

National Infrastructure Commission call for evidence: 'Connecting northern cities'

Evidence submitted by the iBUILD Infrastructure Research Centre,
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Introduction

The iBUILD (Infrastructure **B**Ubusiness models, valuation and **I**nnovation for **L**ocal **D**elivery) Infrastructure Research Centre brings together a multi-disciplinary team from Newcastle, Birmingham and Leeds Universities to improve the delivery of local and urban infrastructure. iBUILD is developing and demonstrating alternative infrastructure business models that: take a whole life cycle view of infrastructure systems; exploit technical and market opportunities from modern interconnected infrastructure; leverage economic, social, environmental, aesthetic and other values from infrastructure; identify changes in governance, regulation and policy to unlock improvements; and, use innovative financing and funding mechanisms.

iBUILD promotes a service and system-wide approach to local and urban infrastructure, believing that there are significant advantages to be gained from planning, investing and managing infrastructure on an interdependent basis. As the recent floods in Cumbria, Northumberland, West/North Yorkshire, Lancashire and Greater Manchester have demonstrated, long-term resilience has to be built into the UK's infrastructure sectors and systems, and the houses and businesses that they serve. Otherwise, the potential economic and social benefits that can be derived from infrastructure investment will be marginal compared to the economic, social and environmental costs of repairing infrastructure that is damaged or destroyed by adverse (but increasingly regular) weather-related events.

The emergence of the National Infrastructure Commission (NIC) reflects the recent emphasis towards national scale infrastructure planning in the UK, and provides an important strategic context for the planning, development and operation of infrastructure. However, it is also important to consider the distinct role of local and urban infrastructure in driving local, regional and national economies. It is at the local and urban scales where infrastructure services are most dense and where the majority of people use infrastructure services in their everyday lives. Balancing growth across different geographical scales – from the local to the city/city-region – is vital to the long-term success of the national economy, as infrastructure drives local economic growth and job creation, as a consequence of construction and management activities as well as the enhancement and facilitation of other economic activities.

The response below first summarises key findings from our research programme that are relevant to all infrastructure delivery, before specifically responding to the consultation questions. Our response draws predominantly on new research identified during the iBUILD project, but also decades of research and experience in the iBUILD team. This includes engineering expertise in the Centre for

Earth Systems Engineering Research (CESER)¹ and the Institute for Resilient Infrastructure (IRI),² and the long-standing track record in local and regional development by the Centre for Urban and Regional Development Studies (CURDS).³

iBUILD focuses on all infrastructure sectors, not just transport, but our work has also drawn lessons from non-infrastructure sectors. Where our research is undergoing external peer review we cite working papers which, amongst other work, can be found at www.ibuild.ac.uk.

iBUILD Mid-Term Review and Policy Manifesto

In March 2015, iBUILD published a mid-term review and manifesto setting out thirteen evidence-based policy recommendations on how local and urban infrastructure business models could be strengthened in both design and in application. The key recommendations are elaborated in the full manifesto document, which is available online.⁴

Research from across the iBUILD Centre has identified five priority action areas for government and industry. If applied to all infrastructure planning and decision-making, these action areas will help to challenge the “timid, uncoordinated, incremental, wasteful”⁵ way the UK currently builds and manages its infrastructure, and help to develop a new approach to delivering infrastructure systems and their services that will enhance the health, wealth and security of UK citizens.

Priority Action Area #1: Have a broader, integrated appreciation of infrastructure

Infrastructure is not just tracks, tubes and trunk roads. Failure to consider the resources that flow along these, the services they provide and the people and businesses that depend on them, will lead to investments that don't deliver effectively. At the same time, it is crucial to understand how all these systems are interconnected; infrastructure depends on other infrastructure to work, not just technically, but also economically and socially. The UK's infrastructure is amongst the most mature and interconnected in the world and therefore has a pressing need to adopt a broad, integrated and sophisticated approach to infrastructure planning.

Recommendation 1: Infrastructure planners, financiers, engineers and other stakeholders need to use a broad, but appropriately specified, definition of infrastructure if they are to identify the full range of opportunities from alternative business models.

Recommendation 2: Housing and ‘hidden infrastructure’, such as efficiency measures, should be considered alongside the large-scale capital investments with which they interconnect, within infrastructure and spatial planning processes

¹ www.ncl.ac.uk/ceser

² <https://www.engineering.leeds.ac.uk/resilience/>

³ www.ncl.ac.uk/curds

⁴ iBUILD (2015) *Are you being served? Alternative infrastructure business models to support economic growth and well-being*, iBUILD Manifesto and Mid-term Report, Newcastle University: Newcastle upon Tyne. The full manifesto can be downloaded from <http://research.ncl.ac.uk/ibuild/outputs/>

⁵ Infrastructure UK (2010) *National Infrastructure Plan 2010*, First NIP: October 2010, HM Treasury: London.

Recommendation 3: National reforms in policy and regulation are required to enable an integrated approach to local infrastructure planning that can identify, and has the capacity to exploit, synergies across infrastructure sectors.

Priority Action Area #2: Enable action at the local scale that connects with the national

Too much infrastructure planning is top-down, yet every piece of infrastructure has to go somewhere; it is inherently local. Top-down approaches to infrastructure development and management stop locally-led and innovative business models from flourishing and discourage innovation. It also risks the wrong infrastructure being put in the wrong place at the wrong time because of a lack of local knowledge, engagement and ownership. These issues prevent the UK from maximising returns from infrastructure investment. The UK must devolve an appropriate and sensible proportion of infrastructure investment and responsibility to local institutions so they can deliver infrastructure that better reflects the values and needs of the communities it serves, yet remain mindful of the national strategy.

Recommendation 4: National and local policy frameworks should be realigned to focus on delivering wider societal benefits and to enable local infrastructure business models to emerge that can provide local solutions that are complementary with mainstream systems.

Recommendation 5: Effective operation of local alternative infrastructure business models requires greater fiscal decentralisation, complemented by a stronger and statutory devolved role for cities and localities in the planning, development and delivery of infrastructure.

Recommendation 6: Provide support for a wider range of innovative local infrastructure financing mechanisms, including tax increment financing, municipal bonds, social impact bonds and crowd source funding approaches.

Priority Action Area #3: Capture long-term value of every kind

Infrastructure is not only about cash returns. Investment in infrastructure provides wider health, economic and environmental benefits for society; infrastructure converts financial value to social value. A new economic valuation system that recognises these long-term, whole-life benefits is essential to maximise the benefits. Infrastructure must also be built for minimum whole-life costs. This might mean paying a bit more upfront for something that will last – and serve – for longer without the need for frequent maintenance; a resilient and sustainable infrastructure.

Recommendation 7: Incorporate measures of social and environment benefit (and cost) into infrastructure appraisal frameworks to recognise the wider societal and environmental outcomes and ascertain the widest possible set of mechanisms to capture revenue and other values.

Recommendation 8: Implement a quantitative framework within the infrastructure appraisal process to assess the value of flexibility and resilience across the whole system over the long-term.

Recommendation 9: Local authorities and infrastructure owners should apply resource assessments as a matter of course to identify the potential of land and infrastructure assets to generate long-term, stable revenue streams and not just one-off, short-term windfalls from selling-off assets.

Recommendation 10: Employ a new approach to infrastructure economics that recognises the long-term and system-wide value of infrastructure provision.

