Innovative Decentralised Urban Infrastructure: Key Factors in the Direction of Development

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Abstract

Is there such a thing as an urban direction to infrastructure innovation in today's rapidly expanding cities? City growth has driven evolution of urban infrastructure through a combination of technological, political and commercial innovations, to produce today's top-down, centralised models; however, these now stand in the way of the innovation necessary to support continuing population growth. The significant investment set out in the UK government's National Infrastructure Delivery Plan provides an opportunity to address this problem. This paper postulates that applying a decentralised (bottom-up/user-led) approach to infrastructure provision can create the space necessary for a new direction of urban innovation to emerge. It draws on case study examples from the literature, where there have been innovations along these lines, to develop a theoretically informed understanding of what needs to be in place for them to be successful. These findings are used to assess a proposed, large infrastructure redevelopment at Digbeth in Birmingham, to determine the likelihood of success of a decentralised approach.

Introduction

Human populations of the world's cities are growing rapidly. 2007 was the year in which, for the first time in human history, over 50% of the world's population lived in cities [United Nations, 2007]. It is estimated that by 2050, that figure will have increased to 70% [United Nations, undated]. Growth is being driven by a range of economic and social factors: chiefly, the ability of cities to provide people with basic needs and essential public goods; and, to act as forums in which people can realise their ambitions and aspirations, achieving a measure of contentment and happiness in the process [UN, 2012].

Historically, city growth has driven evolution of urban infrastructure through a combination of technological, political and commercial innovations, to produce today's top-down, centralised models of infrastructure service provision. 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]. In the mid-20th century these grew and merged into local networks, which gradually became regional and national. Consolidation and standardisation followed, 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 also came to be seen as essential public services, and thus subject to increasing state regulation with some companies, particularly after 1945, taken over by the state. National and regional monopolies thus emerged in the main

infrastructure sectors, further establishing the dominance of the large-scale, top-down centralised model.

Ironically, bearing in mind this history of innovation, today's centralised infrastructure stands in the way of further urban infrastructure innovation; and yet, urban infrastructure systems will have to go through increasingly rapid cycles of innovation to support anticipated, continuing population growth [Bettencourt et al, 2007]. Cities are already society's main engine of innovation as witnessed by the positive correlation between population size and the number of patents produced [Bettencourt et al, 2007]; and incremental infrastructure innovation continues to take place: for example, the telecommunications sector replacing copper wires with fibre optic cable. However, the long life-cycle, capital intensive nature and 'top-down' organisational structure of much infrastructure are resistant to the emergence of new, disruptive, innovative ideas. The 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 stimuli; 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.

With so much staked financially, commercially and socially on existing, centralised, urban infrastructure systems, and bearing in mind the pressing need for further cycles of infrastructure innovation, something significant is required to open things up to innovative ideas, disruptive to the status quo; one possibility is the UK government's National Infrastructure Delivery Plan, addressing perceived shortcomings in the country's infrastructure with a pipeline of infrastructure projects out to 2021, valued at £483bn [IPA, 2016]. Historically, the UK has invested heavily in world class infrastructure that has helped underpin the country's economic growth; however, more recently, the UK's approach has been criticised as 'timid, uncoordinated, incremental, wasteful in its procurement, and insufficiently targeted', with the result that the infrastructure is ageing and no longer fit for purpose [HMT, 2010]. The situation provides an opportunity to explore a decentralised approach to infrastructure that embraces the range of innovations referred to above.

The National Infrastructure Plan covers a wide range of infrastructure projects, including the London to Birmingham high-speed rail scheme (HS2); the Birmingham terminus at Curzon Street is seen as a driver for significant redevelopment of the adjoining Digbeth area, about 1 kilometre east of Birmingham city centre. As with the country generally, Digbeth redevelopment will require significant new infrastructure: particularly energy, transport, water and ICT. 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.

