iBUILD Case Study Report

Redevelopment of Digbeth: The Potential for Decentralised Infrastructure

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Executive Summary

The arrival of HS2 (High Speed Rail 2) at the new Curzon Street station in Birmingham, provides the opportunity for major redevelopment of Digbeth, an urban residential/business area adjacent to Curzon Street, and about 1km east of Birmingham city centre. A significant amount of new infrastructure will be required, with much of the funding having to come from private investors.

Investors will not commit funding unless satisfactory returns are in prospect; to this end, value captured needs to be maximised and costs incurred minimised. The iBUILD research consortium, supported by the Engineering and Physical Sciences Research Council (EPSRC), and the Economic and Social Research Council (ESRC), is addressing these issues through development of new business models that can deliver projects with acceptable value/cost ratios.

Today, the dominant paradigm for most modern networked infrastructures is one of large-scale, centralised systems. This is the result of an evolutionary process: small-scale water, electricity and rail infrastructures growing, consolidating and standardising, with early choices locked-in and characterising the system to maturity. There is an argument, however, that this model may no longer be suited to the provision of infrastructure in today's cities. This study explores what is involved in creating a more decentralised approach that can respond quickly to the highly differentiated needs of modern businesses.

The study focuses on how decentralised urban infrastructure can be achieved. It explores three conceptual frameworks and areas of literature providing ideas: 'user-led innovation' - users of products and services increasingly able to innovate for themselves; 'participatory design' - a clear shift away from the centralised view of 'design for users', towards a more decentralised 'design with users' and, to an extent, 'design by users'; and, 'inverse infrastructures' - displaying 'user-driven', 'self-organisation', 'decentralisation' and 'bottom-up' behaviours that are the opposite of the currently-dominant, centralised infrastructure systems.

The research identifies a number of factors that appear key to successful provision of decentralised infrastructure services in cities:

- the emergence of technologies that enable specific local requirements to be met in ways that cannot easily be achieved with a centralised, one-size-fits-all approach;

- pro-active individuals, active local citizens groups and key professional/industry representatives forming networks, cemented in place by trust and strong communications;
- a policy framework conducive to new smaller scale infrastructure developments;
- common technical standards promoting interoperability and interconnection between different systems, enabling small-scale new developments to be connected to, and operate within, existing centralised infrastructures;
- incentives, such as better functionality of infrastructure and financial benefits to consumers;
- an acceptance that, at least initially, decentralised infrastructures may appear somewhat marginal and niche; and finally,
- emerging decentralised infrastructures that are hybrid in nature, dependent on a variety of centralised and decentralised elements for success.

The research finds that creative zones, such as Digbeth, and the creative industries within them, have a number of factors governing their own success that align positively with the factors for decentralised provision of infrastructure services:

- creative industries are often entrepreneurial, early adopters of new ideas and technologies, stimulating further innovation and acting as catalysts for economic regeneration;
- trust and communication, an essential part of successful networks, plays a big part in entrepreneurialism: creative industries with strong networks tend to be more innovative; and an 'ecosystem of interconnected individuals' (physical and virtual proximity) is seen as vital for innovation; and,
- there are numerous possibilities for intervention by local authorities to help generate networks and encourage development of creative industries; in the local context, factors such as size, existing strengths, culture and history, are particularly important when considering interventions.

Digbeth already exhibits a number of features that can contribute positively to the development of decentralised infrastructure; they are:

- a vibrant community with its own distinct identity;
- the presence of the Custard Factory with its existing networks of social cooperation and actors keen to promote initiatives that enhance social and community benefits;
- the presence of Edible Eastside (Eastside is an area of Birmingham next to Digbeth): a social enterprise providing a different type of infrastructure, promoting, as it does, urban community-based food production and cooking;
- a degree of support from key stakeholders for a decentralised approach, though there is recognition that a hybrid is more likely: a mixture of centralised and decentralised inputs. In particular, there is a desire to avoid a top-down redevelopment of the sort commonly associated, perhaps wrongly, with major redevelopment opportunities;
- the presence of policies and regulations that could encourage decentralised infrastructure provision: for example, national schemes for energy saving; favourable

regulatory regimes for small-scale, renewable energy schemes; and, enterprise zones to encourage the development of small businesses and start-ups; and,
- the success of earlier decentralised infrastructure schemes, such as that at King's Cross Central, charting the way forward.

Digbeth does, however, have some issues militating against decentralised infrastructure that need to be addressed:

- a concern that, while a vibrancy is evident in Digbeth, all of the factors required to support innovative development of decentralised infrastructure (ideas; drive; spark; money; technology; knowledge; business support; networking; and space) may not be there, or may be there but not in sufficient strength; and,
- a sense that a vision for decentralised infrastructure is lacking. There appears to be little enthusiasm for bottom-up development of decentralised infrastructure, or any strong connection to newly emerging ideas on infrastructure.

Tackling these issues will require continued development and maintenance of connections (physical and virtual) between different areas of Birmingham, and between different types of actors and organisations. Development must not fall into a siloed approach: although sub-areas will inevitably have specialisms, such as creative, education, research or business, development plans should not seek to separate them too much, because, ultimately, they are all mutually interdependent.

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1. Introduction

The arrival of HS2 (High Speed Rail 2), at the new Curzon Street station in Birmingham, provides the opportunity for significant redevelopment of Digbeth, an urban residential/business area adjacent to Curzon Street, and about 1km east of Birmingham city centre. Birmingham City Council's HS2 Curzon Street Masterplan has identified Digbeth as a 'creative zone', and as a 'place for growth' (BCC, 2014). Digbeth is portrayed in the Masterplan as an 'historic setting' (p.20), and as having 'established itself as the home of a diverse and dynamic working community of digital and creative businesses' (media, arts, crafts, design, advertising, fashion, software) (p.36). It is hoped that its historic character will be maintained, while at the same time being integrated it into the new city-space around the station.

The redevelopment will require the provision of significant new infrastructure, notably that of the main networked industries: energy; transport; ICT; and, water. The infrastructure challenges faced here are a microcosm of those for the UK as a whole: much of the existing infrastructure is old (in some cases over 150 years old) and in need of renewal; increasing

demands will be placed on it as population grows; infrastructures themselves are increasingly interdependent, risking propagation of local failures to the wider network; and, government policy requires that the bulk of the investment needed for renewal will have to come from private investors (CST, 2009; ICE, 2010).

The iBUILD research consortium, with funding from the Engineering and Physical Sciences Research Council (EPSRC), and the Economic and Social Research Council (ESRC), is addressing these issues (Dawson et al, 2014). The project's hypothesis is that existing approaches to infrastructure provision are expensive, and do not capture the full range of value arising from projects. New approaches are required to improve the value/cost ratio: that is, reduce costs and enhance the economic, environmental and social values derived from the infrastructure. iBUILD is investigating the potential of alternative urban-infrastructure business models to increase value capture, reduce costs and thereby encourage investors to commit funding.

iBUILD has three research streams: the business of interdependence (exploring new business models and developing tools to understand interdependencies between infrastructure, regulation and the economy); re-thinking infrastructure value (developing new approaches to quantify whole-life economic, social, environmental, and other values derived from infrastructure); and, issues of scale in local delivery (exploring opportunities: from improved cross-scale consideration of infrastructure business, to identifying methods to reconcile local, regional and national priorities). These are being brought together in a number of integrative case studies; findings from these will be used as the basis for further research, co-created in conjunction with project stakeholders.

The traditional way to provide infrastructure is top-down and centralised, led by large (public or private) utility companies. For much of the 20th century, this centralised 'large-scale, technical-system' approach has dominated the provision of the main network infrastructures (Egyedi and Mehos, 2012). While this approach has undoubtedly generated significant economic and technological value, it can close-off alternative ways of delivering infrastructure that might be particularly suitable for the local and urban levels. Large-scale, technical systems can be over-reliant on ideas and innovation from large organisations, and unresponsive to a range of technological, economic, organisational and social innovations at smaller scales. In addition, the traditional large-scale, technical system can be too siloed within its own sector, and unable to draw on potential benefits arising from interdependencies between sectors.

Following the main premise of iBUILD, it is postulated here that a more decentralised (bottom-up/user-led) approach to infrastructure provision in Digbeth could create a range of new economic, social and environmental value. It is suggested that there is a high potential for this in creative areas such as Digbeth, where there are a wide range of innovative and differentiated users of infrastructure. The Masterplan for the development of the areas around the new HS2 station appears to be open to a less centralised approach. Other than the major transport routes, little is specified on new infrastructure; most of the ideas on local infrastructure are couched in terms of opportunities and possibilities.

The purpose of this paper is to explore the potential of a more decentralised approach, by identifying case study examples in which there have been innovations along these lines. The aim is to develop a theoretically informed understanding of what made them successful, and to consider their suitability for the Digbeth case. This involves identifying the key factors (inter alia: political; institutional; cultural; economic; and, technological) present when decentralised (or bottom-up/user-led) infrastructures emerge and thrive. This, along with analysis of the local situation, will enable an assessment of the extent to which this approach can contribute positively to the development of Digbeth's creative zone. The case study examples draw from literature and internet-based searches and analysis; the discussion of the possible application of the ideas to Digbeth is based on meetings with local stakeholders, including: Birmingham City Council officials; a locally based architect; a developer; and, a business agency. The paper will thus provide a firm foundation for more detailed work on innovative infrastructure provision in creative areas such as Digbeth.

In section 2, the paper provides an outline of Digbeth as an historic industrial area, its more recent development as a creative area along and the potential to further this, and the possibilities for new infrastructure. Section 3 introduces the idea that innovative provision of urban infrastructure might be achieved by a more decentralised approach. Sections 4-6 investigate three conceptual frameworks (user-led innovation, participatory design and inverse infrastructures), which involve a more decentralised approach to innovation and infrastructure. For each of these a number of examples are identified and described. Section 7 introduces creative areas in major cities and towns, such as London and New York, with the aim of revealing indications of any decentralisation of innovation and infrastructures. Drawing from the literature and examples in the previous sections, the aim of section 8 is to identify the key features and conditions present when decentralised infrastructures emerge and thrive. Section 9 concludes by considering the suitability of Digbeth for decentralised infrastructure development.