Priority Action Area #4: Deliver more efficient planning, procurement and delivery

Approaches to project financing, funding and delivery should not be chosen for political reasons. Mechanisms must be adopted that can best deliver the desired economic, social and environmental values, regardless of their political flavour. Many of methods and tools to enable this already exist: the Project Initiation Routemap, Building Information Modelling (BIM) systems, life-cycle assessment, so they must be used. These approaches support more efficient planning and procurement, minimise costs and human effort, preserve the environment, and maximise the potential to reuse and recycle materials and components in the future.

Recommendation 11: Implementation of the Project Initiation Routemap has been shown to have many cost reduction benefits and should be made standard practise for all public funded projects.

Recommendation 12: Planning and design of infrastructure should consider the material and resource demands of infrastructure pipelines to identify opportunities for reducing waste in the construction and operation phases, whilst designing for end of life material recovery or repurposing of infrastructure.

Priority Action Area #5: Accelerate the uptake of innovations through practical action and demonstration

Action often speaks louder than words. Alternative approaches to infrastructure business models are emerging. However, to quickly identify the most successful approaches and encourage their wide uptake locally, nationally and internationally, a number of ambitious demonstrator sites should be established for integrated infrastructure planning and testing of innovative infrastructure business models.

Recommendation 13: Establish full-scale urban demonstrator sites for integrated infrastructure planning and testing of innovative infrastructure business models.

1. To what extent are weaknesses in transport connectivity holding back northern city regions (specifically in terms of jobs, enterprise creation and growth, and housing)?

Key messages:

- *Transport infrastructure is one of many drivers of jobs, enterprise creation, growth and housing in cities and city regions and will rarely achieve these goals in isolation.*
- *Intra-city infrastructure is often more important and effective for jobs, enterprise creation, sustainable growth and housing.*
- *Poor connections to other regions in the UK (aside from London) also play a role in holding back the economies of northern city regions and means that the UK misses out on generating additional growth.*

Redressing regional inequalities

The starting point is to consider the evidence of how transport infrastructure might help enhance the overall economic performance of the north of England, especially compared to the rest of the UK, and in particular London and the south. And how improved transport connections within the north, and between the north and other UK nations and regions, including London and beyond, can support balanced growth in the north of England and rest of the country in the long-term.

The UK is a useful case study in which to consider how local and regional development policy has, over a number of years, sought to address spatial inequalities as it has been marked by persistent disparities since the 1930s, which have endured and exerted significant influence upon the national political economy, politics, and policy.⁶

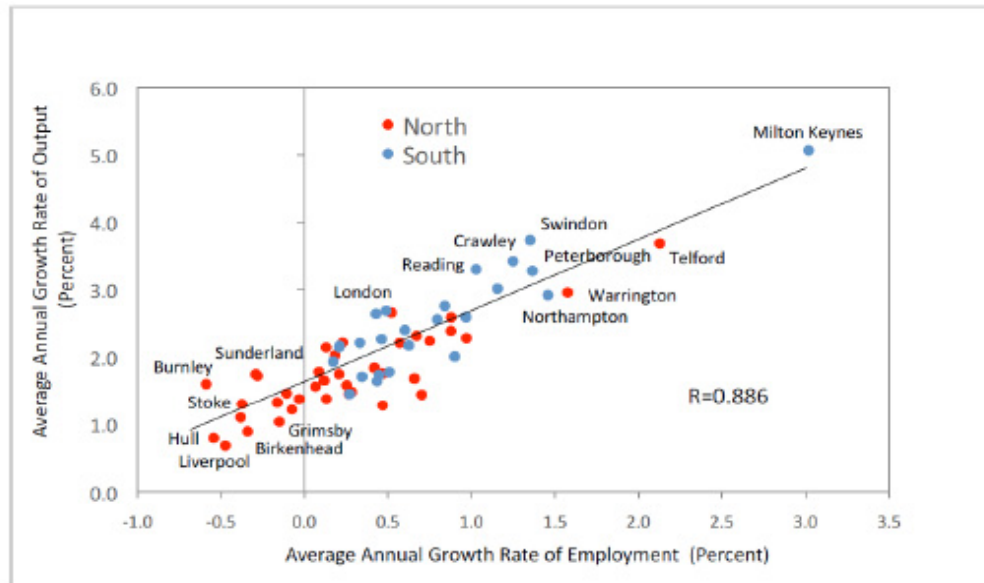
In a report,⁷ prepared for the 'Foresight Future of Cities' project,⁸ a long-term assessment is given of the evolving economic performance of UK cities in order to explain how UK cities have adapted and evolved over a long period within the national economy. UK spatial economic disparities are profound and there is a visible north-south pattern to them, as illustrated in Figure 1, which shows the relationship between output and employment growth in British cities over a 30-year period (1981-2011).

⁶ Martin, R. (1988) 'The Political Economy of Britain's North-South Divide', Transactions of the Institute of British Geographers, 13(4): 389-418. Pike, A., Rodriguez-Pose, A., Tomaney, J., Torrisi, G. and Tselios, V. (2012) 'In search of the 'economic dividend' of devolution: Spatial disparities, spatial economic policy and decentralisation in the UK', Environment and Planning C: Government and Policy, 30(1): 10-28.

⁷ Martin, R., Gardiner, B. and Tyler, P. (2014) 'The evolving performance of UK cities: city growth patterns 1981 – 2011', Future of cities working paper, Foresight Government Office for Science: London.

⁸ See: <https://www.gov.uk/government/collections/future-of-cities>

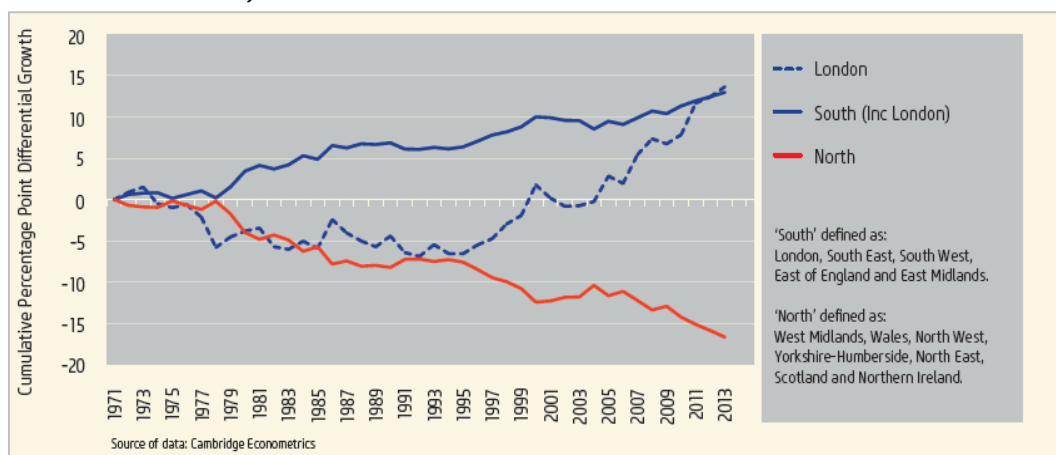
Figure 1: Relationship between output growth and employment across British cities (average annual growth rates for 1981-2011)



Source: Martin *et al.* (2014): p18.