In the context of the proposed Digbeth project, this paper postulates that a more decentralised (bottom-up/user-led) approach to infrastructure provision can create the space needed for a disruptive new approach to infrastructure innovation to emerge. Its aim is to explore the potential of this approach by drawing on case study examples from the literature, where there has been

innovation along these lines; develop a theoretically informed understanding of what needs to be in place for success; and, use the findings to analyse and draw conclusions on the scope for a new direction in urban infrastructure innovation at Digbeth. The paper begins with some background on the Digbeth area, before going on to review published literature on inverse infrastructures, user-led innovation, participatory design, and creative zones in cities; from this are elicited the factors that need to be in place for the decentralised approach to be successful. These factors are applied to the Digbeth area to assess the likelihood of success with decentralised infrastructure there; and finally, conclusions are drawn.

Digbeth: Then, Now and in the Future

Digbeth can trace its history back to the 12th Century and an important trade route between Coventry and Birmingham; in the 18th and 19th Centuries it was a major centre of industry with many workers living there, often in poor conditions; today, all of the slum housing has been demolished and Digbeth is predominantly made up of low-rise, brick built factories and warehouses, with a scattering of grander Victorian architecture and 'islands' of terraced housing (see Figure 1) [Dargue, 2016].

Figure 1. Views of Digbeth c.2000 (Courtesy of Adrian Pym Photography)

In the last 20 years, creative industries (media, design, digital, art galleries, TV production) have developed in and around the Custard Factory (see Figure 2). 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 cultural activities) and a strong residents' association.

Digbeth now stands on the threshold of a major new opportunity as a 'Creative Zone'. Birmingham City Council has recognised the potential that the planned, nearby HS2 railway line has to help

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

rejuvenate Digbeth, and has prepared a Masterplan [BCC, 2014] that envisages Digbeth building on the creative industries already there.

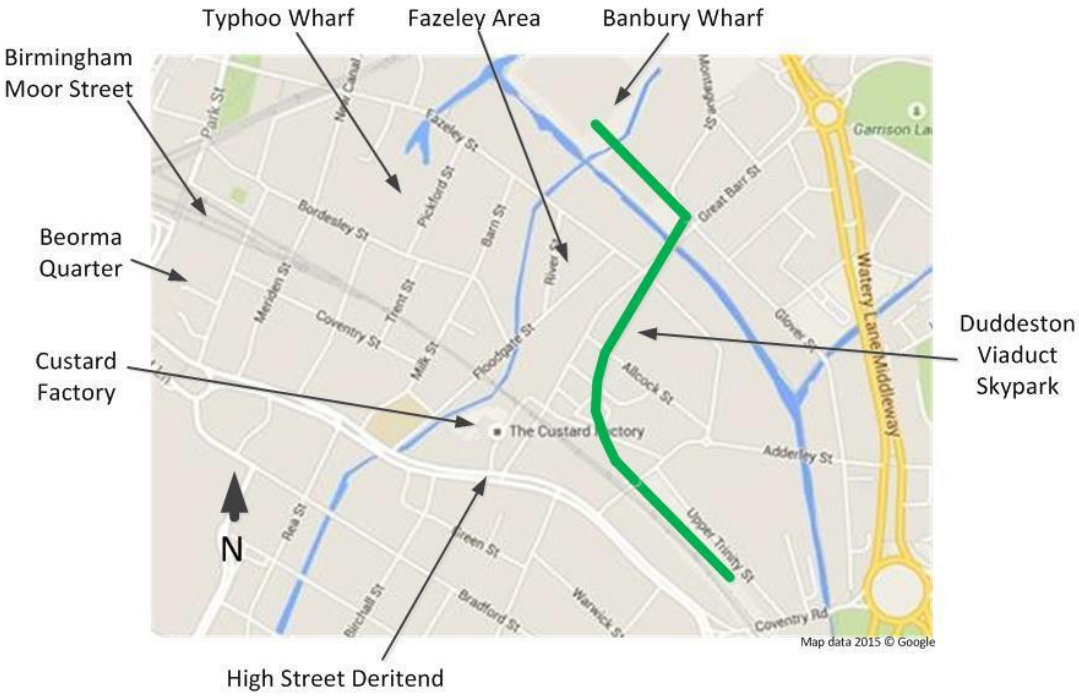

Figure 2: Plan of Digbeth

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'.