2. Digbeth as a Developing Creative Industry Area

History is certainly all around in Digbeth with 19th century industrial developments, the canal, railway bridges and factories all present. In the last 20 years, creative industries (media, design, digital, art galleries, TV production) have developed in and around the Custard Factory (see Figure 1). The Custard Factory was established in 1837 by the firm of Alfred Bird to, as the name suggests, produce custard powder; it remained in production until 1964, after which it fell into disuse and became derelict. In 1993 redevelopment commenced, and it became (in its own words) 'Birmingham's creative quarter' and 'the UK's leading destination for creative and digital businesses, independent shops and alternative culture outside London'.[1] Further space was provided in 2008 when Fazeley Studios were opened near the Custard Factory (about 200m to the north east).[2] Additionally, Digbeth is home to a wide range of small businesses working in sectors from social enterprise, through food distribution, to small scale engineering. It has a small number of residential streets and an active community; there is a particularly vibrant night life (night clubs, music, arts and other

[1] http://www.custardfactory.co.uk/
[2] http://www.fazeleystudios.com/

cultural activities). On the down-side, there is a general perception among stakeholders that the infrastructure and services (transport, ICT and banking) are not of the quality expected of a location so close to a city centre.

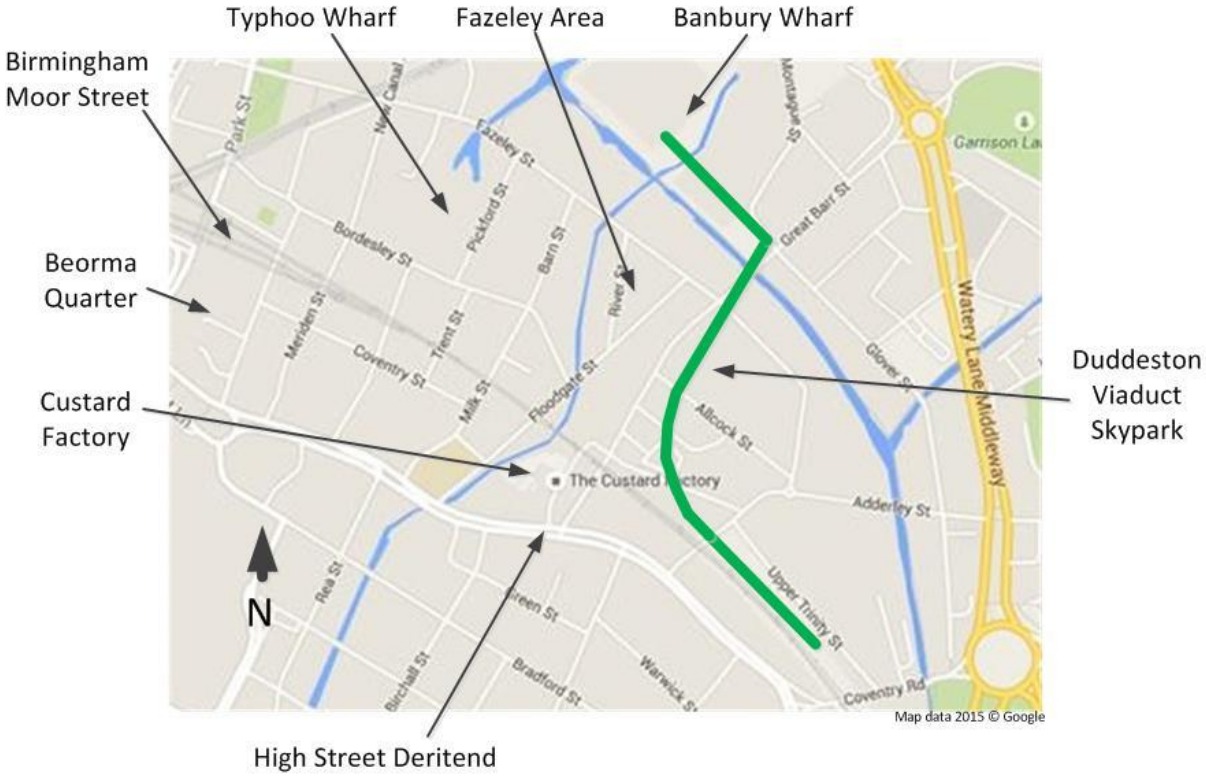

Figure 1: Plan of Digbeth

The Masterplan describes five main redevelopment areas in Digbeth:

- *Typhoo Wharf*: a disused tea factory described as having 'distinctive buildings and an attractive canal-side location'. It is seen as a regeneration opportunity with refurbished and new buildings.
- *Fazeley area*: a mixed area mainly of traditional small businesses and industries bordering on the Custard Factory. Redevelopment ideas include new buildings and refurbishment of historic ones, along with use of the large old railway arches.
- *Banbury Wharf*: an old industry area next to the canal in the northern part of Digbeth. This is proposed for development mainly as a new residential area.
- *Duddeston Viaduct Skypark*: a disused, eye-catching 165 year old brick-built, arched viaduct several hundred metres long. One option is for it 'to become a green spine' … 'creating an exciting resident and visitor experience'.
- *Shaws Passage/Beorma Quarter*: close to the city centre (Bullring and Selfridges), the Beorma quarter is already under redevelopment, while ideas for Shaws Passage (nearer the new HS2 station) are still being formed.

The Masterplan mentions some development ideas, but much of it is couched in terms of 'opportunities' for development. In this sense, the Masterplan is high-level and rather

general; within the broad framework put forward, ideas are expected from investors, developers and others.

On infrastructure the Masterplan is similarly rather general. Other than proposals for the main transport routes, there is little on provision of other infrastructure; much detail is still to be decided on, notably to the canal basin. The infrastructure ultimately provided will depend very much on the opportunities for access that are taken up: for example, in relation to Duddeston Viaduct Skypark, there are expected to be 'opportunities to provide public access points and bridges across the river', and 'potential to create a new publicly accessed open space enclosed by bars, shops and other visitor activities'.

3. Providing Innovative Decentralised Urban Infrastructure: What? Why? Who? How?

Before investigating conceptual frameworks and case study examples of decentralised infrastructure provision, it seems worthwhile undertaking a ground-clearing exercise: i.e. clarifying the terminology used, the main questions, and the focus of the enquiry. This is done by asking four general questions: What? Why? Who? How?

What?

The two main concepts dealt with here are *infrastructure* and *decentralisation*: the latter having two related concepts - *user-led* and *bottom-up*. *Infrastructure* is taken to mean the main networked industries of transport, energy, ICT and water; this is a sectoral view. The iBUILD project has considered the idea of infrastructure in further depth, including a range of less physical and sectoral aspects such as resources, processes, services and societal needs (iBUILD, 2013). This has led iBUILD to define infrastructure broadly as 'the artefacts and processes of the inter-related systems [enabling] the movement of resources in order to provide the services that mediate, and ideally enhance, security, health, economic growth and quality of life at a range of scales'. While containing some important insights, iBUILD recognises that this definition lacks focus, and that a more conventional sectoral view can help to make the scope of infrastructure more manageable. However, it is noted that this must not constrain thinking to major systems, and that processes outside large-scale, technical systems must be recognised. In this study, therefore, while the focus is primarily on the main infrastructure sectors, there is no exclusion of wider and softer definitions of infrastructure that could include social or economic services, such as education, health, finance and banking.

Decentralisation implies activities occur distributed across an area, and are undertaken by a large number of smaller organisations. In general terms, it has been described as 'the redistribution or dispersal of functions, powers, people or things away from a central location or authority'.[3] Similarly, in relation to infrastructure, decentralisation has been defined as decision-making 'distributed throughout numerous agents' and 'without any active planning or direct intervention', though system coordination is normally achieved through some institutional arrangements and peer-to-peer coordination (Egyedi and Mehos, 2012, p.5).

[3] http://en.wikipedia.org/wiki/Decentralization

In infrastructure provision, *user led* refers to the roles of those who initiate, contribute to, manage, develop, and apply infrastructure, and who are themselves users (Egyedi and Mehos, 2012, p.4). The notion of user-led provision is in distinct contrast to centralised, large-scale, technical systems, in that it is the producer who is at the centre of the large-scale system, while users are distributed across the area. However, the user-led idea is not necessarily directly equivalent to decentralisation. Whereas producers can be seen as the opposite of users, they could equally be decentralised; i.e. small-scale and localised. Furthermore, in a decentralised world, it is quite possible that the user and producer overlap, and even merge together, thus leaving the term 'user-led', and its implied separation from the producer, as constraining. It is concluded, therefore, that while the term user-led can draw attention to an important process (and will be drawn on to some extent below), overall, it is a more limited and partial concept compared to decentralisation.

Finally there is the notion of *bottom-up* and its opposite *top-down*. They appear to be much the same as decentralisation and centralisation, with which they are described as 'twinning concepts' (Egyedi and Mehos, 2012, p.6). Bottom-up and top-down present no preconceived notion of user and producer; however, bottom-up and top-down do encapsulate the idea of directionality, which is absent from decentralisation and centralisation: i.e. there is an upward movement (of innovation, provision etc.) in bottom-up, and a downward movement in top-down. 'Top-down influences typically originate in supranational, national, regional, or local governments, and in large (multinational) companies', while, in contrast, 'bottom-up influences on infrastructure development typically stem from technology users, citizens or grassroots organisations' (Egyedi and Mehos, 2012, p.6). There is, however, a question mark over whether specifying the direction of influence is constraining. For the purposes of this report, it has been concluded that this is indeed the case, and, therefore, that centralisation and decentralisation are the appropriate terms to use in response to the 'What?' question, unless referring to specific user-led or bottom-up processes.

