along with key facts about that asset. This prompted discussion of what counted as infrastructure, how this affected participants' daily life and how participants' experienced infrastructure decision making.

Linking infrastructure and wellbeing: participants were introduced to Max-Neef's (1991) nine fundamental human needs to represent different facets of wellbeing. After familiarisation with these concepts, participants worked in small groups to link each infrastructure sector to any human need where they identified a positive or negative relationship. More details of the methods and results of this activity are included in Appendix B.

Designing future infrastructure: participants worked in small groups to design infrastructure for a virtual, anonymous city in the future, represented on 3D maps (see below) and in the computer game Minecraft. Participants were able to consider all infrastructure sectors and no objectives were required for the future infrastructure, other than being a nice place to live. Participants developed their infrastructure futures as a group over a period of one hour and this exercise concluded with a whole group discussion of the key features of each future.

3D map used to facilitate group discussion of infrastructure futures

How did people express perceptions about infrastructure?

Despite initial concerns about knowing little about infrastructure, the workshop activities helped the participants to articulate nuanced and complex perceptions about infrastructure. In this section, we discuss how perceptions are **formed and articulated**, to inform the *practice* of eliciting perceptions. The following section describes the **values and perceptions** that were articulated, to inform decisions that should be shaped by public perceptions.

Context matters

The current layout and performance of infrastructure (the context) has a strong influence over perceptions of infrastructure. This may sound obvious but it can mask preferences for solutions that would be more desirable in a different context. For example, several participants expressed deep frustration with cyclists sharing road space with them. Taken alone, this might have suggested they were not supportive of increasing or prioritising active travel. However, most recognised that the lack of space and poor layout of current roads caused the challenges of sharing road space. All participants prioritised dedicated road space for cyclists in the 'designing future infrastructure' exercise. Disentangling the effect of context on perceptions can help to identify future aspirations that are less strongly influenced by the installed base and more likely to be transformative.

Framing is important

The manner in which participants are asked to express preferences about a topic and how that topic is framed can have strong influences over their preferences. Participants explicitly recognised the influence of politics and political ideals on infrastructure decision making, citing the productivity-driven motivation for HS2 and the imbalance in funding between London and the North. The government's framing of infrastructure was a cause of real frustration for many participants, and resulted in some strong and negative perceptions of individual projects. There was a real mismatch between the political framing of infrastructure (for productivity) and what participants perceived infrastructure should be for (wellbeing). Yet framing is rarely explicitly addressed during public engagement, which could overlook some significant effects on perceptions. It could be argued, that by using the five characteristics of infrastructure and Max Neef's nine fundamental human needs to structure the workshop that we were framing the topic. However, we explicitly accounted for this framing when analysing perceptions.

Network interconnection

Members of the public are frequently engaged to discuss individual infrastructure networks, or individual assets within infrastructure networks. This can be partially attributed to the fragmented governance of infrastructure. However, this fragmented engagement overlooks the significant effects of changes in one network on other infrastructure networks and on the broader connection between places and across time. Some participants felt that there was very little connection between individual decisions and a coherent vision of infrastructure, which influenced their perspectives of specific projects negatively. The lack of co-ordination, combined with poor communication is causing citizens to disengage with infrastructure decision making. This could present a real barrier to understanding public perspectives and incorporating them into infrastructure planning. The fragmented approach to engagement also means that the opportunities for exploiting interconnection, which our participants were able to identify, would be missed.

Interconnection with wellbeing

Many participants noted how extensively infrastructure shaped daily lives and wellbeing, using terms like 'it's how a city operates' or 'it's how things get done'. However, it is unusual for participants (or in fact experts) to be able to articulate how infrastructure shapes lives or improves wellbeing. Therefore, expressing preferences about how infrastructure could contribute to improving their wellbeing (which is one of the principal purposes of investing in infrastructure transformation) is similarly hard. Citizens hold unique knowledge about the lives that infrastructure shapes and how their wellbeing could be improved.

We provided participants with a structure of Max Neef's nine fundamental human needs to represent different facets of wellbeing and asked them to use these to make these connections. This exercise highlighted many different types of relationships between infrastructure sectors and elements of wellbeing: directly and indirectly; positively and negatively; and in the short- and long-term.

Direct impacts on wellbeing from some infrastructure sectors were perhaps easier to identify; for example, the access to work, education and social networks that the digital and transport systems provide, or the cleanliness and health that the water and waste systems provides. However, infrastructure can also affect our wellbeing indirectly, for example, the current configuration of the energy system creates carbon emissions contributing to the climate crisis and increases the chances of flooding, which affects our security and health.

The same infrastructure system can affect wellbeing both positively and negatively. For example, several participants expressed concern about an increasing reliance on digital communication and the impact this would have on relationships and social skills. Some also noted that transport can provide access to work, education, and social networks but can also damage physical health because of air pollution and sedentary lifestyles. These positive and negative effects also happen over different timescales; for example, the positive effect of fossil fuel-powered heat on health in the short-term compared to the negative effect of carbon emissions or indoor air quality on health in the long-term.

Importantly, it's not just what is built that can affect wellbeing but how it is built: engaging individuals and communities in decision making processes can meet needs directly (e.g. the need to engage in society and decisions). Excluding people from decision making can mean their needs are overlooked and solutions fail to support their wellbeing or meet with resistance.

Without providing a structure to address the relational nature of infrastructure, participants might struggle to articulate perceptions that are crucial to developing infrastructure that improves wellbeing.

Justice and fairness are key

Justice is one of the core values related to infrastructure transformation discussed in the following section, but it also affected the way that perceptions were formed. The transparency of decision making was questioned frequently and many participants cited the frustration at a lack of transparency as a reason for disengaging with participatory processes. Many assumed that they were frequently engaged when solutions had already been decided and this affected their trust in the group that was eliciting their perceptions and often made them reflect negatively on the project itself. If there was a sense of injustice in the proposed project, for example, an imbalance in infrastructure spending between north and south, this could also negatively affect perceptions of a particular project.

Explicitly considering procedural and recognition justice when designing engagement processes might help reduce the negative effect of these processes on perceptions. Attending to the distributional justice of proposed projects and allowing participants to discuss and debate the distribution of costs and benefits may also reduce the negative effect on perceptions.