Figure 2, below, is taken from a report for the Regional Studies Association, which advocates a new policy model to spatially-rebalance the UK economy.⁹ The graph illustrates the growth in overall disparities between London, the south and the north, which includes Scotland, Wales and NI. There has been phenomenal growth in London (as the UK's only global city) over the past 20 years, and the steady growth of the broader south, which has many strong economically-performing cities and localities, and many linkages with the London mega city-region. Any reversal of the spatial imbalance between the north and south is not forecast to occur for the foreseeable future.¹⁰

Figure 2: Cumulative percentage point differential growth gaps of GVA (2011 prices): The North, South and London, 1971-2013



Source: Martin *et al.* (2015): p5.

⁹ Martin, R., Pike, A., Tyler, P. and Gardiner, B. (2015) Spatially Rebalancing the UK Economy: The need for a new policy model, Regional Studies Association: Seaford.

¹⁰ Ernst and Young (2015) Rebalancing: UK region and city economic forecast, Ernst and Young LLP: London.

The persuasiveness of prevailing contemporary theoretical frameworks that seek to explain the root causes of spatial imbalances in the UK, by drawing upon New Economic Geography and New Urban Economics approaches, is evident in contemporary UK policy discourse.¹¹ There are powerful champions, in both national and local government, and in certain think-tanks, for building and strengthening transport infrastructure connectivity between northern cities as a means of creating a new ‘northern’ agglomeration – branded as the ‘northern powerhouse’ – as a counter-balance to a dominant London economy.¹²

The question posed by the NIC is the extent to which weaknesses in existing transport infrastructure are holding back the north of England economically. With this in mind, it is useful to consider what the OECD said in its 2012 ‘Growth in All Regions’ study.¹³ This empirically-rich piece of research, undertaken over a number of years, found that so-called ‘lagging regions’ together generated more aggregate growth than ‘high performing’ regions, and crucially that:

“Growth [in poorer performing regions] tends to follow simultaneous gains in several areas, such as human capital, infrastructure and innovation, rather than just one of these factors being responsible. This emphasises the importance of a multidimensional policy approach and the benefits of enhancing areas of complementarity, rather than tackling individual sectors in isolation. A second key message is that human capital is very important for boosting regional growth in all types of regions. And finally, growth dynamics vary with levels of development; they are not the same for underdeveloped regions as for advanced regions”.¹⁴

Transport infrastructure is only one ingredient

Transport infrastructure is one important and contributory ingredient of successful local and regional economic development strategies. However, transport, by itself, may not provide the means to grow a local economy unless it is aligned closely with skills development and innovation strategies. As an example, Rodríguez-Pose and Fratesi found that, despite a focused concentration of transport infrastructure investments in certain economically under-performing EU regions, there was no noticeable impact on regional economic convergence.¹⁵

However, the perceived failure of certain local and regional development policies should not necessarily be seen as an ‘infrastructure problem’, but instead should perhaps be viewed more as a question of how infrastructure can sometimes become embedded within narrow, unbalanced local and regional strategies that pay insufficient attention to skills, enterprise, innovation, which are all underpinned by

¹¹ Martin, R., Pike, A., Tyler, P. and Gardiner, B. (2015) Spatially Rebalancing the UK Economy: The need for a new policy model, Regional Studies Association: Seaford.

¹² DfT (2015) The Northern Powerhouse: One Agenda, One Economy, One North, report on the Northern Transport Strategy, Department for Transport: London. RSA (2014) Unleashing Metro Growth: final recommendations of the City Growth Commission, Royal Society for the encouragement of Arts, Manufactures and Commerce: London.

¹³ OECD (2012) Growth in All Regions, Organisation for Economic Co-operation and Development: Paris. The OECD research was based upon 23 international case studies across the OECD Member States, and included case studies of Greater Manchester, Leeds City Region and Tyne and Wear City Region in the north of England.

¹⁴ Ibid: p59.

¹⁵ Rodríguez-Pose, A. and Fratesi, U. (2004) ‘Between Development and Social Policies: The Impact of European Structural Funds in Objective 1 Regions’, Regional Studies, 38(1): 97-113.

effective local and regional socio-economic institutions and governance.¹⁶ The debate around HS2 and its potential contribution or otherwise to re-balancing the economic geography of the UK (see Tomaney for a review of the international evidence on high speed rail and economic geography),¹⁷ is testimony to the challenge of identifying causal evidence of direct linkages between transport infrastructure investment, city/urban growth and the narrowing of socio-economic disparities. Whilst there may be an association between the quality of transport infrastructure and the level of economic development,¹⁸ the key question is whether “transport investment promotes economic growth or does growth encourage more demand for transport, and thus further investment?”¹⁹.

Inter vs. intra-city investment?

If there is potential for additional investment in transport infrastructure in the north of England – and given the current disparity between capital spending per capita in London compared to the rest of England²⁰ we believe this is one essential component of stimulating the Northern Powerhouse – a key question is whether this investment is better spent on inter-city regional or intra-city regional transport in the north or on connections between the north of England and the rest of the UK? It is suggested that lower transport infrastructure and service costs are more likely to benefit core regions to the detriment of poorer ones because more productive cities or regions will already have a competitive business environment.²¹ This means that firms in core cities or regions will have an initial advantage over firms located in peripheral ones, which transport infrastructure connections between the two areas might exacerbate rather than reverse. Consequently, instead of improving connections *between* poor and core cities and regions it may be more beneficial, at first, to improve local transport infrastructure *within* cities and regions.²² This was one of the main conclusions in the Manchester Independent Economic Review, which recommended that, “the greatest economic benefits are to be gained from focusing on improving transport within the travel-to-work areas of cities themselves, rather than between them – and this is the case for Manchester. Thus, transport within Greater Manchester is the first and much more important priority”.²³ Likewise, the Eddington Transport Review called for investment to be prioritised in urban (i.e. intra-city region) transport infrastructure systems where it is possible to demonstrate more immediate and clearer economic benefits.²⁴ This supports iBUILD research that local infrastructure investment, in particular in transport infrastructure, investment in local infrastructure generates more jobs and return, more quickly, than large national capital programmes.²⁵

¹⁶ North, D. C. (1990) *Institutions, Institutional Change and Economic Performance*, Cambridge, Cambridge Univ. Press.

¹⁷ Tomaney, J. (2011) ‘The Local and Regional Impacts of High Speed Rail in the UK: A Review of the Evidence’, written evidence (HSR 14) submitted to the House of Commons Transport Select Committee Inquiry into High Speed Rail: <http://www.publications.parliament.uk/pa/cm201012/cmselect/cmtran/writev/rail/m14.htm>

¹⁸ Mackinnon, D. Pirie, G. and Gather, M. (2008) ‘Transport and Economic Development’, in Knowles, R., Shaw, J. and Docherty, I. (eds.) *Transport Geographies: Mobilities, Flows and Spaces*, Oxford, Blackwell: 10-28.

¹⁹ Bannister, D. and Berechman, J. (2001) ‘Transport Investment and the Promotion of Economic Growth’, *Journal of Transport Geography*, 9: 209-218: p214.

²⁰ HoC (2012) *Regional breakdown of regional public transport expenditure: Differences in public transport spending across England*, March 2012, House of Commons Scrutiny Unit: London.