The Views of Digbeth Stakeholders

A small number of informal interviews were held with senior members of important stakeholder groups in Digbeth, to get an understanding of how they viewed decentralised provision of infrastructure. The groups were: an architectural practice; a property developer; a local authority; and, a business incubator. Broadly, they were supportive of the concept of a decentralised approach, though there was recognition that a hybrid approach (a mix of centralised and decentralised) would be likely to emerge. In particular, there was a desire among stakeholders 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 an area.

Some stakeholders were concerned about whether Digbeth was big enough to support a decentralised approach to infrastructure. They pointed out that 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, if not all, of these, innovation and business development is less likely. In its existing form, Digbeth has shown that it can provide the space, drive and spark (for example, the Custard factory), but there is the risk that it is rather separate and cut off from the main city centre 'business' area , 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 as yet this is missing in Digbeth.

Another limitation was that stakeholders were unable to give examples in Digbeth of bottom-up infrastructure provision, with the exception of social infrastructure. Notwithstanding their broad support for the concept of decentralised infrastructure, there was some scepticism that infrastructure could be provided in a bottom-up way; the general view was that infrastructure is something provided by others. As will be seen later on, this reflects the study's findings in other creative areas, where the focus of stakeholders appears to be on expressing disappointment about the quality of existing infrastructure, notably broadband, rather than taking action to do something about it.

Decentralised Infrastructure Innovation

Inverse Infrastructures

One of the most developed frameworks for decentralised provision of infrastructure comes from the Next Generation Infrastructures (NGinfra) knowledge institute based at Delft University in the Netherlands[3]; its findings are summarised in the book 'Inverse Infrastructures: Disrupting Networks from Below' [Egyedi and Mehos, 2012]. Particular kinds of infrastructures are referred to as 'inverse', because they display features that are the opposite of the top-down, large-scale, technical system model that is dominant at the moment in infrastructure networks. Egyedi and Mehos describe the 'prominent and prototypical characteristics' of inverse infrastructures as: 'user-driven';

[3] http://www.nextgenerationinfrastructures.eu/

'self-organisation'; 'decentralisation'; and, 'bottom-up [2012, p.4]. The research has found that: users can have a more influential role in technological development than conventionally thought: users can self-organise at a small-scale level to optimise a local situation, which can lead to further activity and interaction among users, triggering more further development; in decentralised systems all the major aspects of decision-making, control, system development, business and investment are distributed among numerous different agents away from a central point, with institutional arrangements emerging through the interaction of multiple agents; and, bottom-up influences come from the interests and actions of users of technology, citizens, communities and small businesses, rather than from network operators as is prevalent under current top-down arrangements.

The research covered a diverse range of case studies from different sectors, although the energy and ICT sectors tended to dominate. It found that an important condition required for the formation of inverse infrastructures is a certain level of communication and trust. 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. On the trust side, 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.

The research found 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 research 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).

The inverse infrastructures work recognises that some central and local government policies are required to encourage and support inverse infrastructures; that this will always be in tension with the core idea of inverse infrastructures; and therefore, that a delicate balancing act will be required. 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]

User-led Innovation

The idea of the user taking a prominent role in innovation is established in the wider literature, notably Eric von Hippel's 'Democratizing innovation' [2005], which focuses on innovation in relation to manufactured products and software. 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). This 'user-centred' innovation process is in contrast to the traditional model in which manufacturers undertake innovation in a closed way, retain the knowledge gained, and users act primarily as a source of demand and revenue. 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 and introduces the role of specialist users (described as 'lead users'). 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.

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. 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]. 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].

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, 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; 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].

Creative Zones in Cities

There is 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 [Nathan et al, 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.

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; Nathan et al, 2012]. Thus, the close-working of creative people, sometimes in same building, 'may generate vital spark' [Nathan et al, 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].

Infrastructure is not totally absent 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 a 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. There, a company called Metropolitan Infrastructure Limited has been set up to manage the supply of a range of infrastructure services in the area. 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.