Forming perceptions is a journey

The characteristics of infrastructure make it hard for participants to describe what infrastructure is, or what it should be. For example, many of our participants were unable to describe what they thought of when asked about infrastructure. Participants did not have fully formed views when they arrived at the workshop. Under these circumstances, trying to elicit perceptions straight away would result in incomplete or inaccurate perspective. In such complex systems, it is important to engage with the process through which perceptions are formed, which involves interpreting new information with existing experiences, worldviews and socio-cultural understandings about the world [3], [23]. We used the five characteristics to gradually introduce participants to elements of infrastructure's complexity: for example, talking about a range of sectors in the 'visualising infrastructure' activity and bringing in infrastructure governance; providing a framework to address some of the relational elements of infrastructure in the 'linking infrastructure and wellbeing' activity; and collectively engaging with multiple infrastructure sectors in the 'designing future infrastructure' activity. Gradually introducing these elements resulted in participants becoming much more fluent and engaged. There was also a discernible movement from individual preferences in the initial, more abstract, discussions towards a collective sense-making exercise where communal benefits are ultimately privileged over personal preferences. Developing participants' understanding of a system, not simply imparting information, can improve their ability to articulate knowledge and express perceptions. It is important to explicitly structure activities to enable participants to go on this journey towards forming complex and nuanced perceptions.
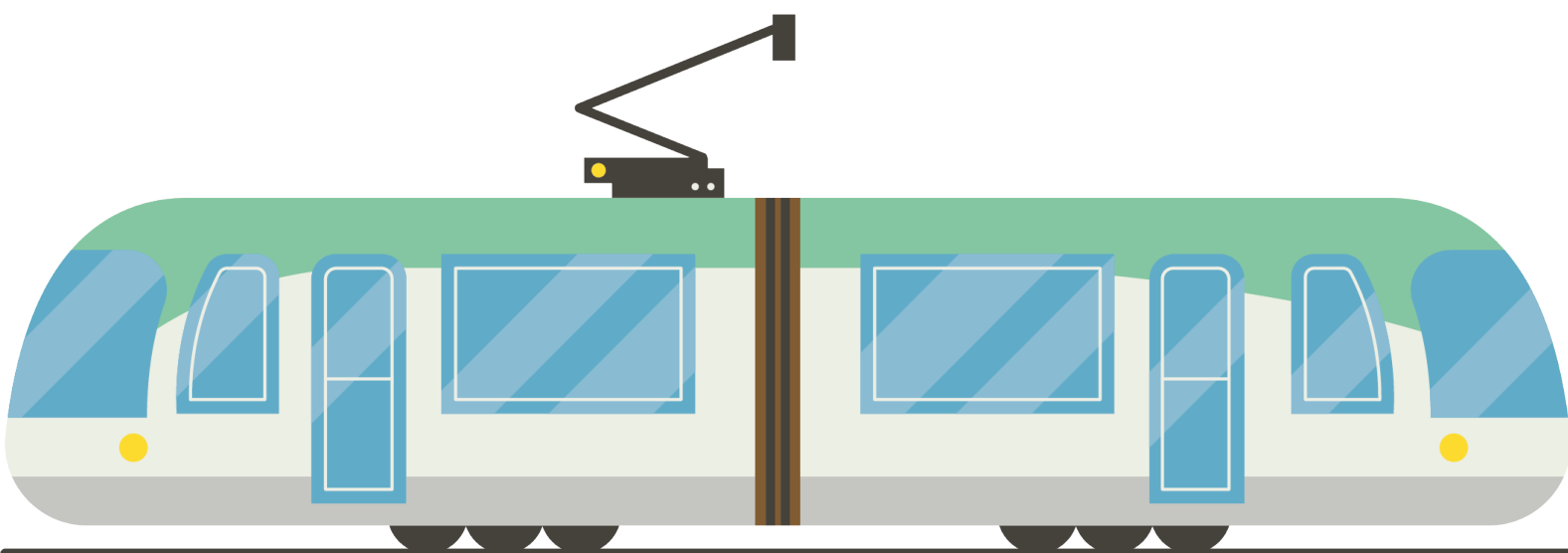
What do people think about infrastructure

The discussions we had with participants throughout the workshop, but particularly in the 'designing future infrastructure session' were analysed to identify our participants' aspirations for future infrastructure. We did this to identify whether there was a common vision for infrastructure that could be used to guide decision making. We found that the elements of these aspirations were remarkably similar to the 'public values for energy system change' identified by Demski et al (2015) with the notable addition of 'place' as a key driver of future visions. We reproduce the six public values identified by Demski et al (2015) with an additional value of place in Table 1 below, illustrated with examples from our participants.

Value related to infrastructure	Examples from our participants
Efficient and not wasteful: Systems that do not involve wasting and/or produce waste products and that are efficient. Systems that do not waste opportunities arising from system change, and capitalise on the resources and capacities.	• Using locally available resources such as a river for transport and energy generation. • Reducing waste production and using waste to generate electricity and heat
Environment and nature: Systems that use and produce infrastructure services in an environmentally conscious way and do not unnecessarily interfere with, or harm, nature.	• Creating a network of green spaces for leisure and transport • Using renewable energy • Avoiding car use in city centres
Security and stability: Systems that ensure access to infrastructure services both in terms of availability and affordability. Systems that are reliable and safe both in the production and delivery of infrastructure services.	• Providing electric car charging stations • Making the cost of public transport affordable for all • Multiple sources of renewable electricity • Effective flood alleviation measures
Social justice and fairness: Systems that are developed in ways which are mindful of implications for people's abilities to live healthy lives. Systems that are fair and inclusive and where all actors are honest and transparent about their actions.	• Accommodating disabled and older people in plans for car-free city centres • Engagement of citizens in transparent decision making processes
Autonomy and power: Systems that are developed in ways that do not overly threaten autonomy, infringe upon freedoms, or significantly compromise abilities to control personal aspects of life.	• Infrastructure owned and operated by local authorities
Process and change: Systems that are developed with a focus on the long-term trajectories being created; that take into account system interconnections and interdependencies; and represent improvement both in terms of socio-technological advances and quality of life.	• Co-treating food waste with sewage • Using water assets to act as flood defence, amenity and transport • Building in flexibility to move away from gas for heat
Place: Systems that create a distinctive and attractive place that contributes to improving the quality of life of those who live there.	• Attractive network of green places improving quality of life • Facilities to support community engagement and interaction

These values go far beyond identifying particular attitudes or the acceptability of particular technologies. They help explain how public perceptions can emerge depending on the particular social and cultural context [3]. This can mean that perceptions of infrastructure transformations are not just about infrastructure itself but can relate to broader concerns about how society or the environment might develop in the future. Engagement with the public that explicitly addresses these concerns could help address some of the challenges associated with the relational and obdurate nature of infrastructure.