²¹ Lafourcade, M. and Thisse, J-F. (2011) ‘New economic geography: the role of transport costs’, in De Palma, A., Lindsey, R., Quinet, E. and Vickerman, R. (eds.) *A Handbook of Transport Economics*, Cheltenham, Edward Elgar: 67-96.

²² Puga, D. (2002) ‘European regional policies in light of recent location theories’, *J. Economic Geography*, 2 (1): 373-406.

²³ MIER (2009) *Reviewers’ Report*, Manchester Independent Economic Review: Manchester, p26.

²⁴ Eddington, R. (2006) *The Eddington Review of Transport: Main Report*, Department for Transport: London.

²⁵ iBUILD (2015) *Are you being served? Alternative infrastructure business models to support economic growth and well-being*, iBUILD Manifesto and Mid-term Report, Newcastle University: Newcastle upon Tyne.

2. What cost-effective infrastructure investments in city-to-city connectivity could address these weaknesses? We are interested in all modes of transport.

Key messages:

- *Transport investment must generate and capture value of all-kinds: economic; social; environmental; and resilience.*
- *There are limited daily inter-city commuting flows between different urban areas in the north of England*
- *New infrastructure business models should be considered, in particular avoiding certain finance deals that incur high rates of debt and diminishing returns to tax-payers and users.*

A multi-dimensional view of value

The iBUILD Manifesto highlights that spatial planning plays a critical role in modulating the demands placed upon energy and communications infrastructure, and that efficiency measures and demand management strategies can reduce costs for infrastructure users, thus freeing up additional capacity to support growth and regeneration and deferring the need for expensive capital investment in new infrastructure. iBUILD research highlights the need to assess how new infrastructure investment (e.g. in city-to-city connectivity) generates value and efficiency in its broadest sense – beyond just the financial and economic to incorporate the social and the environmental – to provide a ‘return’ for tax-payers, users, communities and businesses in the north of England. In particular, national and local governments and the private sector should be examining how different business models and the use of alternative techniques can improve the life-cycle of infrastructure assets and systems so that they can generate longer-term economic, social and environmental value.

Standard economic approaches typically assume that individuals are rational, and that markets behave in an efficient fashion, and environmental, demographic and other socioeconomic factors are stationary. It is inevitable, therefore, that existing approaches only partially assess the true long-term economic, social and environmental cost and benefits of infrastructure. A key consideration for capturing value is the purpose of the infrastructure service; is it to maximise revenue, or to provide an affordable service or amenity to citizens, communities and businesses? The iBUILD Manifesto recommends that “measures of social and environmental benefit (and cost) are incorporated into infrastructure appraisal frameworks to recognise the wider outcomes and ascertain the broadest possible set of mechanisms to capture revenue and other values”.²⁶ iBUILD analysis also recommends that a similar holistic view of the economic costs and benefits of infrastructure investment is undertaken to help unlock future funding and finance by identifying the economic values of the

²⁶ Ibid: p 12.

systems of infrastructure provision that include benefits that are dispersed across the economy and society over long-term timeframes.²⁷

A long-term view on value

When thinking about ‘cost-effective’ transport measures it is important for the NIC to consider for whom the transport infrastructure will be cost effective? In view of the recent COP21 Paris agreement and commitments by governments (including the UK) to ‘de-carbonise’ national economies, alongside the importance of ensuring that transport infrastructure services are socially, economically and environmentally inclusive, further and future investment in public transport (particularly rail) within the north of England will be crucial. However, this may be challenging for two reasons. First, the private motor vehicle is the most utilised travel mode in north of England city regions.²⁸ Second, the quality of commuter, sub-urban and trans-Pennine rail rolling stock in the north of England, coupled with the cost of commuting, has long been found wanting.²⁹ In 2009, a study for The Northern Way found that commuting patterns between Greater Manchester and the Leeds City Region were 40% lower than expected given the proximity of the two city regions, and that overall commuting (i.e. monetary and time) costs were the main factor for the low commuting levels.³⁰ Further analysis of the daily commuter flows between different cities in the north of England have also revealed very few inter-city travel to work journeys (Table 1).

Table 1: Daily inter-city commuting in the north of England

From	To	Total commuters	% by train	% by car
Leeds	Sheffield	1,154	12.9	79.4
Sheffield	Leeds	2,477	16.4	73.5
Manchester	Liverpool	666	21.0	67.9
Liverpool	Manchester	1,706	30.5	58.1
Manchester	Leeds	530	28.7	51.7
Leeds	Manchester	718	31.6	54.0
Manchester	Sheffield	236	31.8	51.7
Sheffield	Manchester	527	44.8	43.3

Data source: Census 2011, based on local authority boundaries.

Source of table: Alasdair Rae (tweet published on 26 December 2015 available at <https://twitter.com/undertheraedar/status/680748659068157953>).

²⁷ Brown, A., Passarella M. V. and Robertson, M. (2014) ‘The Economics of Infrastructure’, in A Brown and M Robertson (eds.) *Economic evaluation of systems of infrastructure provision: concepts, approaches, methods*. iBUILD/Leeds University Report: Leeds.

²⁸ SDG (2014) *Transport Constraints and Opportunities in the North of England*, Steer Davies Gleave: London.

²⁹ CfBT (2014) *North of England Rail Services: Busting the Myths*, Campaign for Better Transport Briefing, August 2014: London.

³⁰ Overman, H.G., Gibbons, S., D’Costa, S., Mion, G., Pelkonen, P., Resende, G. and Thomas, M. (2009) *Strengthening economic linkages between Leeds and Manchester: feasibility and implications*, The Northern Way: Newcastle upon Tyne.

We need to ensure that public transport (such as rail and metro (light-rail)) is the preferred mode of choice for the majority of people who live and work in the north of England, which may mean reviewing and changing the way rail infrastructure is planned, funded, financed and managed. In particular, the NIC should consider carefully whether it is sustainable and cost-effective for the government to use private finance-type initiatives to invest in transport infrastructure when the cost of servicing private finance (capital investment) debt in the UK has been nearly double the rate of servicing government debt.³¹

³¹ NAO (2015) The choice of finance for capital investment, Report by the Comptroller and Auditor General, The National Audit Office: London.

3. Which city-to-city corridor(s) should be the priority for early phases of investment?

Key messages:

- *City regions in the north of England are primarily polycentric in nature and alleviating transport constraints should reflect the reality of functional urban economic geographies in the north.*
- *The breadth and depth of evidence produced by The Northern Way Transport Compact, and other recent research sources, provides valuable sources of data, analysis and recommendations for how best to improve city-to-city transport corridors in the north.*
- *Road and rail networks in the north of England, which provide crucial city-to-city transport corridors, need to be more resilient to extreme weather events or other significant disruptions.*

Road transport

City regions in the north of England are characterised by complex and overlaying patterns of trip movements, which reflect the polycentric nature of many city regions. To focus simply on radial trips to the centres of the northern core cities would mean that key transport constraints that affect city-regional economies are not fully considered. There are, however, noticeable pinch-points in urban areas, particularly in the strategic road network in the north, where investment is required to help alleviate congestion. Although traffic volumes have declined since the start of the economic downturn in 2008, rising city populations, along with economic growth, suggests that there will be future increases in traffic where and when networks have capacity to accommodate this.³²

Looking at projections for future road congestion in the north of England (see Figure 3), there are particular challenges forecast for Greater Manchester, Leeds City Region and Tyne and Wear. According to the Department for Transport's Northern Transport Strategy:

“There are areas of very high congestion on the road network, with high demand for freight from the Northern ports. Congestion on the strategic road network is worst where it is also heavily used by local commuter traffic, such as the M60 in Greater Manchester, the M62 in the Liverpool City Region and in West Yorkshire, M1 around Sheffield and the A1 and A19 in the North East and Tees Valley”.³³

At the same time, drawing upon greater use of smart technology and efficiencies, we should consider how Intelligent Transport Systems, led academically by bodies such as the Institute for Transport Studies (University of Leeds) and Transport Operations Research Group (Newcastle University), and Urban Traffic Management Control Systems, can best support improved transport connectivity and

³² SDG (2014) *Transport Constraints and Opportunities in the North of England*, Steer Davies Gleave: London.