Focusing on the notion of decentralisation raises the question about what is being decentralised. We can distinguish three elements of the whole process that can be decentralised:

- technological innovation – moving away from idea that all innovation comes from distant professional experts
- design – putting together infrastructure systems, a potential for input from the user or small-scale supplier
- provision – the organisation and operation of the business, moving away from large-scale centralised provision to smaller localised

Why?

In order to understand the reasons for pursuing a more decentralised form of infrastructure provision, some background is necessary on the centralised model of infrastructure that has become deeply entrenched in the 20th century, along with a glimpse at the changing nature of the economy that infrastructure serves. Although the large-scale, centralised system has become the dominant paradigm of modern infrastructure, most modern networked infrastructures, including telecommunications, water services, railways and electricity,

emerged in the 19th and early 20th centuries from small-scale, local developments (Egyedi and Mehos, 2012, pp.6-8). As these infrastructures grew, particularly in the early and mid-20th century, small infrastructure companies merged to form larger ones, and local networks gradually became regional and national. Consolidation and standardisation ensued, with the development of 'inter-networks'; and in a process of 'path dependence', early choices became locked-in and characterised system progress to maturity (Edwards et al, 2007, pp.i-ii). During this period of growth, networked infrastructures came to be seen as essential public services, and were subject to increasing state regulation - some companies, particularly after 1945, were taken over by the state. National and regional monopolies thus emerged in the main infrastructure sectors, further establishing the dominance of the large-scale, centralised model of infrastructure provision.

Despite a major redirection of government policy in much of the developed world in the late 20th century, in the early 21st century the centralised model appears particularly well embedded and resilient. The policy redirection involved privatisation, together with the break-up of monopolies; it has had a major impact on the infrastructure industry, but the centralised model has survived relatively intact. The main consequence of privatisation has been a shift of provision from government organisations to large private (and often multinational) companies, and the emergence of a degree of competition. The competition is, however, predominantly between large companies, and the main elements of the centralised model remain in place. To be sure, some decentralised infrastructures have emerged in recent years for a variety of reasons: not just, and not primarily, privatisation and liberalisation (see sections 4 and 6 below). The centralised model, therefore, can be seen as a socio-technical model that has become locked-in, not just for technological or economic reasons, but for reasons of social expectation and habit; it has become embedded within the fabric of society and the way we live our lives (see the socio-technical transition literature e.g. Smith and Stirling, 2008; Scrase and Smith, 2009).

Despite the apparent lock-in of the centralised model, and the limited examples of decentralisation (covered in the following sections), it is right to ask whether it is the most suitable model for today's cities. If, in everyday life, infrastructure is perceived primarily as an exogenous given, almost like the air we breathe, then perhaps the centralised model is the most suitable. However, industries in developed economies have become more differentiated: i.e. they have moved away from traditional, large-scale and standardised manufacturing processes ('Fordism'), towards a more nimble, service-based economy with smaller-scale and specialised activities ('post Fordism'). This movement suggests a need for infrastructure that can respond rapidly to change; and this, in turn, seems to fit better with a more decentralised approach. This is particularly the case if infrastructure (the main networked industries) becomes more fluid, merges with the general economy, and is no longer seen as something discrete and separate. This process is an especially pertinent description of modern creative industries with their small-scale, new ideas and flexibility.

What is the motivation for the decentralisation of infrastructure? The traditional, large-scale, centralised approach, can close off alternative ways of delivering value that might be particularly suitable for local and urban levels; similarly, it can be unresponsive to a range of

technological, economic, organisational and social innovations; and, it can result in large-scale systems becoming too siloed within their respective sectors: i.e. cross-sectoral interdependencies that have the potential to deliver benefits at lower levels, may not emerge in centralised systems. Infrastructure interdependencies bring risks, but they can also bring opportunities. The government has recognised the potential these opportunities have to encourage private investment, by improving the value/cost ratios of infrastructure projects. In terms of cost reduction, infrastructure interdependence-based opportunities include co-location of services (for example, cables and pipes sharing the same trench), and more efficient (and therefore cheaper) scheduling of street works; while, opportunities to improve value include dual-use of infrastructure, such as a road embankment acting as a flood defence barrier, or an electricity cable being used to carry data (HM Treasury, 2011).

All in all, therefore, decentralisation brings the potential for new ideas, innovation, greater flexibility and adaptability, a move away from a one size fits all approach, and a greater responsiveness to users, that appears lacking in the centralised model.

Who?

Who is involved in the decentralisation of infrastructure? The centralised model is dominated by large, specialised, public and private companies, including: research and development organisations; manufacturers; network operators; and, service supply companies. In contrast, and drawing on the introduction to Egyedi and Mehos (2012), a decentralised world could include:

- users of infrastructure services, such as citizens, public sector organisations, and NGOs. They may actively work with producers, developing and feeding back ideas; in this sense the process can be seen as user-led, or one of user participation. User involvement can also be conceived as bottom-up: i.e. ideas move upwards, towards larger organisations.
- locally based community groups, perhaps in some form of cooperative association. It certainly can be seen as decentralised, though in many cases members of the group are both users and producers, thus highlighting the limitations of the user-led notion.
- small/medium sized businesses at the local level, involved in infrastructure provision. They, again, could be both user and producer, or they might work with a small local infrastructure service provider: i.e. staying at bottom, not moving up).

How?

How can decentralised urban infrastructure be achieved? There are possible conceptual frameworks and areas of literature from which ideas can be derived: ‘user-led innovation’; ‘participatory design’; and, ‘inverse infrastructures’. These are discussed in turn below, followed by a look at developments in creative areas in other towns and cities.

4. User-led Innovation

Although this report has characterised user-led innovation as a subset of decentralisation, the idea of the user taking a prominent role in innovation is established in the literature, notably Eric von Hippel’s ‘*Democratizing innovation’* (2005). Von Hippel describes a world in which ‘users of products and services – both firms and individual consumers – are increasingly able

to innovate for themselves' (von Hippel, 2005, p.1). Users have the potential to develop what they want, rather than relying on large manufacturers. This 'user-centred' innovation process is in contrast to the traditional model, in which manufacturers undertake innovation in a closed way and use various means, notably patents and copyrights, to retain the knowledge gained. The users' role is primarily as a source of demand, which manufacturers respond to. In distinct contrast to this, von Hippel argues that 'a growing body of empirical work shows that users are the first to develop many, and perhaps most, new industrial and consumer products. Further, the contribution of users is growing steadily as a result of continuing advances in computer and communications capabilities' (von Hippel, 2005, p.2).

Von Hippel depicts a set of decentralised processes for technical innovation that appear particularly pertinent to this study. The emphasis is on the role of the user in technical innovation, which though important, is only a subset of this study's main focus of attention. Von Hippel also deploys the term 'user-centred', which, stresses the importance of the user role in the innovation process, but also introduces a little ambiguity: to what extent does the user lead and how active are they in innovation? In a narrowing of the scope of users, the book introduces the role of specialist users (described as 'lead users') to innovation. Their importance comes from the specialist knowledge they have gained using the product, and their desire to overcome problems encountered. Although innovative products are normally further developed and commercialised by established manufacturers, the importance of the knowledge of specialist users means they can continue to play a role with the manufacturer in product development.

The book explores the role of the user in innovation, mainly in relation to manufactured, physical products and software. Two examples of physical products – mountain bikes and surgical instruments – are outlined in boxes 1 and 2, including the role of lead users.

User-led Innovation in Infrastructure

Unfortunately, von Hippel's book does not discuss the role of the user in infrastructure innovation. However, there are some interesting discussions of user-led processes in the literature on infrastructure, relating particularly to energy. A traditional view of innovation in the energy sector (and other infrastructure sectors), posits innovation as originating in research laboratories and percolating through (and possibly being developed within) the manufacturing and supply chain, finally reaching the end-user a long way from the original innovation (Hyysalo et al., 2013, p.491). In contrast to this, studies of sustainable, small-scale energy technologies (energy efficiency and renewable energy technologies) have shown the important role of the citizen-user, and have drawn on the work of von Hippel (Ornetzeder and Rohracher, 2006; Hyysalo et al, 2013). Two examples of user-led innovation in energy – energy technology in the home, and thermal solar collectors – are outlined in boxes 3 and 4 below. The importance of clarity about who the users are is noted by Ornetzeder and Rohracher, who say that in innovation studies, users are often organisations or firms (users of some products and producers of others). They go on to say there is a range of 'intermediate users' (e.g. doctors are intermediaries with the patient the end-user); in their case studies they are referring to users of energy technologies in homes (Ornetzeder and Rohracher, 2006, p.139).

Box 1: Mountain bikes

The development of mountain bikes began in the early 1970s, when some adventurous bikers in California took their machines off-road, but found that their conventional cycles were not up to the job. These early users developed bikes with stronger frames, wheels and brakes – described as 'clunkers'. By the mid-1970s, the early user-developers began to start making machines for others, and a cottage industry emerged with six small assemblers in Marin County, California. In 1982, a small company brought the first mass-produced mountain bike to the market, and by the mid-1980s mountain bikes had been integrated into the main cycle market; sales have grown significantly since then. Innovation from users did not cease once mountain bikes became established, as specialist users continued to seek higher performance capabilities from their bikes, and developed the improvements required to meet their own needs. The development of mountain bikes is described as a 'low cost, innovation niche': that is, the conditions for user innovation are favourable. This relates to the cost of information needed to develop a solution – in this case much of the information required was held by the users themselves, and derived from their own experience of biking.

Source: von Hippel, 2005, pp.72-76.