What can we learn? How to talk to the public about infrastructure

In our workshops we explicitly addressed the connective, relational, obdurate and collective nature of infrastructure and its fragmented governance when eliciting public perceptions. The methods used and responses we received have generated a number of lessons for future engagement activities in local and national government, and private sector infrastructure operators:

If you want to know about future preferences and values, find ways to take people out of the current context

We found that when participants were engaged in a creative task that was ostensibly unconnected to the current context of infrastructure in their locality, they are able to see past some of the constraints that shape their negative perceptions. Our participants were able to overcome their very strong reaction against cycling in earlier exercises to design cities with cycling at the heart of the transport system. This is a very different result to asking participants directly whether they would like more cycling infrastructure in Leeds. The answer to that direct question is likely to be contingent on constraints and trade-offs that interact to influence perceptions. For example, some of our participants did not support expansion of cycling infrastructure in the current context, because there was a high level of competition for road space and conflict between cyclists and private car owners and there was no viable alternative for public transport that would reduce private car use. Therefore, we recommend that this context is either explicitly addressed, to identify these contingencies, or that participants are taken out of the current context to consider preferences more abstractly.

The purpose of engagement is very important here. If seeking perceptions about desirable future infrastructure we suggest it is more effective to engage with the values shaping perceptions rather than focusing on preferences for particular technologies. This requires careful design of engagement activities to prompt participants to engage with their underlying values, rather than immediate perceptions. This is likely to require deeper deliberation and expert facilitation, which clearly has resource implications for the party seeking to engage the public. However, identifying a set of values, or principles, could prove a more effective approach to understanding core reasons for public acceptance or rejection of proposals for infrastructure transformation (Demski et al 2015). Once established, these values could be used as a basis for improved dialogue and more effective decision making.

Even if seeking opinion about a specific project or scheme, where the current context is a far more important constituent of perceptions, it is worth explicitly addressing the current context. The example of cycling given above identified that the context of competition for road space and a lack of alternatives strongly shaped negative perceptions of cycling. This would imply that with alterations that specifically addressed these constraints – providing separate space for cars and bikes, and providing high quality public transport – these negative perceptions could be overcome.
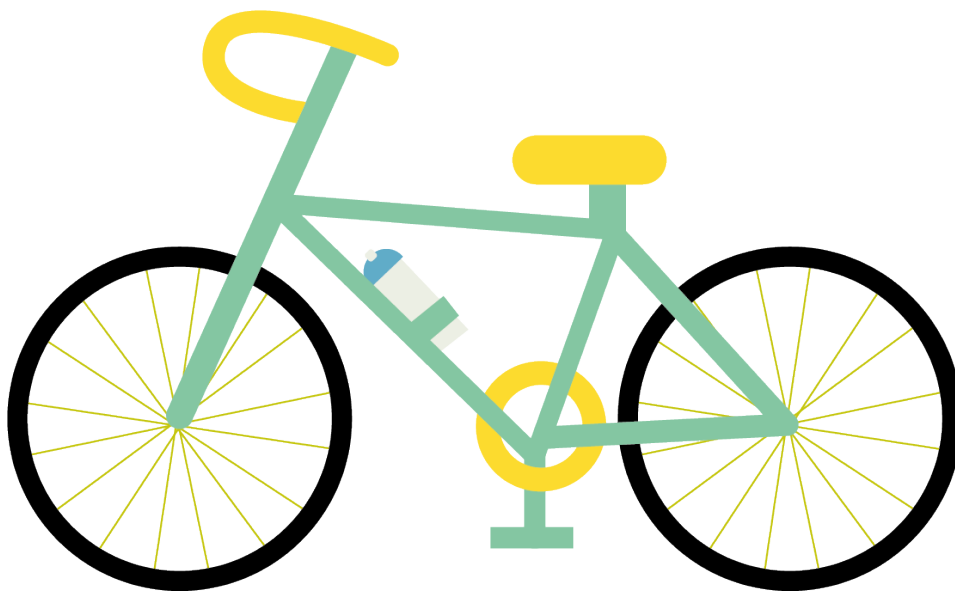
Build capacity about how things work

We found that spending time talking about what infrastructure was and how it affected quality of life built participants' confidence and capacity to articulate their preferences and perceptions. Initial exercises to build familiarity with local infrastructure and to map the relationships between infrastructure and quality of life improved participants' knowledge of how the infrastructure system worked and overcame the invisibility of infrastructure that can make elicitation of perceptions so challenging. Facilitators of the designing future infrastructure exercise were also very knowledgeable about the infrastructure system and could respond immediately to participant queries about particular technologies or systems. Therefore, we recommend that participants' capacity is built in this way to improve the ability of participants to debate and discuss the topic at hand and allow them to more clearly articulate preferences.

Building participants' capacity has an important effect on participants' experience of participation, which for many is not a positive one (Inch, 2015). Talking about a seemingly technical and complex topic, like infrastructure, can feel overwhelming and make the process of engagement very stressful. Providing a framework to support articulation of perceptions could improve the experience of participation. Many of our participants found initial discussions quite difficult and felt they had no contribution to make, which is a difficult position in which to place participants. Providing a more structured approach to participation that seeks to build understanding of a system as well as elicit perceptions resulted in more confident participants who felt more able to articulate their views.