³³ DfT (2015) *The Northern Powerhouse: One Agenda, One Economy, One North, report on the Northern Transport Strategy*, Department for Transport: London, p22.

flows between cities and city regions in the north; especially, if it proves problematic and undesirable, in the long-term, to continue to ‘build our way’ out of congestion.

Figure 3: Forecast congestion in the northern road network



Source: HS2 Ltd (2014).³⁴

The One North (Transport) Plan states that:

“The Department for Transport’s trans-Pennine study of 2011 confirmed that enhancing the Leeds-Manchester-Sheffield triangle of corridors would support the economic growth of these large city region economies. Given the extensive use of these three corridors by longer distance trips between the North’s city regions (including Tees Valley, Hull/the Humber and Lancashire), the study found that connectivity enhancements across this triangle would lead to balanced economic growth of the wider North”.³⁵

There may be important lessons for how to plan, secure and implement future investment in supporting transport infrastructure connectivity and linkages from the detailed research and planning that supported the Manchester Northern Hub project, led initially by The Northern Way.³⁶ In particular, it will be useful to reflect upon how strong and robust evidence-based arguments can be constructed, that are able to secure local and national ‘buy-in’, by demonstrating why investment in a specific transport bottleneck in a particular city region would improve connectivity and accessibility across the wider north of England.

Rail transport

³⁴ HS2 (2014) *Rebalancing Britain*, HS2 Ltd: London.

³⁵ One North (2014) *One North: A proposition for an interconnected north*, Manchester City Council: Manchester, p13.

³⁶ See list of reports prepared and published on the Northern Hub at:

http://www.northernwaytransportcompact.com/the_northern_hub.html

In terms of rail, Network Rail's growth scenarios (see Table 2 for growth scenarios between different core cities in the north) have been used to inform longer-term network planning, and suggest the highest growth scenarios for journeys between Newcastle and Manchester, Sheffield and Liverpool, and Manchester and Leeds.

Additional growth is only likely to be achieved through transport investment with journey speed and frequency increases. For example, the fastest Newcastle-London service is 2h36m whereas the fastest service between Newcastle-Manchester is 2h25m despite being two thirds the distance as the crow flies. As London is currently more accessible to many northern cities than to each other, strengthening inter-city links will incentivise the creation of new, and additional, intra-northern business opportunities.

Table 2: Network Rail Growth Scenarios to 2042-43

	Lowest growth scenario	Highest growth scenario
Liverpool - Leeds	+31%	+89%
Manchester - Leeds	+33%	+103%
Manchester - Liverpool	+28%	+92%
Newcastle - Leeds	+17%	+62%
Newcastle - Liverpool	+13%	+94%
Newcastle - Manchester	+30%	+109%
Sheffield - Leeds	+27%	+94%
Sheffield - Liverpool	+31%	+103%
Sheffield - Manchester	+30%	+98%
Sheffield - Newcastle	+12%	+95%

Data Source: Figure 6.6, Network Rail (2013) Long Term Planning Process: Long Distance Market Study

Source: SDG (2014: p47).

Integrated, whole-systems, view of infrastructure

In reference forward to question 4, there is a clear need for road and rail infrastructure planning to be tied into growth of major hubs. Capacity constraints around major ports and airports hinder their growth and contribution to both the Northern and UK economies.

Furthermore, it is important to consider the resilience of the infrastructure networks to extreme events or other disruptions. Many journeys have only one reasonable routing option for each mode. Alternative routes are often much longer or in some instances completely unavailable. Building resilience into the system can be more costly but avoids undesirable cascading impacts on the

economy³⁷ and when infrastructure is designed with multiple uses and values in mind it can provide additional resilience benefits.³⁸ Within cities, relatively small-scale engineering interventions to manage surface water flooding on the road network – if the sites are carefully based on disruption across the whole city – can have an enormous benefit to overall traffic movement.³⁹

³⁷ Fu, G., Dawson, R.J., Khoury, M. and Bullock, S. (2014) 'Interdependent networks: Vulnerability analysis and strategies to limit cascading failure', *European Physical Journal Part B*, 87(7):148.

³⁸ Khoury, M., Bullock, S. Fu, G. and Dawson, R.J. (2015) 'Improving measures of topological robustness in networks of networks and suggestion of a novel way to counter both failure propagation and isolation', *Infrastructure Complexity*, 2(1): 1-20.

³⁹ Pregolato, Ford, Robson, Dawson (in review) 'Disruptions of urban environment to rainfall extremes', *RS Open Science*.

4. What are the key international connectivity needs likely to be in the next 20-30 years in the north of England (with a focus on ports and airports)? What is the most effective way to meet these needs, and what constraints on delivery are anticipated?

Key messages:

- *Lower forecast public investment in the UK is expected to be a constraint to delivery and overall economic growth.*
- *Ports, airports and major infrastructure hubs require investment in connecting infrastructure to ensure that these assets are able to realise their full potential.*
- *Additional growth opportunities may be opened up by international high speed rail connections to the north.*
- *The public sector has an important role in managing, growing and utilising strategic infrastructure assets to support growth.*

Key role of ports, airports and rail for growth

In an assessment of future strategic transport infrastructure needs, the OECD suggests that, “major international gateway and corridor infrastructures, such as ports, airports and key rail routes, are crucially important to the exports and imports of all the products and resources of modern-day economies. These infrastructures will become even more important in the future”.⁴⁰ Given the crucial economic role of ports and airports in the north of England (The Northern Way 2011), it is important that public and private investments continue to be made to improve port and airport infrastructure and surface transport accessibility in and around seaport and airport sites. The OECD estimates that annual investment requirements for these sectors amount to some 2.5% of world GDP, which rise to 3.5% of GDP if electricity generation and other energy-related infrastructure investments in oil, gas and coal are included. Currently, however, public sector infrastructure investment in the UK only totals around 1.5% of GDP, and the Office for Budget Responsibility (OBR) forecasts that this investment will fall to 1.4% of GDP by 2019/20.⁴¹ The Infrastructure and Projects Authority has outlined a £411bn pipeline of infrastructure projects worth more than £50m up to and beyond 2020/21.⁴² Of the 399 regional projects and programmes in the pipeline, 136 are allocated directly to the 3 north of England regions.

⁴⁰ OECD (2011) Strategic Transport Infrastructure Needs to 2030: Main Findings, Organisation for Economic Co-operation and Development: Paris, p4.

⁴¹ OBR (2015) March 2015 Budget Forecast, Office for Budget Responsibility: London.