Box 2: Surgical equipment

The role of surgeons in the development of surgical equipment has been investigated by researchers. In surveys, a significant minority of surgeons have been found to participate in the development, or improvement, of equipment and/or techniques. The main motivation was found to be overcoming problems encountered in their own surgical practice – surgeons have a tendency to care greatly about having 'just right' equipment and techniques. In cases where innovations have commercial potential and require significant manufacture, established manufacturers take on the development, but innovating surgeons often continue to play a key role as 'lead users'. Lead users are well ahead of most other users in their particular specialism, and foresee significant benefits (for themselves and for others) in continued innovation. Lead users also tend to develop and test their own ideas, even when working with manufacturers; indeed, lead users can retain more knowledge of the equipment than the manufacturer, particularly about its use, even when it has become a commercially established product.

Source: von Hippel, 2005, pp.30, 109, 176; Also Lettl, Herstatt, and Gemunden (2004); Lüthje (2003).

Box 3: Energy technology in the home

The development of energy technology in the home has become increasingly important as users seek to improve thermal efficiency and reduce consumption. The conventional perspective is that homeowners are passive recipients of technology, developed by an elite group of specialists in major companies and research and development organisations. However, research has shown that certain kinds of homeowners (in particular those in non-standard houses with specific problems) can have an active influence on the innovations and developments in home-energy technology. While established experts and professionals remain leading actors, in research in the UK, Galvin and Sunikka-Blank (2013) argue that 'homeowner-retrofitters' exert a significant 'upward influence' on the 'socio-technical system', in which the technologies are developed. This is achieved by: fostering skills among contractors and imparting their own skills; developing new techniques and devices, or modifying existing ones; and, innovating in ways that influence solutions already available. Similarly, in a study of the development of home heat-pumps and wood-pellet burners in Finland, Hyysalo et al (2013) found a wide range of active involvement of users in technological development. This ranged from user inventions and designs, to user modifications and add-ons. Again, it was observed that these tend to be for very specific applications (but which are nevertheless quite widespread) in which mass produced technologies are found to be limited. It is true that the majority were modifications and add-ons of a fairly modest scope and novelty, but they nevertheless demonstrate a departure from the conventional top-down perspective on the development of home energy technology.

Sources: Galvin and Sunikka-Blank (2013); Hyysalo et al. (2013).

Box 4: Thermal solar collectors

The first major wave in the development of thermal solar energy collectors occurred after the oil crisis of the early 1970s, and was a top-down initiative led by research and development in public institutions and major companies. This initiative began to stall in the early 1980s as oil prices fell. At this time a second wave of development occurred in Austria, and was a more user-led and bottom-up process. Skilled, amateur inventors in Styria, Austria, developed solar collectors suitable for the conditions and activities in their local rural area. Arising out of established patterns of social cooperation, solar energy self-building groups began to emerge and spread enabling know-how about solar (and other renewable energy technologies) through communities across Austria and beyond. An association for renewable energy was founded in 1988, which, although it represented an increase in professionalism, was set up to encourage further self-build and user-led development processes. While large solar energy companies played a significant role in the market, 'the self-build movement could be seen as a "development division" for solar heating systems, in which over many years a great number of practice-relevant technical improvements and new forms of applications were compiled and realised'.

Source: Ornetzeder and Rohracher (2006).

5. Participatory design

An area of enquiry related to user-led innovation is that of 'participatory design'. As the name implies, the focus is on design rather than innovation; but it continues the move away from traditional closed and elite top-down processes, towards 'co-design' processes involving a wide range of actors, particularly users. When considering design in connection with users, distinctions can be drawn between:

- design *for* users (users are the central focus in design, but their involvement is peripheral);
- design *with* users (users participate in the design process, though do not lead it); and,
- design *by* users (users lead in the design process).

Participatory design involves a clear shift from design for users, towards design with users and, to an extent, design by users.

The design of technological systems is a central feature of participatory design. The idea enables people affected by the technology they use, to participate in a collaborative design process. While technological systems are the focus, there is an explicit social and political angle to it that goes well beyond 'merely the insertion of public dialogue within technological development practices' (Asaro, 2000). It is about understanding how user-centred design and development fit into wider social and political frameworks.

Participatory design has an international community of researchers and a developing literature. A major collective work is the *Routledge International Handbook of Participatory Design* (Simonsen and Robertson, 2013); the authors suggest participatory design offers ways and means of:

- clarifying design goals;
- formulating needs;
- designing coherent visions for change;
- combining business orientated and socially sensitive approaches;
- initiating participation and partnerships between different stakeholders;

- establishing mutual learning processes among heterogeneous participants;
- conducting iterative experiments aimed at organisational change;
- managing step-wise implementation based on comprehensive evaluation; and,
- providing a large toolbox of different practical techniques to enable participation (Simonsen and Robertson, 2013, p.xix).

Techniques and tools of participatory design include the use of 'co-design spaces', which are not just physical spaces, but environments that encourage and are supportive of non-experts; and design workshops, which can include the use of scenario techniques drawing on drama, theatre and design games (Sanders and Westerlund, 2011; Sanders et al, 2010; Liem and Sanders, 2011). It is important that the processes are on-going, not one-off. The literature on participatory design describes a range of applications in areas such as health and education, but there is no discussion of networked infrastructures (Frauenberger et al, 2015; Simonsen and Robertson, 2013).

One area of infrastructure where there seems to be potential for more participation by end-users is the electricity sector, particularly via the use of smart grid systems for controlling electricity demand. These can help to flatten the load-demand curve (over a day or through the week), easing the management of supply and reducing prices for users. However, it appears that the focus of smart grid development in recent years has been on technological provision (by established companies and experts) and financial incentives for the end-user, all of which appear to have made the end-user a passive recipient rather than an active participant (Geelen et al, 2013; Verbong et al, 2013). Recommendations have been made that smart grid products and services should be designed to enable end-users to become 'active co-providers' within 'collaborative communities' (Geelen et al, 2013). This could enable greater exchange of ideas and more active learning from end-users, leading to further user participation in the design and deployment of smart grid systems.

6. Inverse infrastructures

The most developed framework for decentralised provision of infrastructure in the literature, is the book *Inverse Infrastructures: disrupting networks from below* (Egyedi and Mehos, 2012), a major output of the European Union-funded Next Generation Infrastructures project based at Delft university in the Netherlands. Particular kinds of infrastructures are referred to as 'inverse', because they are upside-down: they display features that are the opposite of the 'large-scale, technical system' model that is dominant at the moment in infrastructure networks. In this model, some centralised authority, normally a government or a large company, own and control all major aspects of the infrastructure: from research, development, and technology, to investment and marketing (Egyedi and Mehos, 2012, pp.1-2). The authors see the emergence of examples of infrastructure that display features that are the inverse of this model. They describe the 'prominent and prototypical characteristics' of inverse infrastructures as 'user-driven', 'self-organisation', 'decentralisation' and 'bottom-up' (Egyedi and Mehos, 2012, p.4). These are described in more detail below

User-driven

Traditionally, in the analysis of large-scale, technical systems, users have been treated as invisible or passive recipients of services. In a similar way to the ideas of user-led innovation and participatory design discussed above, the authors of *Inverse Infrastructures* draw on additional research that suggests that users have a more influential role in technological development than conventionally thought. They note that, hitherto, research has not investigated thoroughly the role of users in the development of large-scale, technical systems like infrastructures, and it is this gap they seek to fill. They argue that users can and do (and indeed should) initiate, contribute to, and manage infrastructure development and provision. Users are considered to be individual citizens and consumers, households, communities, professionals, public institutions, small and large businesses.

Self-organisation

A second key characteristic of inverse infrastructures is self-organisation. In contrast to the grand and all-encompassing plans developed by large organisations in the large-scale model, users self-organise at a small-scale level to optimise a local situation. Self-organisation, in an attempt to improve elements of local infrastructure, can lead to further activity and interaction among users, triggering more inverse development. Although the editors of the book emphasise users as the active agents in the process, in many of the examples in subsequent chapters, the local agents are small-scale producers, or in some cases a blend of both user and producer. A particular feature of self-organised systems is that important system properties emerge spontaneously, and not from the grand plans of the large-scale model. There is, therefore, what the authors refer to as a process of 'complex adaptation', which has parallels with complex adaptive systems in physics and biology; a dynamic 'at the edge of order and chaos' is evident (Egyedi and Mehos, 2012, pp.4, 17-37).

Decentralisation

Decentralisation is a key feature of inverse infrastructures. In a decentralised system, all the major aspects of decision-making, control, system development, business and investment, are distributed among numerous different agents away from a central point; thus, there is no single, central authority characteristic of the traditional, centralised, large-scale, technical system. Pre-designed, elaborate and highly visible institutional arrangements are distinct features of centralisation, but this does not mean that decentralised systems have no institutions. The institutional arrangements that govern operations in decentralised systems tend to emerge from the interaction of multiple agents: from peer-to-peer coordination, rather than direct intervention by a central authority (Egyedi and Mehos, 2012, p.5). In addition, what is centralised and what is decentralised can depend on perspective. While many see locally or regionally controlled infrastructures, such as energy systems in some European countries, as decentralised, Egyedi and Mehos (2012, p.6) argue that they are essentially centralised. Thus, while physical size and location (local/regional versus national) can, to some, be defining features of centralisation/decentralisation, to Egyedi and Mehos, it is the type of organisation and control that is important. If control remains with governmental organisations and established infrastructure companies at local level, it can still be seen to be centralised (Egyedi and Mehos, 2012, p.6).

Bottom-up

The concept of bottom-up (versus top-down) is twinned with decentralisation, but particularly draws out the direction of influence. Top-down refers to influence from government (supranational, national and local) and/or major companies, and might be achieved through research and development programmes, major investments and consumer pricing regimes. Bottom-up influences come from the interests and actions of users of technology, citizens, communities and small businesses.