Expressing perceptions of complex systems, such as infrastructure, requires capabilities to understand the system and articulate insights about that system that may not be available to many potential participants. This has the potential for some sections of society, who possess those capabilities, to be empowered at the expense of others. We argue that a just process would provide a framework, such as the five characteristics of infrastructure that guided the analysis in this article, to enhance the capabilities of all to express perceptions. This would not only reduce systemic inequalities but may improve the quality of outcomes.

Importantly, the framework was introduced sequentially to support the journey through which perceptions of a complex system are formed [3], [23]. In the earlier stages of the workshops participants were empowered to understand and articulate the issues which they must then address in a collective sense-making exercise that encouraged them to privilege communal benefits over individual preferences This can more effectively capture the complexity and nuance of perceptions and encourage collective sense-making.

Building capability to engage may require additional time and resource to develop materials and frameworks and to deliberate with participants, but it could improve the quality of outputs as well as the experience of participating and reduce some of the systemic inequalities associated with participation.

Think carefully about framing

We found that the obdurate view of what infrastructure is (large assets) and what it does (support economic growth and productivity) had a significant influence on how participants had been engaged and, importantly, on their perceptions. Participants explicitly recognised the influence of politics and political ideals on infrastructure decision making, citing the productivity-driven motivation for HS2 and the imbalance in funding between London and the North. The government's framing of infrastructure was a cause of real frustration for many participants, and resulted in some strong and negative perceptions of individual projects. Therefore, we recommend, that participants are allowed to *examine a broader range of issues that motivate public concern*, including the need for any infrastructure assets.

Participants expressed frustration at being unable to address social and political issues or to discuss how infrastructure investment might meet their needs most effectively when debating infrastructure. Like in the energy sector, we found that the majority of engagement activities recalled by participants occur at the project scale [24]. At this level of engagement, participants cannot question the need for infrastructure or the goals it is designed to serve, both of which matter a great deal to the public [4].

We argue, like Stirling [25], that there is a need to examine a broader range of issues that motivate public concern. In our workshops, we purposefully framed infrastructure as interacting with political systems (including ownership and governance explicitly) and social systems (explicitly examining the relationship between infrastructure and quality of life). This broader examination of infrastructure systems highlighted real tensions between infrastructure, society and politics that would obstruct change – infrastructure transformation is not a neutral and technical problem. It also allowed participants to articulate the values driving their perceptions more clearly and to be more creative when designing future infrastructure systems.

Allowing a broader framing of the topic of interest can feel risky and the relationship between the outcomes of engagement and the problem as defined by policy makers can seem less well defined [26]. However, there is a great deal of evidence that infrastructure is nested within social and political systems and that excluding these systems from public participation could result in disengagement and ineffective transformation strategies.
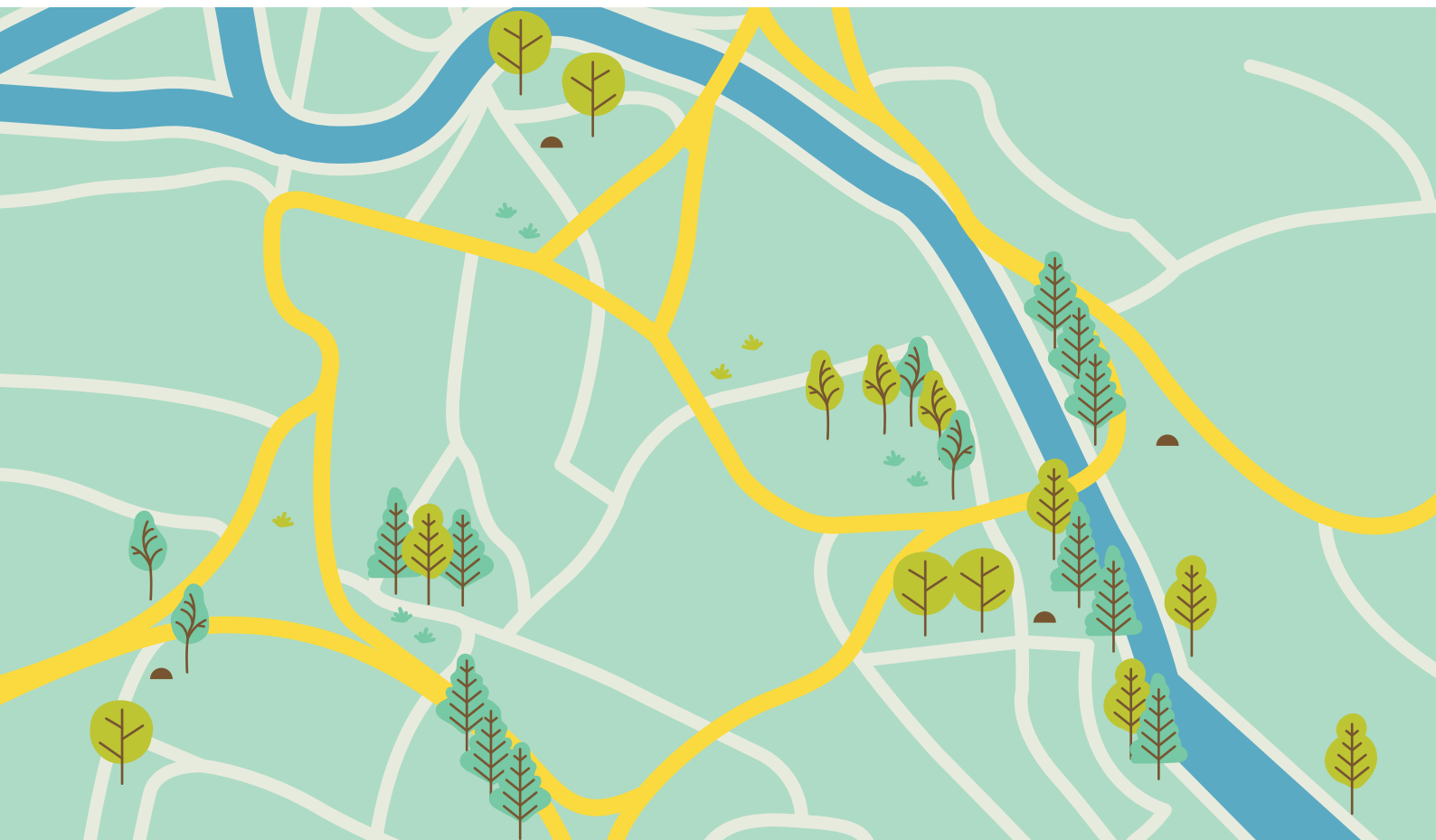
Address interconnection in participation