⁴² HMT (2015) Infrastructure Pipeline Update, HM Treasury/Infrastructure and Projects Authority: London.

Table 3: OECD estimates of global infrastructure investment needs (2009-2030)

Global	Infrastructure Investment Needs 2009-2030				
	Annual Average Investment (\$ Billion)		Aggregate Investment (\$ Billion)		
Infrastructure facilities	2009 - 2015	2015 - 2030	2009 - 2015	2015 - 2030	2009-2030
Airports capital expenditure	70	120	400	1,800	2,200
Port infrastructure facilities capital expenditure	33	40	200	630	830
Rail 'new construction' (incl. maintenance)	130	270	920	4,060	5,000
Oil and Gas – transport & distribution	155	155	930	2,325	3,255
Total	388	585	2,450	8,815	11,280

Source: OECD (2011: p10).

Transport for the North is expected to publish a multi-modal transport and logistics strategy in March 2016, which will set out future plans for investment in ports and airports. This will be important in the context of total freight handled by all UK ports having fallen by 5% in the second quarter of 2015 compared to the previous year, and given the recent industrial and economic problems on Teesside; the location of the UK's third largest freight port (Table 4). Major port tonnage remained stable for the second year in a row with 491.9 million tonnes handled at UK ports in 2014.⁴³

Table 4: Top ten UK ports (millions of tonnage) in 2014

Port	2013	2014	Percentage change	
Grimsby & Immingham	62.6	59.4	↓	5%
London	43.2	44.5	↑	3%
Tees & Hartlepool	37.6	39.5	↑	5%
Southampton	35.8	36.7	↑	2%
Milford Haven	41.1	34.3	↓	17%
Liverpool	31.1	31.0	↔	0%
Felixstowe	26.2	28.1	↑	7%
Dover	25.3	27.6	↑	9%
Forth	26.4	24.6	↓	7%
Belfast	16.8	16.8	↔	0%

Source: DfT Annual Port Freight Statistics (2015).

⁴³ DfT (2015) Annual Port Freight Statistics, Department for Transport: London.

Port infrastructure

Given the challenging competitive global environment, some ports have sought to harness their distinctive local assets to create new growth paths via transformational change, for example Bremerhaven's infrastructural adaptation to catalyse the offshore wind industry. Ports are also looking to capture new market opportunities and sustainable growth through innovation, business diversification and adding value to existing activities. The notion of SMART ports, particularly in the fields of logistics, smart traffic and trade flows (e.g. Hamburg, which is complementing SMART processes with existing renewable energy activity), is growing in significance and is beginning to form part of the long-term strategies of ports in the north of England. Some east coast ports (e.g. Hull and Port of Tyne) are taking forward plans to embrace new and adaptive capacity in areas such as renewables and offshore wind. For example, Hull and Humber Ports have plans for significant growth opportunities in the UK's largest Enterprise Zone (484 ha of land has been allocated for port and renewable uses). This is complementary to the potential growth offered by ports such as the new deep sea facility – the Liverpool 2 project – which is planning to double container handling capacity at the Port of Liverpool.

Airport infrastructure

Air connectivity supports trade internationally, attracts inward investment and supports inbound tourism, and the north of England's international air connectivity is provided in three ways:⁴⁴

- By direct air links from the north's airports;
- By air links from airports elsewhere in the country, principally Heathrow, accessed by domestic flights or by surface transport; and
- By air links from the north to other hub airports located in Europe, the Middle East (e.g. Dubai), or further afield.

Further growth of direct air links from the north of England would enhance international connectivity, as well as minimise end-to-end journey times. From June 2016, the Chinese carrier Hainan Airlines will commence a four flights a week service between Manchester and Beijing – the first direct scheduled flights between the UK and China outside London. The north remains dependent on connectivity via Heathrow, Amsterdam and Paris, which is why local authorities and Local Enterprise Partnerships (LEPs) have taken a keen interest in airport expansion in London and the south of England. Given the difficulties surrounding the expansion of airport capacity in the south, consideration may need to be given to the UK having more than one hub airport, with Manchester – the busiest in the north – a candidate to act as a second complementary hub. However, this must be complemented by improved road and rail accessibility to the airport if it is to serve the wider region.

⁴⁴ The Northern Way Transport Compact (2011) [The economic case for transport investment in the north](#), The Northern Way; Newcastle upon Tyne.

The public sector

There is an important role for the public sector (i.e. local authorities) in owning airports and managing investment in airport capacity in the north (e.g. Manchester and Newcastle), often working in partnership with private infrastructure investors. Some shrewd commercial investments by the Greater Manchester local authorities, as part of the Manchester Airports Group, have paid dividends in economic and financial terms, and generated valuable revenues in austere times. In addition, Airport City Manchester – through its commercial development and logistics activity – is making progress and perhaps suggests that there are additional land development and income-generating plans and activities that airports in the north of England may consider – with local authorities and private sector – to help supplement core business activity. This kind of municipal enterprise is welcome and its wider experiences and learning could be more widely shared.

5. What form of governance would most effectively deliver transformative infrastructure in the north, how should this be funded and by whom, including appropriate local contributions?

Key messages:

- *Northern Powerhouse infrastructure should not just be about transport. Transformational opportunities are more likely to emerge by taking a systemic view across all infrastructure sectors, including housing.*
- *The unique (in the UK) TfL governance structure and scope of infrastructure oversight in London offers a number of advantages and important lessons for the Northern Powerhouse.*
- *Local and northern-wide policy frameworks should focus on delivering wider societal benefits and enable local infrastructure business models to emerge that can provide local solutions that are complementary with mainstream systems.*
- *Effective operation of local alternative infrastructure business models requires greater fiscal decentralisation, complemented by a stronger and statutory devolved role for cities and localities in the planning, development and delivery of infrastructure.*
- *Governance must provide support for a wider range of innovative local infrastructure financing mechanisms, including tax increment financing, municipal bonds, social impact bonds and crowd source funding approaches.*
- *The governance of local infrastructure funding and financing is effective when it is based on productive, shared relationships between local, sub-national and pan-regional institutions acting in strategic partnership with an engaged and co-ordinated national government and its agencies.*

Governing infrastructure funding and financing

Governing the funding and financing of urban infrastructure has become a central concern for states at the national, metropolitan/city-regional and city scales. Huge and mounting pressures for infrastructure renewal and development are being generated by ageing and physical deterioration of assets and systems, increasing demands for higher levels of more integrated, sophisticated and sustainable services, and a growing emphasis upon the critical role of infrastructure in national economic competitiveness, modernisation and recovery.⁴⁵ There are clear linkages between governance and strategic planning, and between governance and local infrastructure funding and financing, decision-making, appraisal, accountability and scrutiny. These issues have been a key focus of inquiry within the iBUILD Research Centre.⁴⁶ There is a case for statutory spatial planning, particularly at the scale of functional economic areas, which is currently (re)emerging in a piecemeal and uneven way, but which is required at the metro, regional and pan regional scale if economic, social and environmental challenges are to be

⁴⁵ Wellman, K. and Spiller, M. (2012) *Urban Infrastructure: Finance and Management*, Wiley: Chichester. OECD (2013) *Annual Survey of Large Pension Funds and Public Pension Reserve Funds: Report on pension funds' long-term investments*, Organisation for Economic Cooperation and Development: Paris.