Examples

Several examples of inverse infrastructures are discussed in the book, four of which – Wireless Leiden, wikis, wind energy in Denmark, water supply and drainage (the Dockside Green project) – are outlined in boxes 5-8 below. Wireless Leiden (box 5) provides an example of possibilities of providing locally-based Wi-Fi in a bottom-up, user-led manner. Undoubtedly, a small number of specialist users (amateur technical experts) led the way in the initiative, but a broader range of locally-based users have been active in organising, maintaining and developing it. Wikis (box 6) provide, perhaps, the most distinct example of user-led and self-organised infrastructure. Users can create and edit pages and thus, through a process of self-organisation, ideas, knowledge and value emerge in an inter-connected web, rather than as the result of a top-down plan. Wind energy in Denmark (box 7) is a good example of a successful, decentralised infrastructure, in which the key organisations leading the developments (small locally based companies and cooperatives) are distributed across local and regional areas. A participative culture enabled inter-action among a multiplicity of actors and organisations, leading to the emergence of ideas in a manner suggestive of bottom-up and self-organised processes. Greater decentralisation of water supply and management through the application of, among other things, green roofs (the Dockside Green project, box 8), can yield a range of environmental, economic and social benefits: absorption, storage and slow release of water can mitigate the effects of flooding; heating and cooling costs in buildings can be reduced; biodiversity can be increased; and a more pleasant urban environment created.

Box 5: Wireless Leiden

Wireless Leiden is a city-wide wireless infrastructure network offering local residents Wi-Fi technology at favourable rates. It originated in 2001, when an electronic engineering specialist realised the potential of locally based Wi-Fi technology and its connection to the internet. Together with a group of amateur computer and radio hobbyists, they undertook the significant re-engineering and software development required to produce a workable system and comply with wireless communications regulations. Within a year, the project got off the ground with a rudimentary network, operated and used by an increasing community of local enthusiasts; a local association, Wireless Leiden, was set up in 2002. The objective of the association was that all residents would be able to use the network; however, to grow much beyond a small network used by enthusiasts, without significant new financial and other resources, was a challenge. It required a number of locally based actors, with expertise and interests other than the technical ones, to get the project going. A particularly important input was volunteers with publicity skills, who raised the profile amongst the general public and organisations such as schools. In the years 2003-07 the network gradually expanded and a community of users and volunteers developed including: people who undertook a variety of maintenance activities distributed across the community; and people who contributed to the continuing development and improvement of the infrastructure. The maintenance and other voluntary work led to important social benefits. This social motivation for participation has been very important, as the tangible economic benefits appeared limited. The project thus demonstrates social value as well as economic.

Sources: chapter 8, *Inverse Infrastructures*; van Oost (2009).

Box 6: Wikis

Wikis are websites that allow users to create and edit pages, and make links between the pages. Self-organisation is an inherent feature: they allow apparently random and uncontrolled contributions of any interested person, enabling knowledge and ideas to propagate through an inter-connected web, rather than via a top-down structure. Wikipedia is the most successful and well known example; it appears puzzling on the surface as to how such a self-organised thing can be so successful. There is a dynamism in self-organisation, wikis provide an architecture of participation and underlie the success of many collaborative projects on the internet. It is a knowledge infrastructure that creates value from the activities of people once they connect. 'Collective intelligence of a community of users is harnessed over time to enable the creation of value' (p.118). In some ways the 'immaterial' properties of the internet make it different from other infrastructures. Research findings show a mixture of reasons for participation in wikis, including: social; altruistic; reputational; intellectual curiosity; as well as economic interests. To be sure, all wikis have some kind of centrally designed structure and basic operating rules. In Wikipedia for example there can be problems such as vandalism with some sites, and centralised processes and procedures have been developed to alleviate these.

Source: chapter 6, *Inverse Infrastructures*.

Box 7: Wind energy in Denmark

Since the 1970s, wind energy has developed successfully in Denmark; this is in contrast to the lower levels of success experienced in a neighbouring country, the Netherlands. An argument for this difference is that Denmark's approach has been predominantly bottom-up, in contrast to more of a top-down approach taken in the Netherlands. In Denmark, small, locally-based companies, often cooperatives, were closely involved in the development of wind turbines. The involvement of a variety of locally-based actors enabled a good interactive learning process to occur, which helped support the high degree of patience required during the uncertainties of the trial periods. This was enhanced by geographic proximity, mutual trust, and the co-operative and participative culture that already existed in Denmark. In the Netherlands, much top-down money went into R&D, but the established, large electricity generators played a more dominant role than in Denmark, and their resistance to smaller scale, renewable technology significantly slowed its development. There were, nevertheless, some important top-down elements in Denmark, such as support systems for the initial research and development, and regulatory/fiscal support for the developing market. Ultimately, a hybrid model of top-down and bottom-up features developed; what really seemed to matter was good interaction and learning between the various actors in the process.

Source: chapter 7, *Inverse Infrastructures*.

Box 8: Water supply, drainage and sanitation

There is potential for decentralised water infrastructure including: individual augmentation of water and waste treatment; and individual water harvesting and purification. This can be undertaken in houses, whether connected to water networks or not. The Dockside Green project in Victoria, Canada, is an interesting case study of rainwater harvesting and management. While the systems are developed and managed in a highly localised and decentralised manner, central initiatives, such as the development of favourable tariff structures, can be influential in motivating rainwater harvesting; issues of water quality and environmental factors are also important. 'Green roofs' are an interesting water-related, urban infrastructure development, which involve a degree of decentralisation, because the involvement of building owners and occupiers is necessary. Anticipated benefits include water/flood management (absorb, store, slow release); they can also reduce heating and cooling costs in buildings, increase biodiversity, and make for more pleasant urban environment. Decentralised systems of water management can develop on their own, but they often complement centralised systems and require active support or acceptance by water authorities. Regulatory coherence between central and decentralised processes is necessary, as is an overall institutional incentive framework for decentralised water systems.

Sources: chapter 9, *Inverse Infrastructures*. Lamond et al. (2014).

Aside from the *Inverse Infrastructures* book, the literature on infrastructure is not replete with examples of what can be construed as inverse infrastructures; however, some examples can be cited: boxes 9-11 below include sustainable energy communities in the UK, the urban energy autonomy experiment in Seoul and an urban mobility scheme in Berlin. As with the examples on user-led innovation in boxes 3-4 above (energy technology in the home and solar collectors), the energy sector provides the richest source of the inverse phenomenon.

Box 9: Sustainable energy communities in the UK

The last two decades have witnessed a significant increase in the provision of renewable energy (such as solar PV, hydro and wind) at the local level in community and cooperative-based organisations. In many parts of rural and urban UK, for example Oxfordshire (Parag et al., 2014), Scotland (Bomberg and McEwen, 2012), and the west of England (BWCE, 2015), a variety of 'sustainable energy communities' have arisen, and are integrated into local networks including: community and environmental groups; small businesses; and local authorities. Although predominantly centred on energy, they can include management of related water and ICT matters. They are normally established as Industrial and Provident Societies (IPS), which are legal entities for trading or voluntary organisations, and differ from conventional companies in that their objectives (some form of mutual benefit for members and/or wider community) go beyond solely making profits for owners/shareholders. One form of IPS is the Co-operative Society, which operates for the mutual benefit of its members; many very small and larger renewable energy co-operatives have been formed in the UK in recent years (Willis and Willis, 2012). Another form of IPS is the Community Benefit Society, which aims to benefit the wider community as well as its members); Bath and West Community Energy (BWCE) is one such example of this. Environmental and social goals are the principal motivations for sustainable energy communities; BWCE, for example, emerged out of initiatives from local (environmental) Transition groups and is networked with other community groups. While all of this undoubtedly exemplifies a decentralised and bottom-up process, there are some important top-down elements. Local authority planners, for example, often play a significant role in the networks, and the national regulatory framework for energy (such as subsidies and feed-in tariff arrangements) also plays an important role.

Sources: Parag et al. (2013); Bomberg and McEwen (2012); Willis and Willis (2012); BWCE (2015).

Box 10: Urban energy autonomy in Seoul

Since 2012, Seoul has been conducting an urban energy experiment, named 'One Less Nuclear Power Plant', with the aim of achieving energy self-sufficiency in the city. The experiment is intended to propose and implement 'new ideas, technologies and practices to alter existing ways of supplying, transmitting and consuming energy to provide reliable, environment-friendly, self-sufficient, and affordable energy in and beyond urban areas' (Lee et al, 2014). There is a mixture of bottom-up and top-down elements in the initiative. It represents significant decentralisation – from national to city level – though it has been initiated primarily by city level government actors. One of the key objectives is social sustainability, which is to be achieved through governance structures enabling citizen participation in decision-making processes. A major driver for this has been significant expansion of nuclear power, which, though emitting much less CO_2 than fossil fuel electricity generation, has been seen as problematic in the context the 2011 nuclear disaster in Fukushima, Japan, and subsequent social unrest at major electricity transmission line construction sites. There are also policies to encourage a more bottom-up approach by increasing local, small-scale renewable energy generation, and an increasing number of citizen-based solar power cooperatives have been observed in this regard.

Source: Taehwa et al (2014).

Box 11: Urban transport, 'BeMobility', Berlin

This is an experiment in developing a sustainable urban mobility scheme. It is a prototype involving the integration of electric-car sharing into public transport. It demonstrates the importance of ICT: in particular, the bottom-up influence of small companies, in niche 'smart city' projects and urban infrastructure innovation. A variety of public and private actors, such as car companies, electricity generators, component manufacturers, car park operators, transport authorities and research institutions, were given a 'protected space' to experiment with new technologies (particularly ICT), and develop urban infrastructure innovation. The urban information infrastructure and the bottom-up influence of ICT 'intermediaries' (small companies working on system integrative aspects), are seen as essential elements in the experiment. System development is distributed within the range of private and public actors in decentralised style, though the protected space is dependent on a top-down governmental intervention.