We specifically chose to elicit perceptions of an interconnected infrastructure system, rather than focus on individual infrastructure systems. This increased the complexity of the system we were asking our participants to deliberate. However, exploring the nature of interconnections between systems allows citizens to identify solutions that manage and exploit these interconnections and to consider the benefits of particular technologies in relation to others. This can reveal significantly different preferences than if technologies or systems are considered in isolation [27]. Therefore we recommend that participants are allowed to explore the nature of interconnections between infrastructure systems.

The physical connectivity of infrastructure systems was widely recognised by participants and this connectivity was frequently exploited when designing future infrastructure systems. A technical example of this was the co-treatment of waste and wastewater to produce energy for heating and electricity. There was similar support for using particular spaces for multiple purposes. This was most frequently discussed in relation to green space and water; using it for flood alleviation, leisure, energy generation and transport. Participants were also able to manage temporal changes in this connectivity – accepting that a particular area might be out of use for leisure when it was required to store water for flood alleviation. Participants also addressed a lack of connection in current infrastructure by improving links between places in the virtual city and making those links accessible to all.

Increasing the complexity of the problem that the public are required to examine may increase the time required for them to debate particular issues. However, our work demonstrated that citizens are able to understand a broad spectrum of connections between infrastructure systems and to actively exploit those interconnections and to address disconnections. Addressing connectivity revealed far more complexity in public perceptions and led to solutions that were more creative and innovative than those that might be generated by a business as usual approach. Consulting citizens about individual infrastructure systems or assets might miss these insights and underplay the complexity of public perceptions and the latent creativity of citizens.
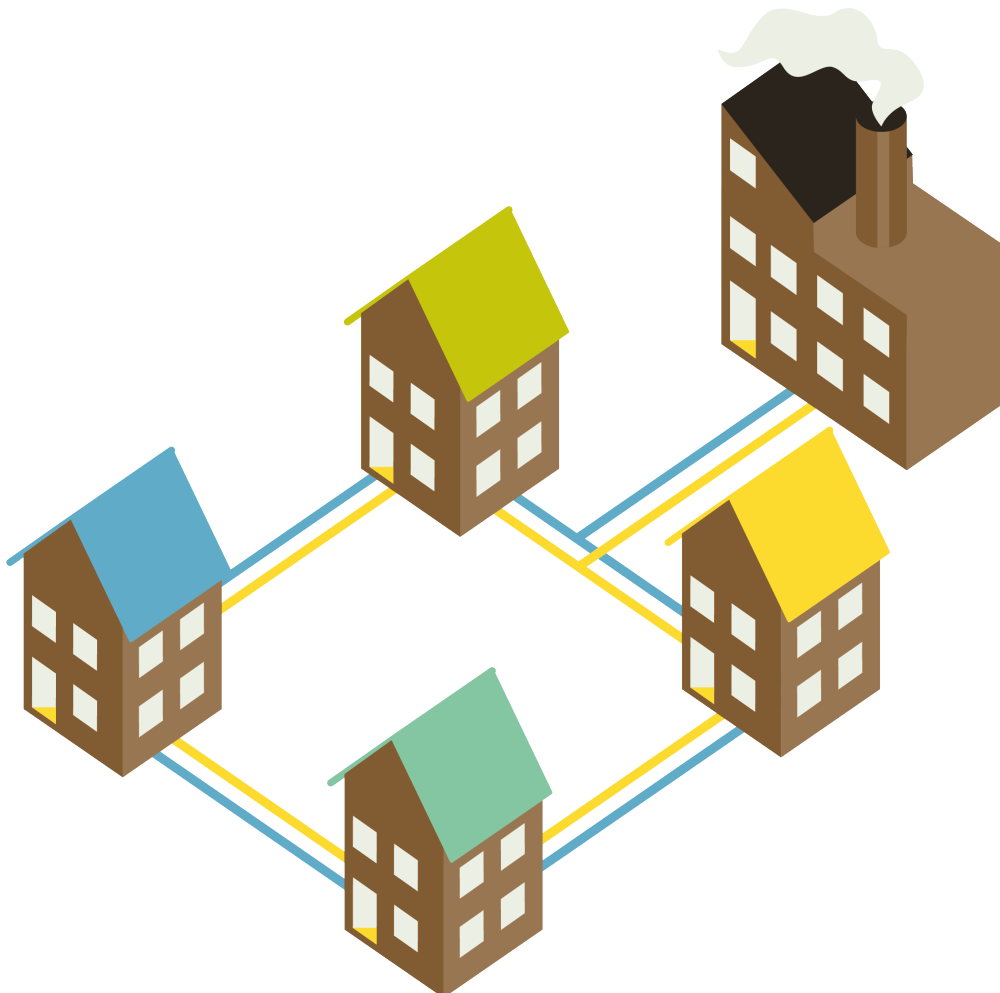
Have a more explicit focus on wellbeing

Our workshops had a specific activity examining the links between infrastructure and wellbeing. This forced participants to consider explicitly the many ways in which the different infrastructure systems directly and indirectly affected their wellbeing. This explicit focus on wellbeing helped to address its embeddedness and made its influence on daily life more visible. This can mean that changes to infrastructure are considered more carefully in relation to how they can most effectively improve wellbeing in the whole, rather than objecting because of a negative impact on one aspect of wellbeing. We recommend that wellbeing and its relationship to infrastructure is considered more explicitly and broadly when engaging the public.

There is a strong rhetoric in infrastructure planning that infrastructure boosts quality of life but this is not supported by sufficient evidence for this linkage to be taken into account fully when making decisions about infrastructure. This can make it hard to prioritise wellbeing in decision making and result in projects or policies that do not make sense to citizens, such as High Speed 2. Addressing wellbeing more explicitly would help to make decisions more transparent and the distribution of costs and benefits clearer.