Key Factors for Decentralised Infrastructure Innovation

The research has shown a wide range of factors to be important for a decentralised approach to infrastructure innovation. It is difficult to be objective about which factors are more important than others, but perhaps the most important is opportunity; without an opportunity for innovation, it is impossible to make any progress. This is particularly important with regard to infrastructure, where the long life-cycles and high sunk-costs of existing infrastructure militate against anything other than incremental change. Situations where an existing infrastructure is life expired, such as that in Digbeth, are one source of opportunity for innovation.

If opportunity is there, then leadership, and lead users, are the next priority, closely followed by issues of communication and trust. The top-down approach to infrastructure provision is well-established, and multi-million pound infrastructure companies have a vested interest in maintaining the status quo; therefore, change is unlikely to come about unless an individual, or small group of people, are willing to inject substantial amounts of energy into promoting a new idea. Technical skills are required as well as those of leadership, hence the importance of identifying lead users; and trust and communication within that team, and between the team and the wider world, will be critical to success. Physical connectivity has also been found to be important; this can take the form of people being co-located in the same office, but can also be on a larger scale: the ability to move about in the city with ease, experience what is going on elsewhere, and draw inspiration from that.

Leaders, lead users, trust and communications play a necessary part in providing the ideas, spark, knowledge, and networking necessary to develop an innovative idea in the first place; however, they are not sufficient; incentives, money, technology, business support and space must be in the mix as well. Technological innovation often provides the springboard for wider innovation, but without money to support development new ideas are unlikely to get to market. Business support is important in situations where those leading do not have the full range of skills to tackle all the issues that will face a new business; and there needs to be sufficient incentive, whether commercial, reputational or intellectual, to make it worth persevering with the project.

Finally, there is a variety of what might seem to be dull, but no less important for that, factors, such as the policy environment, common technical standards, and business and social cultures. A lack of supporting technical standards can be a major blockage to infrastructure innovation: for example, development of an electricity micro-generation idea could be killed off if the standards to support its connection to the national network are not in place. Similarly, government policy can be a boon or a deterrent: policies like a feed-in tariff for green energy could be very important to the micro-generation example above. And culture will have a big part to play in determining just how receptive banks and markets are to new ideas.

To summarise therefore, the key factors affecting a the success of a decentralised approach to infrastructure innovation are:

- Opportunity;
- Leadership and lead users;
- Communication and trust;
- Physical connectivity;
- Ideas; drive; spark; money; technology; knowledge; business support; networking; and, space;
- Technical standards;
- Government policy; and,
- Culture

Is Digbeth Ready for the Decentralised Infrastructure Approach?

It is clear that the arrival of HS2 in Birmingham does provide an opportunity that could be addressed by the decentralised approach to infrastructure innovation. The existing infrastructure is old and is likely to prove unable to serve the planned development; and, other than some high-level ideas about transport provision, the HS2 Curzon Masterplan does not specify much in the way of

infrastructure. Additionally, there is a desire among stakeholders to avoid a top-down redevelopment of the sort commonly, and perhaps unfairly, associated with major redevelopment opportunities. The door is potentially open therefore, to an entirely new approach.

However, the research found no examples in Digbeth, other than for social infrastructure, of bottom-up infrastructure provision. Although the stakeholders appeared broadly supportive of the decentralised infrastructure concept, there was no real sense of newly emerging ideas on infrastructure. This is in line with the study's findings in other creative areas, where stakeholder focus appears to be on expressing disappointment about the quality of infrastructure, notably broadband, and, occasionally, the wish for more say in what is provided. The general view is that infrastructure is something provided by others.

That said, Digbeth does have its leaders, lead users and examples of trust and communication. One of its distinctive features is its vibrant community and 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.

Despite examples of trust and communication being present, stakeholders felt that connectivity needed to be improved to help with the generation and development of new ideas. Linked to this was a concern about scale; there was a feeling that Digbeth is too cut-off from the city centre and as such the vital ingredients of innovation (drive, spark, money, technology, knowledge, business support, networking, and space) are not there in sufficient quantity.

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.