Source: Khana and Venters (2013).

Discussion

The case studies of inverse infrastructures are diverse; they draw from different sectors (although the energy and ICT sectors tend to dominate), and show different patterns of decentralisation and user involvement with no single model emerging. Scanning the examples given in the boxes, features that appear important are: the emergence of technology (such as communications and energy technologies) that enables specific local requirements to be met in ways that cannot easily be achieved with a centralised one-size-fits-all approach; pro-active individuals (e.g. radio enthusiasts) and active local citizens groups (e.g. in relation to energy and the environment); networks containing these people as well as key professional and industry individuals and organisations; and a policy framework conducive to new smaller scale infrastructure developments.

In the conclusion of the book *Inverse Infrastructures*, the authors attempt to: synthesise the characteristics of inverse infrastructures; distinguish the conditions under which they are likely to arise and the incentives people have to initiate and participate in them; and highlight the policies that are required to encourage and support them. Perhaps the most distinctive condition required for the formation of inverse infrastructures, identified in the conclusion, is a certain level of communication and trust. A degree and form of communication is necessary to enable initiation and coordination of new infrastructure ideas and to allow and encourage the contribution from locally based actors and groups: 'Inverse self-organisation requires communicative interaction and feedback loops about local and non-local information' (p.246). The availability of easy-to-use and powerful communications, afforded by the internet and new ICT technology, is seen as highly significant and helps to explain, perhaps, why many inverse infrastructures are in these technical fields.

However, it is not just technology that facilitates good communication, but also the quality of personal relationships, in particular the level of trust. As the authors point out, the 'willingness and readiness of individuals to act and react' is an essential element of self-organisation, which depends on the quality of personal relations. It is trust that is seen as 'an important and recurring catalysing factor' in examples of inverse infrastructures. Thus, a degree of 'good faith' is necessary in the successful operation of Wikipedia; and in locally based initiatives, a sense of belonging in a community, and the trust that results from that, can trigger 'reciprocal behaviour': for example, in the Wireless Leiden initiative (p.247).

The authors also note that common technical standards can enable the development of inverse infrastructures (p.248). Standards can promote interoperability and interconnection between different systems, enabling small-scale new developments to be connected to, and operate within, existing centralised infrastructures. Standards also provide a degree of certainty about the infrastructure and market for new investors.

The incentives for participation in inverse infrastructures are wide-ranging and instructive about the circumstances under which they can emerge. The main incentives highlighted by the authors are: better functionality of infrastructure, e.g. more internet bandwidth or a better and more reliable water supply; financial benefits to consumers, notably through drawing on local advantages not easily gained by a one-size-fits-all centralised supplier; independence from central suppliers and control over service; interest and curiosity – the satisfaction individuals can get from realising and developing their expertise in areas such as local Wi-Fi; and sharing, mutual support and the sense of belonging that can come from being active within a local community initiative (pp.247-248).

In the conclusion the authors recognise – not least because of the continuing dominance of the centralised large-scale model – that some central and local government policies are required to encourage and support inverse infrastructures. The suggested policies include: incentives to enable the formation of networks; interactive learning and community engagement; research and development subsidies; subsidies to support upscaling; pricing regimes to allow, for example, minimum prices for services; and standards on interoperability and inter-connection (to enable inverse infrastructures to connect and operate within centralised, large-scale systems) (pp.251-252). They are, nevertheless, aware that central government policies are somewhat in tension with the core idea of inverse infrastructures and a delicate balancing act will be required (pp.260-262). In specifying the need for a policy framework, there is a risk of reverting to some form of top-down institutionalisation that could stifle the very self-organisation and emergent/adaptive behaviour at the heart of inverse infrastructures.

Critique

It seems opportune now to stand back a little and offer a critique. Two features of the case studies stand out in particular, and suggest the need for a note of caution. First, in comparison to established infrastructures in the networked industries, most of the examples of inverse infrastructures are very small, somewhat marginal and niche. While they may offer some interesting and useful possibilities at a small level, there is little to suggest that they will seriously challenge the dominance of the large-scale, centralised model. Also, the majority of the examples are limited to the ICT and energy sectors, in which technological developments allow scope for some small-scale developments. Second, most examples of inverse infrastructures contain a mix of bottom-up and top-down features – they are hybrid in some way and dependent on at least some top-down elements for success. For example, wikis and Wikipedia have a planned system structure and some centrallyorganised principles to allow them to operate successfully; small localised energy systems are generally dependent on favourably pricing regime for sustainable energy, and they can require some governmental facilitation of interaction and technical learning within networks. This reflects the

conclusions of *Inverse Infrastructures*, noted above, that some local and central governmental policies are necessary to support their development.

It is interesting to note (reflecting these points) that the conclusion strikes a more circumspect tone than the earlier introductory and conceptual chapters of the book. The first three chapters stress differences and distinctions between the inverse and the large-scale models – chapter 1 covers the main features described above (user-driven, decentralisation etc.), chapter 2 focuses on emergent behaviour and self-organisation, while chapter 3 compares and contrasts the institutional systems, policies and technology of the two models. The authors thus imply in these chapters that the inverse model will eventually (and possibly should) seriously challenge the dominance of the large-scale model. Distinguishing between two distinct and separate models might be necessary for the purpose of understanding different dynamics, but this could overemphasise differences. In contrast to the earlier chapters, the conclusion highlights some limitations of the inverse model. It is noted, for example, that while inverse infrastructures evolve and develop, up-scaling is difficult and may, out of necessity, involve more top-down governance (p.242). They also conclude that inverse characteristics are 'points on a scale' and 'inverse in degrees' (p.243): i.e. bottom-up features are embedded with top-down, the latter including, for example, standard-setting and a facilitative policy approach. All this suggests, as an outcome, (though not explicitly stated in the book) the emergence of hybrid models, and it is these that should be the object of attention, rather than some idealised, inverse model.

There is, thus, some ambiguity in the book about the development of inverse infrastructures. Are they seen as a serious challenge to the dominance of the large-scale, technical system model, and even as *replacing* it? Or, more modestly, are they seen as *complementing* large-scale systems in a small number of localised niche areas? The latter seems more realistic and would suggest the need to develop infrastructure business models that reflect a mixture of centralised and decentralised features.

7. Creative industries, creative cities

This case study has the Digbeth creative zone at its heart, so investigation into the literature on creative industries, and their potential for business innovation, seems particularly worthwhile. The notion of creative industries (and creative cities and areas), is rather broad-ranging and needs some unpacking. A little clarity is needed on what they are, their purpose, their relationship with economic change, regeneration and innovation, and their part in adding to the attractiveness of life in towns and cities.

Creative industries, by one definition (the UK government's Department of Culture Media and Sport), are those based on individual creativity, skill and talent, and include 13 sectors: advertising, architecture, art and antiques, computer games, crafts, design, designer fashion, film and video, music, performing arts, publishing, software, TV and radio (Work Foundation, 2009, p.5). However, there are two problem areas with this definition that are particularly relevant to this study (Work Foundation, 2009, p.6). Firstly, it is difficult to distinguish creative industries from other industries on this (or other) definitions. Creative industries are complex and enmeshed with other industries. This is particularly the case with

software, a central element of the IT industry, which is enmeshed with a wide range of other (nominally non-creative) industries, including infrastructure. Second, what are considered to be 'cultural' industries (arts-based), valued primarily for their cultural and artistic contribution to life, can be conflated with 'creative' industries, which are often valued primarily for their economic contribution. Business innovation and economic regeneration are important in the latter and they reflect the changing nature of the economy (Evans, 2009). To confuse the issue further, the notion of 'creative cities' shifts the focus a little away from economic regeneration towards creating liveable, vibrant and attractive cities (Landry, 2000).

Reflecting the disparate nature of creative and cultural industries, there are a wide range of cities, and areas within cities, that are considered to be creative. Areas may be creative in the sense that they are cultural and artistic areas, or creative in terms of innovative new business developments, particularly those related to digital technology. There are numerous interesting examples in the UK of what have been termed creative areas. One of the most distinctive is an area of east London, centred on Shoreditch but extending into adjacent areas such as Clerkenwell and Hoxton. It encapsulates both the artistic and cultural aspects of creative areas and business innovation based, notably, on digital technology. Traditionally a working class area east of London, Shoreditch has become gentrified in the last 20 years. With an inflow of 'hipsters', street-level cultural and artistic activities have thrived (as in other areas of east London) (Pappalepore et al, 2014). It has also become home to many creative industries including arts, media and web-based technology companies (Centre for London, 2012). Urban economic regeneration based on digital technology has been a particular focus in recent years, as areas of east London have moved from 'creative city to tech city' (Foord, 2013). Emerging out of this is the 'Tech City UK' initiative (Tech City UK, 2015). Tech City UK is a public organisation that developed out of an organisation set up in 2010 to promote the development of east London's tech city. It then developed into a UK national organisation focusing on the development of high tech digital companies in many towns of cities across the UK.

Numerous other varying examples of creative areas in cities and towns in the UK can be cited (Landry, 2000). A distinct example in the north of England is Media City UK in Manchester (Salford Quays). This was initiated from a top-down scheme to transfer significant parts of the BBC and ITV from London to Manchester; many small media and creative businesses have begun to cluster around the media giants. A very different example in the north of England is the Ouseburn Valley, a small area near the centre of Newcastle-upon-Tyne.[4] This area of previously derelict industry and run-down houses has developed in the past two decades in a more bottom-up manner, without large, outside investment. It has become a haven for artists, musicians and small craft industries, together with some new digital technology businesses.