Linkages between infrastructure and wellbeing included quite direct relationships, for example clean water being essential for health but participants were also able to identify far more nuanced relationships. For example, the use of energy to produce clothing to support the need for protection, or having a say in the process of infrastructure development or operation to support the need for participation. Participants also recognised that infrastructure could have a positive impact on wellbeing, such as providing mobility to access employment, and negative, for example poor air quality from transport affecting physical health. Participants didn't have the chance to debate these dynamics in detail but this would provide a useful future approach to identifying how changes to infrastructure could most effectively maximise wellbeing.

Consider representation, procedure and distribution of benefits and impacts

Justice is both a core value of infrastructure change and also plays a significant role in shaping perceptions. As such, it should be considered explicitly throughout the process of engagement. Building capacity, as described above, could reduce systemic inequalities of participation and result in processes that are more representative. Participation that is more representative is better able to recognise and accommodate the interests and values of marginalised groups and result in just outcomes. Representation can also be improved by including collective activities, such as the group activity to design future infrastructure. The collective sense-making involved in this type of activity provides a vital opportunity for participants to engage with the complexity of infrastructure systems and use the collective knowledge of the group to make sense of that complexity. Participants in our workshops were engaged in debating a collective problem, one of designing infrastructure to maximise societal wellbeing. When asked to design future infrastructure, participants frequently designed to meet the needs of others, rather than prioritising their own preferences.

A lack of transparency and a feeling that the subject of engagement was a fait a complis, caused our participants to disengage in participatory processes and also negatively affected their perceptions of projects. More equitable and inclusive decision-making processes are required which improve transparency and clarity of purpose. This could include engaging people earlier in a decision-making process, so that their perceptions are able to influence option selection, rather than seeking agreement on a selection that has already been selected. The scope and purpose of engagement should be made explicit, including how participants' views will be used to shape the decision making process. The scope of engagement should explicitly address the framing, as discussed above, and this should be taken into account when analysing perceptions.

Attending to the distributional justice of proposed projects and allowing participant to discuss and debate the distribution of costs and benefits may also reduce the negative effect on perceptions. Our participants were concerned with a broad range of costs and benefits, many stemming from infrastructures embeddedness with wellbeing, which should be addressed in assessments of cost and benefit. Furthermore, participants were concerned with the distribution of infrastructure funding across regions of the UK, therefore, distribution of costs and benefits over a range of scales should be addressed.

Conclusions

We identified five characteristics of infrastructure that make it difficult to debate with the public: It is *connective* in that it links technologies and events across places and over time and also links between infrastructure systems. It is *relational*; its form emerges from the interaction of different elements of the system. It is *obdurate*; long-lasting, built on an installed base and embodying historically specific ideas about appropriate ways of living. And it is *collective*; the services provided are for more than one person and infrastructure is frequently a precursor for some other desired outcome, such as economic growth or wellbeing. A final, yet crucial, characteristic of infrastructure is the ***fragmented governance*** of the system; no organisation or department has overview of all aspects of its design and operation. In order to overcome the challenges associated with these characteristics, specific attention should be paid to the scope, purpose and procedures of engagement. Our work also highlighted a need to build the capability of participants to articulate their perceptions.

When considering the scope of engagement, the strong influence of the current context – the way that infrastructure is currently configured and operated – on perceptions should be appreciated. Organisations seeking to elicit perceptions should design the scope of participatory activities to explicitly address this context and examine how the obdurate nature of infrastructure affects preferences now or in the future. It may be beneficial to engage participants in more abstract representations of infrastructure that allow them to debate their key aspirations whilst removing them from the influence of this context. To support this, the framing of infrastructure should be made explicit to allow participants to debate assumptions about what infrastructure is or what it is for and to examine a broader range of issues, including political and social systems. Allowing participants to debate the interconnection of infrastructure will allow them to engage with the fragmentation of infrastructure governance and identify opportunities to exploit these interconnections or overcome disconnection.

The purpose of engagement should be clear and explicit through participatory processes. We argue that for such a connective and relational system as infrastructure, it would be more effective to engage with the values that participants would like to see reflected in future infrastructure systems. We found that there was real variation in responses to individual structures and projects, but strong alignment in the values that participants were seeking to achieve through these structures and projects. These values could be used to develop a shared vision for infrastructure transformation or as criteria to support the design of individual parts of these systems.

The procedures used to enable participation should explicitly reflect the principles of representative, procedural and distributive justice. These principles should affect procedures to select participants, design of participatory processes and the use of outcomes of these processes. Encouraging collective debate of infrastructure systems, by working in groups and having shared objectives, better reflects the collective nature of infrastructure itself. This supports better representation and fairer distribution of costs and benefits across citizens and across space.

These recommendations all require effort to build the capabilities of participants to examine infrastructure's complexity and articulate their preferences. We argue that building this capability, using frameworks such as the five characteristics of infrastructure and the nine dimensions of wellbeing used in this report, can address systemic inequalities to participation and result in more just and acceptable infrastructure systems.
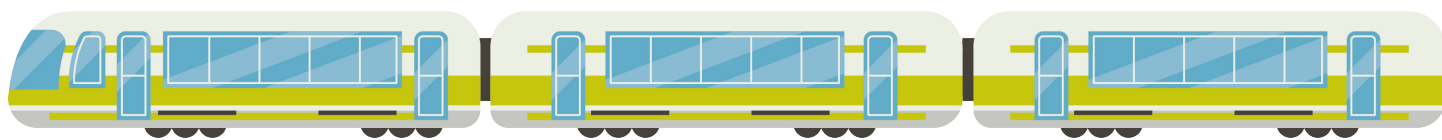
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Buttercrumble is a creative communications studio based in Leeds, founded by alumni of the University of Leeds, Chloe and Abigail Baldwin. Collaboration and research are at the core of their brand. They are passionate about delivering important messages to communities through fun graphic design and illustration. Buttercrumble developed the brand guidelines and produced all illustrations for this report as part of the University's Cultural Institute Creative Labs: the Climate Edition.