Culturally, the picture is confused. There appears to be no outright rejection of the decentralised approach, but there does not seem to be any great belief in it either. What comes through strongly is maintenance of the status quo with regard to infrastructure provision: infrastructure services are provided by large corporations involving national networks, and it is for them to do the work necessary to improve infrastructure in Digbeth. At the same time, however, Digbeth has a number of examples of community-driven initiatives, so the drive and commitment are there. It may be that cultural aspects are linked very strongly to the issue of leaders and lead users mentioned earlier, and that change needs those individuals to step forward.

Conclusion

Historically, urban infrastructure innovation has had a clearly discernible direction: the invention and commercialisation of new technology on a small scale has developed over many years to achieve today's large scale networked infrastructure systems. There seems to be, however, some justification in saying that this trajectory has run its course: within those systems it is possible to see continuing, incremental innovation, but infrastructure's large sunk costs and long life-cycles are militating against more radical and disruptive innovation.

Further innovation of urban infrastructure is required to meet the challenges posed by urban population growth. It is suggested that a decentralised method of urban infrastructure provision offers the chance to break away from the current paradigm and develop a new approach to infrastructure to address the challenges and opportunities emerging in the world's cities. The research has found eight key factors that need to be in place to support the decentralised approach and a new direction for urban infrastructure innovation:

- Opportunity;
- Leadership and lead users;
- Communication and trust;
- Physical connectivity;
- Ideas; drive; spark; money; technology; knowledge; business support; networking; and, space;
- Technical standards;
- Government policy; and,
- Culture

The Digbeth area of Birmingham, where there are plans for significant infrastructure redevelopment, was analysed using the eight key factors, to see whether it would be suitable for application of the decentralised approach. The research found that while there was a distinct opportunity, and examples of community-initiated schemes were evident, there was little interest in applying the decentralised approach to infrastructure, largely because infrastructure is seen as something that is provided by others and therefore, perhaps outside the scope of community action. The research did not, however, find any fundamental barriers to prevent application of the decentralised approach in the future, should the necessary leadership be found.

Acknowledgements

EPSRC and ESRC for funding that made this research possible (Grant reference number EP/K012398/1)

Adrian Pym of Adrian Pym Photography (https://adrianpymphotography.co.uk/) for permission to reproduce his images of Digbeth

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Chris is a Chartered Civil Engineer and a Senior Research Fellow at the University of Birmingham. He is currently working on a systems approach to the development of new business models for city infrastructure, having previously worked on a methodology for innovation in the rail industry. Prior to joining the University he worked for 20 years in construction with a number of consultants and contractors. Chris is a member of the INCOSE UK Model Based Systems Engineering and Human Centric Systems Engineering working groups.

Professor Christopher J. Baker

Chris Baker currently has two appointments. For 70% of his time he is Professor of Environmental Fluid Mechanics in the Birmingham Centre for Railway Research and Education at the University of Birmingham, with wide ranging research interests in the fields of: wind engineering; wind/crop interaction; road and rail aerodynamics; pollution dispersion; and, transport resilience in adverse weather. He is currently PI for grants of the order of £2.5million from UK research council, EU and rail industry sources. For the other 30% of his time he is Science Director at the Transport Systems Catapult Innovation Centre at Milton Keynes. He was an undergraduate, postgraduate and Fellow at St Catharine's College Cambridge, and has worked in the past for British Rail Research and Nottingham University.

Professor Christopher D. F. Rogers

Chris Rogers, a Professor of Geotechnical Engineering at the University of Birmingham, leads multi-university, multi-disciplinary research on infrastructure systems, utility service provision more generally, and future cities. This includes buried infrastructure mapping and condition assessment, and remote sensing technologies to explore underground space. He is a Deputy Director of iBUILD, a £3.5million consortium exploring infrastructure interdependencies and novel business models. He led two Sustainable Urban Environments consortia exploring sustainable urban regeneration, including Urban Futures, and leads the Liveable Cities programme grant, which is exploring visions of the future in which low-carbon targets are married with resource security and citizen and societal wellbeing. A member of the Lead Expert Group of the Foresight Future of Cities project, he chairs the Institution of Civil Engineers' Innovation & Research Panel and is a core member of the UK Collaboratorium for Research on Infrastructure and Cities (UKCRIC).

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