Internationally, there are many examples of creative industry and area development. Similar to London's Tech City, 'New Tech City' is an area of New York ('Silicon Alley') in which new digital technology industries have developed (Center for an Urban Future, 2012). Start-

[4] https://ouseburntrust.org.uk/the-valley/

ups have proliferated using internet and mobile infrastructures. A key reason for growth is New York's technological and business 'ecosystem', making it a fertile ground for start-ups. In Europe, an example of a different kind of development is Berlin since the fall of the Wall in 1990, which has been described as a magnet for the 'creative class': IT start-ups; design; architecture; advertising; music; art and media productions (Arandjelovic and Bogunovich, 2014). In another European example, a brownfield site in Lyon, named La Confluence, has been significantly developed over the past 20 years with public and private investment, and includes a range of small and larger business and industry (Carpenter and Verhage, 2014).

Innovation in creative areas

Innovation is seen to be an inherent feature of creative areas and industries. They are often entrepreneurial, early adopters of new ideas and technologies; they can stimulate further innovation and act as catalysts for economic regeneration (Evans, 2009; Work Foundation, 2009). In reports on innovation in creative industries, one of the most significant factors is the importance of networks: creative industries with strong networks tend to be more innovative (Evans, 2009; Work Foundation, 2009; Centre for London, 2012). Thus, the close-working of creative people, sometimes in same building, 'may generate vital spark' (Centre for London, 2012, p.42); an 'ecosystem of interconnected individuals' (physical and virtual proximity) is seen as vital for innovation (Foord, 2013). At the local level, there are numerous interventions possible by local authorities to help generate networks and encourage development of creative industries (Work Foundation, 2009, p.56). Local context, such as size, existing strengths, culture and history, is particularly important when considering interventions (Work Foundation, 2009).

Innovative infrastructure provision in creative areas

None of the reports and papers referred to here describe anything about user-led innovation or decentralisation of the form discussed in sections above. The literature is mainly on the development of creative industries in cities, innovation and its contribution to economy (Evans, 2009), and specific examples of creative areas such as Tech City in London (Foord, 2013). The literature has little on infrastructure and none of it focuses specifically on the user-led, decentralised or bottom-up aspect of infrastructure.

Infrastructure is not totally absent, however, from the literature. Numerous concerns are expressed about the need for the provision of good quality infrastructure, notably broadband, for creative industries; but the general assumption is that this is provided externally. In the east London creative area a concern has been ensuring major companies like BT supply super-fast broadband (Foord, 2013). In a recent report on the development of digital 'tech cities' across the UK, concerns were aired by many of the companies surveyed about poor broadband infrastructure, though in no sense are there any bottom-up initiatives (Tech City UK, 2015, p.25). The report also notes transport infrastructure problems in some areas, but again, the expectation is that this is something the authorities will put right in a top-down way (Tech City UK, 2015, p.25). Generally the approach of the survey for the report was that infrastructure is something provided by others.

A small shift away from this mind set is evident in an earlier report on creative industries by the Work Foundation (2009). Some users expressed frustration with having to accept the infrastructure they are given and there is a note of the need to consult business users first before making decisions about infrastructure provision (Work Foundation, 2009, p.48). There are some hints of a move towards more user involvement, for example, improved broadband in Kirklees is mentioned, but this is very brief.

Extending the notion of creative areas beyond industries normally associated with the creative sector, reveals some examples of innovative infrastructure provision. One is King's Cross Central in London, the redevelopment of the area surrounding King's Cross Station, which, although not based primarily on creative industry, has parallels with Digbeth in that it is urban regeneration close to a major railway station.

A decentralisation of infrastructure provision is evident in Metropolitan Infrastructure Limited, a company set up to manage the supply of a range of infrastructure services in the area (detailed in box 12). It is able to exploit opportunities from interdependencies between different infrastructure services and, being more proximate to the user than conventional infrastructure companies, take a more of enterprise/user-centred perspective on infrastructure provision.

Box 12: Metropolitan Infrastructure Limited, King's Cross Central

King's Cross Central is a substantial development on previously derelict land adjacent to King's Cross station, the principal terminus for train services from northern England and Scotland. It is Europe's largest regeneration project and aims, by 2020, to transform one of central London's most run-down areas into an international gateway and archetype for highly sustainable design and construction solutions (Metropolitan, 2015). The 67-acre scheme will consist of 20 new streets, 10 new public places, three new bridges and enhancements to the Regent's Canal.

One of the requirements of the project is to create one of the most sustainable and energy-efficient developments in the UK. This will involve installing a wide range of high-tech, low carbon energy infrastructure: for example, the Section 106 Agreement requires the developer to use reasonable endeavours to install distributed Combined Heat and Power (CHP)/energy centres (Frontier Economics, 2012).

The task of providing this infrastructure, along with the large amounts of utility equipment normally required on a project of this size, was massive and carried with it substantial programme risks for the project. The developers sought to turn this risk into an advantage by creating a business around infrastructure provision. Metropolitan Infrastructure Limited were appointed to provide a coordinated approach to the delivery of utility infrastructure, thereby improving lines of communication and reducing overall costs in the process. Metropolitan is responsible for managing the supply of gas, electricity, hot water for heating, water and drainage to the development: for example, Independent Water Networks (a sister company to Metropolitan) has permission from Ofwat to supply King's Cross Central's water and sewerage services; and another sister company will be operating the CHP plant. King's Cross Central demonstrates, therefore, that by looking at infrastructure interdependence from an enterprise perspective, opportunities can be found to improve infrastructure value/cost ratios.

8. Conditions and features of decentralised infrastructure

Drawing from the literature and examples above, we can identify the key conditions present when decentralised (bottom-up, user-led) infrastructures emerge, and their characteristics when established. For each of the decentralised infrastructure examples (boxes 3-11) discussed above, Table 1 below summarises the main conditions and characteristics. It is

difficult to generalise amongst so much diversity: there are a range of technological, regulatory, economic, social, and business culture factors involved, as well as a mix of bottom-up and top-down features. Some key factors are:

- availability of enabling technology;
- enabling regulatory and policy framework (e.g. subsidy or regulatory rules on issues like pollution);
- a social and business culture that enables new ideas to emerge, people to interact with those ideas, and resource exchange – referred to as 'horizontal connectivity';
- communication;
- trust;
- interest in the greater resilience achieved by small-scale distributed systems; and,
- opportunity facilitated by the concurrence of several key factors.

The key factors identified in the table for each of the case studies are elaborated below:

1. *Technology.* In all cases, some form of technology can be seen enabling small-scale, localised provision of infrastructure. The majority of the examples are related to the energy and ICT sectors, which have an abundance of small-scale, technological possibilities including: micro-electricity generation; energy efficiency technology; and wireless and internet technology. Outside these sectors, there are some small-scale technologies, in water and local transport for example, but these are less prevalent. It is not just the technology scale that is important, but also technology that enables interconnectivity and interoperability, which is fundamental to the internet and development of the smart grid systems appearing in electricity generation.

The enabling technology thus appears necessary, but it is far from sufficient. The examples remain few and far between, thus indicating that while technology is necessary, it is far from being a decisive or determining factor.

2. *Government policy and regulation*. In the majority of the case studies, some form of government action to promote and protect small-scale infrastructure initiatives appears to be important. This ranges across government (central and local) policies to encourage energy efficiency and renewable energy, favourable tariff regimes for small-scale energy (such as the feed-in tariff for small-scale renewable energy), subsidies for research and development and market establishment, and interoperability and interconnectivity standards.

3. *Social networks*. Established networks of social co-operation can be important in the emergence of local infrastructures: for example, in wind energy development in Denmark, and thermal solar energy collectors in Austria. Social (and business) networks can facilitate interaction and exchange of ideas in local areas, and in wider business and technical communities. Social and community benefits, such as the locally-based, sustainable energy communities that have developed across the UK, can also be an important motivation for the development of decentralised infrastructures.

4. *Economy and business*. Economic and business factors, such as a better and lower priced consumer service/product and the motivation of profit-making entrepreneurs, were evident in the case studies, but did not feature as highly as the above factors.

5. *Environment*. Environmental benefits, notably in locally-based, renewable energy schemes, but also in decentralised water management schemes, were a key motivating factor for many participants. In some UK sustainable energy communities, environmental campaign groups play a key role in promoting this.

6. *Other motivations and features*. Other motivating factors include local autonomy, intellectual curiosity and reputation enhancement.

7. *Opportunity*. What all the examples show is that no one factor is decisive; it is the coming together of several factors that creates the opportunity that can ultimately lead to success.

Table1. Decentralised infrastructure: conditions for emergence and characteristics

Case study boxes 3-11	Technology	Governmental: regulation/policy	Economic/ business	Social	Environmental	Other
Energy technology in the home	The potential for small-scale, home-based energy technologies - often renewable	Government policy requiring, or encouraging, better energy efficiency, more renewable energy and lower emissions	Home owners seeking to reduce energy consumption and thus costs	Pro-active home owners can become significant players in socio-technical networks		
Thermal solar collectors	The potential for small-scale, locally based technology. Keen amateur inventors play important role in its emergence		Reducing oil consumption and, thus, the impact of high and rising oil prices	Arose out of established patterns of social cooperation in Austria. Transmission of know-how within social networks important		
Wireless Leiden	Potential of wireless and internet technology on a small-scale. Role of radio and computer hobbyists in early development. Interoperability of internet – can connect new tech ideas to existing infrastructure	The need to comply with wireless and internet standards influenced the development	They have a product, at a price, wanted by local people. However, economic value on its own is not sufficient	Participating in a community initiative created local, social networks resulting in tangible social benefits		
Wikis	Internet and web technology that allows the creation and development of websites by users	High level governmental regulatory policy for the web, but not for specific applications like wikis. Some top-down rules necessary	There are be a wide range of economic reasons for participation in wikis: e.g. developing new ideas, creating business networks, marketing	Wikis can act as foundations for social networks		Other motivations for participation include, altruistic, reputational and intellectual curiosity
Wind Energy in Denmark	Technology has enabled small and medium scale wind energy systems to be distributed across a country	Governmental subsidies and support for R&D to get products established in markets	A patient business culture, tolerant of trial periods and uncertainty, important in success	Local and regional socio-business networks allow interactive learning and knowledge transfer		Geographic proximity, mutual trust, and Denmark's cooperative and participative culture key factors in success