Robin Styles is a research coordinator at the University of Leeds based in the School of Earth and Environment. His work focuses on communicating research and engaging with a broad range of audiences. Robin contributed to this report and designed its layout.

About the project

Multi Actor Adaptive Decision Making (MAADM) is a six-year project exploring how to improve long-term decision making to transform infrastructure systems, funded by the Engineering and Physical Sciences Research Council.

Infrastructure systems play a crucial role in delivering social and economic wellbeing but radical transformation is required to ensure their sustainability and resilience to social and environmental change.

Taking decisions to transform infrastructure is challenging because it is a complex system subject to deep uncertainties such as the impacts of climate change, technology development and changing user behaviour. And there are often multiple organisations involved in delivering it, with shared responsibility but not necessarily a shared vision.

The MAADM project is helping decision makers to adopt new approaches to decision making that can accommodate high levels of uncertainty, to cope with the multiple crises we face. These new decision making approaches can also help overcome barriers to change, particularly by supporting collaborative decisions that can involve lots of different stakeholders and competing voices. We are also developing approaches to support citizens, who rely on infrastructure's services, to have a say in how transformation is managed.

Find out more about the project at https://maadm.leeds.ac.uk/.

Appendices

Appendix A - Methods

Deliberative workshops are a facilitated group discussion where participants are provided with an opportunity to consider an issue in depth. They are widely used to explore public perceptions of emerging areas of science, technology and policy.

Each workshop was attended by 8-10 participants (n = 28). Participants were recruited through a professional recruitment agency and criteria were used to recruit a spread of gender, age, socio-economic groupings and ethnicity. The majority of participants were residents of Leeds but each workshop included participants from neighbouring cities, including Wakefield (West Yorkshire) and Sheffield (South Yorkshire). Participants were recruited to a workshop about infrastructure but were not informed of the specific focus of discussions and were given a small monetary honorarium for their participation.

The workshops were facilitated by the authors and took place over the course of one day. They were designed to engage members of the public as active, imaginative agents, eliciting their insights relating to infrastructure now and in the future. The workshops used a range of deliberative techniques including:

(1) Defining infrastructure: discussion of the definition of infrastructure involving a whole group discussion and a presentation by facilitators;

(2) Visualising infrastructure: small group discussions (n=4-5) of infrastructure in the vicinity of the workshop venue using visual prompts and stimulus material to overcome embeddedness. Participants were encouraged to share their knowledge, experiences and concerns about local infrastructure;

(3) Linking infrastructure and wellbeing: small group discussions (n=4-5) of the link between each infrastructure sector and wellbeing using Max-Neef's (1991) conceptualisation of human needs to represent facets of wellbeing and pre-prepared worksheets to structure discussion. This aimed to stimulate the exploration of the relationship between infrastructure and society; and

(4) Designing future infrastructure: in-depth group discussions (n=2-4) of desirable future infrastructure systems which meet needs more effectively. These were structured around an activity to design infrastructure for a virtual, anonymous city in the future, represented on 3D maps and in the computer game Minecraft. Participants were able to consider all infrastructure sectors to allow them to address connectivity and no objectives were required for the future infrastructure, other than being a nice place to live, to reduce the constraints of framing. Participants developed their infrastructure futures as a group over a period of one hour and this exercise concluded with a whole group discussion of the key features of each future.

As facilitators, we prompted participants' reflections, for example highlighting the possibility that one infrastructure system may be affected by proposals for another infrastructure system or asking what the city might be like for those who lived there.

All data was analysed together to identify insights across activities. Data was coded against the five characteristics to analyse how these characteristics shaped perceptions of current infrastructure and aspirations for future infrastructure. Within these themes, sub-themes were identified to expose a more detailed narrative and data was re-coded to ensure a better 'fit'. For example, we found a strong collective view of the desirable attributes of infrastructure, which aligned closely with the public values for energy system change described by Demski et al (2015). Therefore, data were re-grouped as sub-themes that aligned with these values and grouped under the broader collective theme.

Appendix B – Linking Infrastructure and Wellbeing

B1 Description of activity

Participants were provided with a list of needs (Table B1) that contribute to wellbeing and were asked to make connections between these needs and one infrastructure system at a time. A brief description of the needs was provided on the worksheet and participants were given an opportunity to query/add to the list. Money frequently came up as a suggested addition, but it was clarified that money was a means to achieve many of these needs and not an end in itself.

Table B1: Description of needs adapted from Max Neef (1991)

Need	Description provided
Subsistence	Having enough to eat or drink
Protection	Being safe dry and warm
Affection	Connection with others
Participation	Engaging in society and decisions
Creation	Ability to do meaningful work
Freedom	Ability to do, choose and express who you are
Understanding	Developing knowledge and awareness
Idleness	Leisure
Identity	Defining and communicating who you are