Water supply, drainage and sanitation	The technological potential for some highly localised forms of water management, such as rainwater harvesting and green roofs	Regulatory compatibility between centralised and localised water schemes necessary. Favourable tariffs and acceptance, or support, by water authorities important	Potential for consumer savings through lower water bills and lower energy costs from green roofs	Potential for communal inter-action around local rainwater harvesting, or green roof schemes	Environmental benefits can be a motivation: lower water and energy requirements, flood management	
Sustainable energy communities in the UK	New and better small-scale energy technologies, such as wind, hydro and solar	Local authority planners can play a role in fostering local networks and supporting ideas. National regulations and subsidies (e.g. feed-in tariffs) can play an important role	Though economic motivations are normally not primary, they can be integrated into local business networks	Social and community benefits are sometimes explicit objectives. Small energy cooperatives can also foster local social networks	Environmental goals are often the main motivation, and many emerge out of local and regionally based environmental campaign groups	
Urban energy autonomy in Seoul	New developments in small-scale energy technology make it possible for them to compete with centralised nuclear power	It has been initiated primarily by city-level government		Social sustainability is a key objective: enables more citizen engagement with energy provision and reduce conflict over nuclear power	Primary motivation is energy autonomy to reduce dependence on nuclear power, which has become unpopular	
Urban transport, 'Bemobility, Berlin.	Improving electric cars and charging infrastructures, together with the potential of ICT to facilitate car sharing and organise recharging	Government actors have been involved. Government intervention required to ensure 'protected space' for development	Small ICT companies play an important role. Wide networks of businesses involved including: car companies; electricity generators; and car park operators.	Goal of more socially sustainable urban transport: i.e. reduce problems of private car ownership such as congestion, but retaining benefits of personal transport	Environmental objectives important – improving city air quality	

9. Conclusion: applicability to Digbeth

The aim of this study has been to explore the possibilities for innovative, decentralised infrastructure provision in Digbeth, in the context of existing plans for redevelopment driven by the HS2 project. The study has been particularly interested in the potential for a move away from the traditional, centralised approach to infrastructure provision, towards a more decentralised (bottom-up or user-led) approach. This concluding section of the study considers the extent to which the features and conditions necessary to support decentralised infrastructure provision exist in Digbeth; and the actions to be taken to help Digbeth be more open to such opportunities. The following considers the strengths and weaknesses of Digbeth in relation to the features and conditions identified above, discussions with local stakeholders, and information from websites of local groups.[5]

Digbeth's strengths

One of Digbeth's most distinct features is its vibrant community, which has its own distinct identity. Stakeholders pointed out that there are a wide range of small-scale, bottom-up initiatives taking place in Digbeth: from art events and night life, to the development of sustainable urban landscapes and city food production. The Digbeth Residents' Association is a particularly important organisation at the heart of all this activity.[6] It provides a focal point for local community activities including: social events; neighbourhood watch schemes; environmental initiatives; and many arts, musical and other cultural events. Although the Custard Factory is the most distinct cultural centre in Digbeth, events take place throughout Digbeth. All this shows that there are established networks of social co-operation and actors keen to promote initiatives that enhance social and community benefits. This appears to satisfy well one of the key criteria for the successful emergence of decentralised infrastructure.

In addition to the work of the Residents' Association, there is evidence of other local initiatives with environmental motivations. A distinctive example of this is Edible Eastside (Eastside is an area of Birmingham next to Digbeth): a social enterprise initiative to promote urban, community-based food production and cooking.[7] This came to Digbeth in 2012 with plans including: having working kitchens alongside gardens; offering support to community groups developing urban gardens; and organising training courses in food production and cooking. All of this has the ultimate aim of contributing towards a more liveable and sustainable city.

Key stakeholders also support, at least in part, a decentralised approach, though there is recognition that a hybrid approach is more likely: a mixture of centralised and decentralised inputs. In particular, there is a desire to avoid a top-down redevelopment of the sort commonly, and perhaps unfairly, associated with major redevelopment opportunities. This can lead to an increase in rents, a flight of small businesses, and a loss of the distinct character and vibrancy of the area. The balance to be struck is, therefore, a delicate one,

[5] Discussions with four officers from Birmingham City Council; a locally based architect and a developer; a local business agency. Also attendance at an event on innovative waste management in Birmingham.
[6] http://mydigbeth.co.uk/
[7] http://www.edibleeastside.net/

where there are opportunities for decentralised provision of infrastructure to start and grow; and where the quality, overall, of the infrastructure provided satisfies the needs of the businesses using it.

In terms of government policy and regulation, there are a number of interventions that could encourage decentralised infrastructure provision. There are, for example, national schemes for energy saving, and favourable regulatory regimes (such as feed-in tariffs) for small-scale, renewable energy schemes. At the local level, there are also enterprise zones to encourage the development of small businesses and start-ups. Although all this could help small, innovative enterprises in infrastructure, none of them are distinctive in Digbeth.

The proposed development of Curzon Street and Digbeth for the arrival of HS2 has similarities with other developments such as King's Cross Central (discussed in section 7 above), and suggests lessons can be learned. King's Cross Central's multi-utility and enterprise-orientated Metropolitan Infrastructure Company shows the possibilities for innovative infrastructure provision in areas where a decision has been made to make a big change. In a similar way, though with different details, opportunities exist in Digbeth with a concurrence of important factors: a decision has been made for a major regeneration; it is a vibrant urban area; there is a desire to creative sustainable and liveable urban space; and Digbeth has the physical space to try new things.

There are limitations outlined in the section below, but rather than being unsurmountable barriers, perhaps some driving force is required to overcome them, such as a person (or a group of people or organisation) with vision, ideas and drive. An example of such a driving force is Rohan Silva, a London based entrepreneur, who played a leading role in the launch of the Tech City initiative, and more recently has been behind the launch of 'Second Home', a shared office space for innovators in Shoreditch, in the east London creative area (FT Weekend Magazine, 2015). Second Home is 25,000 square feet of office space for technology, fashion, public relations, music and design start-ups. What Silva offers, particularly, is not ideas per se, but a blend of 'conjuring visions, cajoling, persuading, [and] making things happen' in an 'interplay of business and culture', all of which seems particularly apposite for the potential new developments in Digbeth.

Limitations of Digbeth

The activity and vibrancy of Digbeth's social, cultural and business life is distinctive, but arguably for infrastructure provision, even on a small-scale, it is too limited in scope and too small-scale. A business stakeholder pointed out limitations of scope; successful innovation in business results from a conjunction of numerous factors including: ideas; drive; spark; money; technology; knowledge; business support; networking; and space. Without most, or all, of these, innovation and business development is less likely. In this sense, there are particular problems in Birmingham in relation to the HS2 redevelopment areas, such as Digbeth, as they are rather fragmented. For example, in Digbeth's Custard Factory there is space, drive and spark, but there is the risk that it is rather separate and cut off from the main 'business' area to the north, where technology, knowledge, business support and networking is seen to be more abundant. A kind of 'horizontal connectivity' is required between different

areas to make something substantial and innovative happen, but this does not seem to be evident in Digbeth and adjacent areas of Birmingham.

Another limitation of Digbeth is that, in discussions with stakeholders, the study found no examples (excepting social infrastructure) of bottom-up infrastructure provision. Not only that, there was no sense that infrastructure could be provided in a bottom-up way; the general view was that infrastructure is something provided by others. None of the stakeholders were particularly positive about bottom-up infrastructure, or had any sense of newly emerging ideas on infrastructure. This reflects the study's findings in other creative areas, where the focus of stakeholders appeared to be on expressing disappointment about the quality of infrastructure, notably broadband, and, occasionally, the wish for more say in what is provided.

What could be done?

An important point that came through from stakeholders is the importance of developing and maintaining connections (physical and virtual) between different areas of Birmingham, and between different types of actors and organisations: for example, between those with more of a cultural and creative orientation; and those specialising in business and innovation. Some also stressed the importance of avoiding a siloed approach to the HS2 development; although sub-areas will inevitably have specialisms, such as creative, education, research or business, it is argued that the new developments should not separate these too much. It is necessary to realise that ultimately, in terms of innovation, economic development and a sustainable and liveable city, they are all mutually interdependent.

In practical terms related to infrastructure, this might consist of encouraging existing Birmingham city-based initiatives on sustainable energy and waste management to connect more closely with activities in Digbeth. There is, for example, the Birmingham District Energy Scheme which is owned and operated by Cofely District Energy, a company working in partnership with Birmingham City Council.[8] The scheme produces electricity, heat and chilled water using combined heat and power technologies. Although this is run by the major energy company Gdfsuez, connections with such schemes by Digbeth-based organisations, could provide the necessary knowledge, expertise and technology that smaller local organisations lack. Similarly, there may be potential for Digbeth-based infrastructure initiatives through close working with Birmingham City Council's initiative to transform waste management. This might entail new technologies, community-based initiatives, and new finance and business models to create a cleaner and greener urban environment.

Connections of the sort required to foster decentralised initiatives, could be stimulated by drawing on the techniques of participatory design, described in the section above; these include: designing coherent visions for change; combining business-orientated and socially sensitive approaches; initiating participation and partnerships between different stakeholders; and establishing mutual learning processes among heterogeneous participants. All this could be developed from existing participatory forums, such as the Digbeth Forum, an advisory

[8] http://www.cofely-gdfsuez.co.uk/solutions/district-energy/district-energy-schemes/birmingham-district-energy/.

group of business and residents set up by a Councillor in 2013,[9] and the forums organised by Digbeth Residents Association and the Custard Factory.

[9] http://mydigbeth.co.uk/digbeth-forum/

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