Participants were provided with a worksheet for each infrastructure system and asked to mark relations between that sector and any of the needs that the system helped to meet (or was hindered by that system). Participants annotated the relationship with justifications and examples:
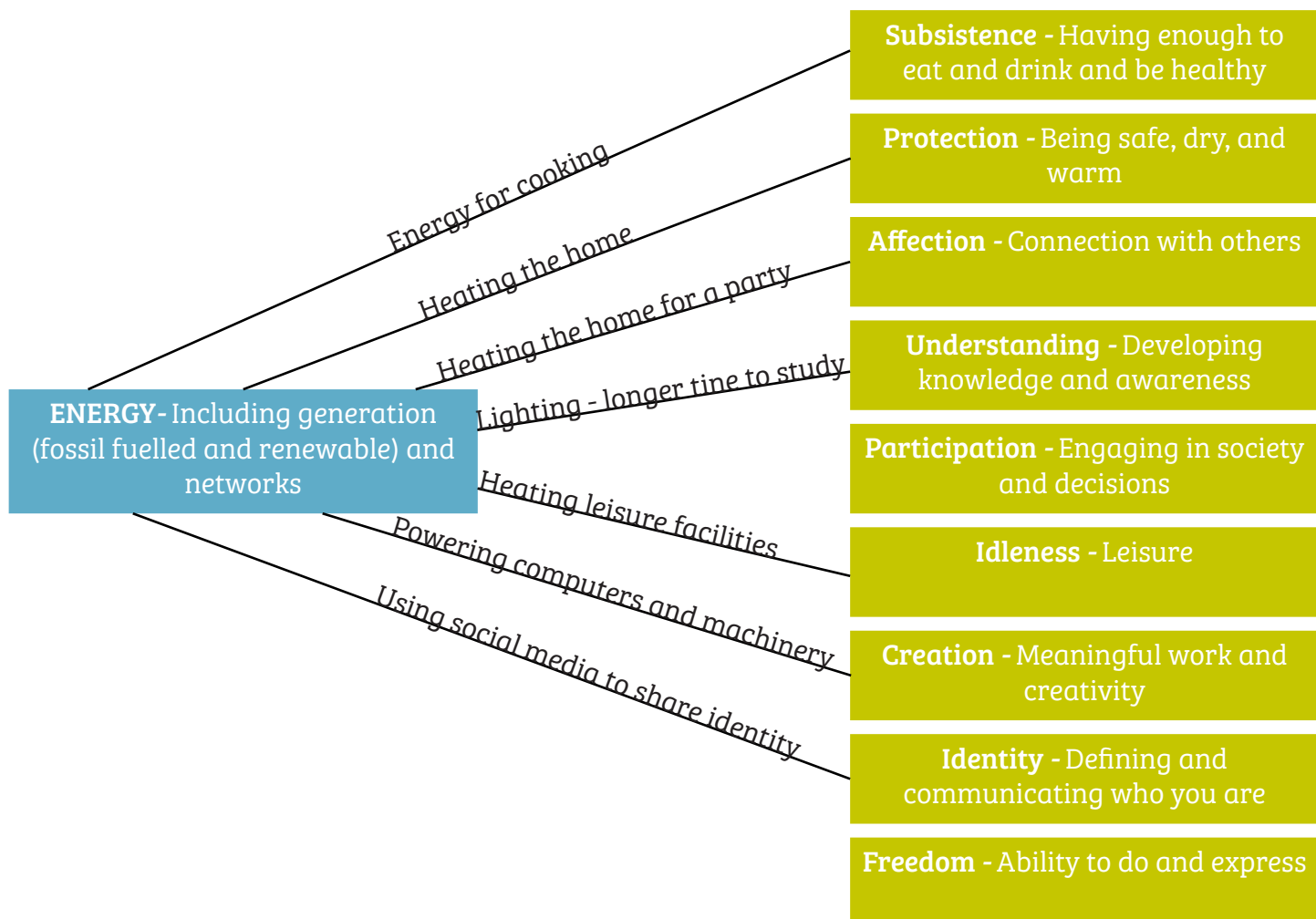
B2 Breadth of connections

Despite initial scepticism about the extent to which infrastructure contributed to wellbeing, participants were able to make connections between all infrastructure systems and some aspects of human needs. They also appreciated the need for interaction between infrastructure sectors to support particular needs, for example the need for energy and digital infrastructure to support communication. Participants recognised the contingent relationship between infrastructure and some needs and that in some circumstances it could have a negative impact on people's ability to meet their needs. When thinking about needs, participants did not limit themselves to thinking about an individual's needs but were able to think about the contribution of infrastructure to wider society and prosperity.

Participants were initially asked to focus on three out of the six infrastructure sectors, to reduce the burden of this task. However all except one of the nine groups that undertook this task were able to identify numerous links between all six infrastructure sectors and many of the nine human needs that were articulated in this exercise. Linkages included quite direct relationships, for example clean water being essential for health. But participants were also able to identify far more nuanced relationships, such as the use of energy to produce clothing to support the need for protection, or having a say in the process of infrastructure development or operation to support the need for participation:

> But, it's everything. Bikes, you need energy to make the bikes. Even going for a walk in the park, you need energy to produce clothing. Energy is in everything. (Headingley)

> What else was there? Oh, just participation, perhaps you mentioned about having more say in what was recycled, where, what use it had... (Harehills)

When reflecting on this exercise, many participants were surprised by how extensive the linkages were and how easy it had been to identify them. Providing a structure (of the nine human needs) to support their analysis seems to have broadened-out thinking and increased engagement in the activity.

> Yes, when you look at waste and you think, "Well what have I got to say about that?" and then you've got lots to say about it. Just didn't realise there were so many that were connected to one that we were doing. We thought it would only be one or two, but it seems to be like most of them in different ways. (Headingley)

The connection between infrastructure sectors in meeting some needs was raised several times and participants clearly understood the importance of this interconnectivity:

> I guess they do connect though, don't they? They are going to interlink, because you can't do the digital without turning your switch on. (Harehills)

B3 Multiple forms of connections

The majority of groups recognised that infrastructure could have a negative impact of individual's ability to meet their needs, as well as a positive impact. This came up most frequently in relation to digital infrastructure, where it was perceived that it could negatively impact on both protection and communication. The increased reliance on digital management of activities such as banking and shopping raised concerns about safety and it was felt that it would be increasingly hard to protect personal data and possessions. Several participants also expressed concern about an increasing reliance on digital communication and the impact this would have on relationships and social skills:

P1: Yeah, because before there was all this internet and stuff like that, your banking, you didn't hear about hacking half as much. You didn't, did you? When you had to go to the bank and draw your money out, or pay you know, it were really unheard of, wasn't it?

P2: Yeah. But, sometimes it's annoying digital, because you want to go, sometimes I feel safer when I have spoken to someone face to face, got my point across and they have said, 'I understand what you are saying,' and sorted it out. Whereas, on the internet you are thinking you can't tell the full story and they don't know you, and it's not a person. (Headingley)

There was also concern about the negative impact of infrastructure on the environment, which was not fully captured by the human needs framework presented, but which could impact their need indirectly. For example [commenting on the interaction between transport infrastructure and protection],

P1: Transport can take us to the gyms and to the open spaces for exercise and leisure.

P2: [notetaking] "Take to open spaces..."

P2: But, a negative is that it creates pollution. (Discussion, Headingley)