⁴⁶ O'Brien, P. and Pike, A. (2015) 'City Deals, decentralisation and the governance of local infrastructure funding and financing in the UK', *National Institute Economic Review*, 233, 14-26.

addressed effectively. The iBUILD Manifesto called for the “broader devolution of infrastructure planning, regulation and delivery” and that “cities and local areas should play a stronger role in national infrastructure planning than they do currently”.⁴⁷

Research has suggested that multiple municipalities in city regions and regions tends to be associated with lower levels of productivity, and that streamlining governance could support improved economic performance.⁴⁸ This comes at a time when significant fiscal pressures have been exerted upon local and sub-national authorities:

“The shift from fiscal stimulus to consolidation since the crisis led to sharp cuts in public investment, which fell by 13% in real terms across the OECD in 2009-12. Since about 72% of public investment is managed by sub-national governments (SNGs), this has created a particular challenge for regions and localities. While cuts in investment have helped protect current services and transfers, they risk undermining growth and service provision in the future.”⁴⁹

Unsurprisingly, the share of public investment managed by sub-national governments is often much higher in federal countries and lower in historically centralised countries (e.g. UK). The OECD Regional Outlook (2014) argued that, whether through shared policy competencies or joint funding arrangements, public investment involves different levels of government at each stage of the investment process, which can make the governance of public and capital investment complex. However, the sub-national governance of public investment can be improved and strengthened in a fiscally-challenged climate in two specific ways:

- First, national and regional/state governments should continue to play an important role in fostering the emergence of more effective metropolitan or pan-regional governance solutions. The obstacles to collective action by local and city authorities are often substantial, and even if all municipalities in a large urban area or region stand to gain from cooperation, there may be no institution among them with the capacity and incentives to take on the costs of gathering the necessary information, mobilising others, etc.
- Second, better sub-national and local governance can be achieved if there is a greater degree of policy coherence at national government level. Traditionally, explicit national policies on local and regional development have tended to be narrowly drawn and to focus on problems rather than on potential. Many other strands of policy, which have profound implications for local and urban development, may never be viewed through an “urban or regional lens”. Governments wishing to improve the economic performance of cities should develop a broader vision of urban policy, devising cross-sectoral strategies that seek to tackle the challenges facing cities and local areas in an integrated way.

⁴⁷ iBUILD (2015), p.10.

⁴⁸ Ahrend, R., Farchy, E., Kaplanis, I. and Lembcke, A. C. (2014) ‘What Makes Cities More Productive? Evidence on the Role of Urban Governance from Five OECD Countries’, OECD Regional Development Working Papers, 2014/05, Organisation for Economic Cooperation and Development: Paris.

⁴⁹ OECD (2014) OECD Regional Outlook 2014, Regions and Cities: Where Policies and People Meet, Organisation for Economic Cooperation and Development: Paris, p21.

Further useful analysis, when considering the practical requirements for governing transport infrastructure in the north, is offered by the OECD, which illustrates how public authorities can best ensure that public investment in infrastructure is governed and delivered in an efficient, smart and co-ordinated manner.⁵⁰ The OECD emphasises the contributions that different tiers of government can make to development and long-term growth, and frames a series of recommendations for national and sub-national/local governments around three pillars:

- Pillar A: Co-ordinate public investment across levels of government and policies. Focus on seeking and creating complementarities in policies and programmes across policy sectors, vertically across levels of government, and horizontally among sub-national governments to increase the effectiveness of public investment.
- Pillar B: Strengthen capacities for public investment and promote policy learning at all levels of government. Different capacities will exist at all levels of government to bolster the conditions for effective investment and to promote continuous improvement from the strategic prioritisation of investment to its delivery and monitoring.
- Pillar C: Ensure that a proper governance framework for public investment exists within and across all levels of government. Important features include: fiscal decentralisation; public financial management; public procurement; and regulatory quality at all levels of government.

Transport infrastructure governance in the north of England

Given the multiple local authority areas covered by Transport for the North (TfN), it will differ in size and scope to Transport for London (TfL). But there are some important lessons from the experience of TfL that the north of England can learn and build upon. One of the key issues for TfN is to secure an appropriate fit and relationship with different city regions and municipalities in the north, and in particular those city regions with new statutory transport bodies, such as Greater Manchester and other Combined Authorities. In summer 2015, the TfN Partnership Board expanded its membership to include council leaders and LEPs representing Cumbria and Lancashire, Tees Valley, North Yorkshire, and Cheshire and Warrington, which was a welcome development. However, it is important that there is both subsidiarity in planning, decision-making and fiscal autonomy, but also recognition that cities and localities in the north of England will benefit from up-scaling and using the pan-regional scale to lobby national government and pool individual and collective assets and funding streams together to leverage additional public and private investment in transport infrastructure. For transformative infrastructure interventions, however, there will be an ongoing requirement for national government to invest directly as a partner in schemes or as part of a multiple and perhaps innovative funding package that encompasses multiple institutions and actors across a range of scales. It will require local areas to contribute physical and financial resources, alongside national government and private and commercial actors, to invest in particular schemes. As with Crossrail in London, the local areas in the north of England that are more likely to benefit most from TfN projects, and are in locations where the market functions better, will be expected to contribute directly or source greater levels of local contributions towards investment. However, there will be areas in the north where the market conditions prevent

⁵⁰ Ibid.

significant private sector or developer contributions, and where bigger national government grants may be needed for investment purposes.

To support the long-term investment planning and delivery of TfN, it would be beneficial for the body to be placed on a statutory footing, in order to provide public institutions, business and other parts of the private sector with the necessary confidence and assurance that the organisation had a degree of permanence or certainty. Moving to a statutory basis would also formalise the scrutiny and transparency of TfN, nationally and locally, which is important when public resources are expected to form part of an overall investment pipeline.

The governance of planning, funding, financing and delivery of transport infrastructure in the north of England should be underpinned by evidence-led policy and strategy. The Northern Way commissioned high-quality research on the economic geography of the north, and its Transport Compact was key to the emergence of a number of ideas that we are now being delivered on the ground. We would encourage the NIC, Infrastructure UK and national and local governments to continue to commission and draw upon independent ‘research excellence’, regardless of political, policy or institutional change. As ippr north indicated in a recent report:

“The irrefutable logic of a regional tier in transport policy has meant that the ideas of the Northern Way have survived despite the policy changes of recent years, and have helped guide government spending decisions on smart motorways as well as the Northern Hub and rail electrification”.⁵¹

Innovative practices, tools, instruments and governance arrangements are being modified or constructed in order to fund and finance local infrastructure, many of which blur and/or straddle traditional notions of public-private boundaries (Table 5). We would expect TfN and its partners to adopt a variety of these practices to suit specific projects and geographical contexts, subject to appropriate fiscal powers and capability being evident. Some transformative transport schemes will require national government financial backing, in the form of direct grant, infrastructure guarantee or through borrowing. However, the likelihood is that international and national private infrastructure financiers will be reluctant to invest in the early and riskier phases of the infrastructure life-cycle of major transport projects. Even in London, where the market dynamics are far more buoyant than in the north of England, it is difficult for large-scale projects to attract private finance:

“Some commentators cite that a “wall of money” from Sovereign Wealth Funds, Infrastructure Funds, Pension funds and other similar investors is available to invest in infrastructure, and that this provides evidence that projects such as Crossrail 2 could be privately financed. While there is no doubt that these investors are keen to invest in infrastructure, Crossrail 2 is unlikely to meet many of their investment requirements. The size of the project, the construction risk, the demand risk and the likely reliance on non-patronage revenues to pay the bulk of the project

⁵¹ Cox, E. and Raikes, L. (2015) Transport for the North: A blueprint for devolving and integrating transport powers in England, ippr north: Manchester.

means that, without direct government guarantees, such investors are unlikely to invest in Crossrail 2”.⁵²

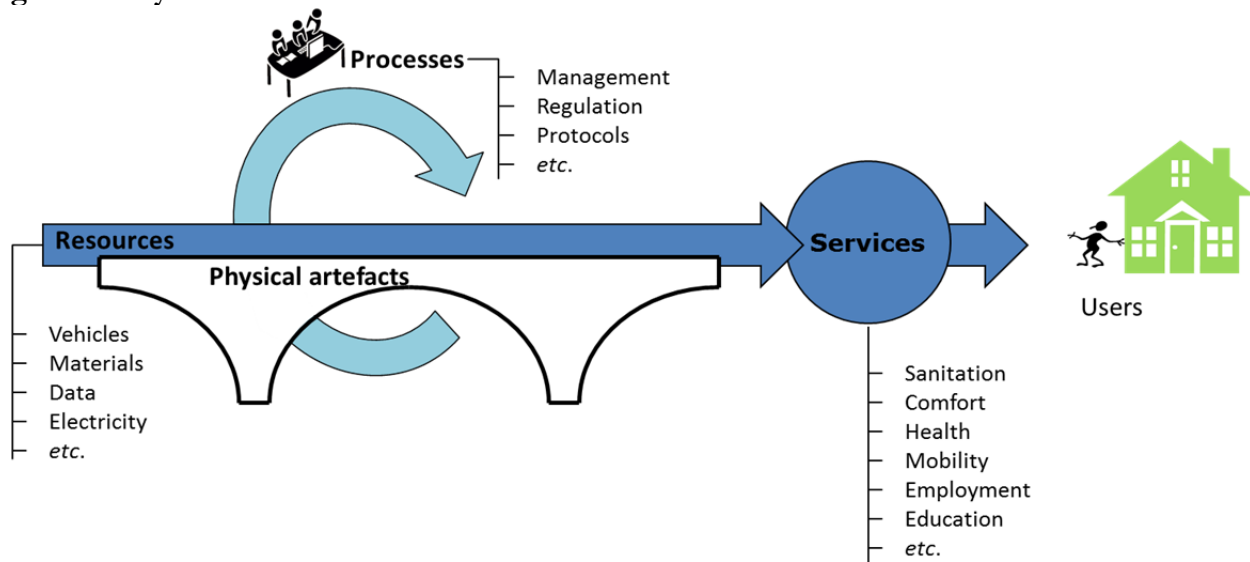
Alternative business models and an integrated approach

Business models take into consideration different governance, but must also consider the wider infrastructure system that comprises (Figure 4):

- *physical artefacts* – includes the physical links, nodes and components of infrastructure systems such as roads, bridges, pipes and cables;
- *processes* – includes actors, institutions, management, regulation, protocols and procedures that govern the infrastructure over its lifecycle;
- *resources* – includes people, vehicles, water, electricity and data that are conveyed by the physical artefacts and the materials used in the construction of the artefacts; and,
- *services* – such as warmth, mobility, sanitation, transportation, welfare services and communication that benefit a wide range of users.

Infrastructure is therefore the artefacts and processes of the inter-related systems that enable 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.⁵³ Moving beyond a narrow or solely economic view and distinct from the world of more conventional goods and services, an infrastructure business model therefore describes how infrastructure systems create, deliver and capture economic, social and environmental values over the whole infrastructure life cycle.⁵⁴

Figure 4: A systems view of infrastructure



Source: iBUILD (2015: p5).

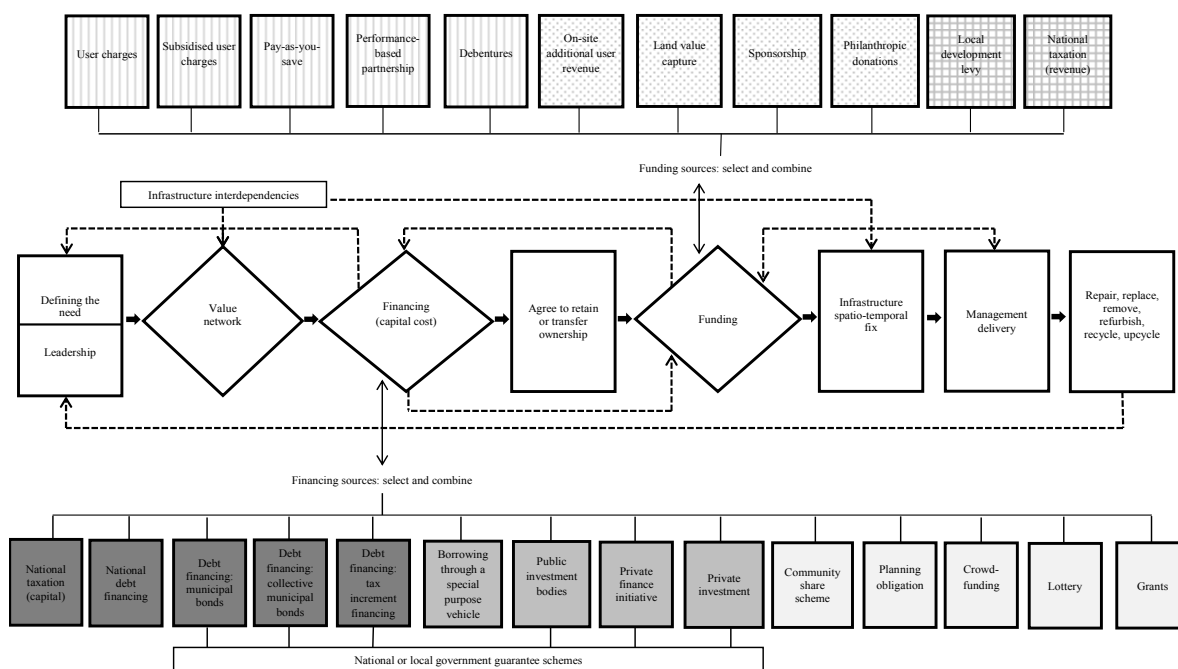
⁵² PwC (2014) *Crossrail 2: Funding and Financing Study*, PwC: London, p7.

⁵³ Dawson, R.J. (2013) *Bridges n'that: An infrastructure definition for iBUILD*, iBUILD Briefing Note 1, Newcastle University: Newcastle upon Tyne.

⁵⁴ Bryson, J.R., Pike, A., Walsh, C.L.L., Foxon, T., Bouch, C. and Dawson, R.J. (2014) *Infrastructure Business Models*, iBUILD Briefing Note 2, Newcastle University: Newcastle upon Tyne.

iBUILD has undertaken a review of over hundred UK and international local infrastructure business models, both traditional and non-traditional, across all infrastructure asset classes.⁵⁵ The business models are diverse. Value creation includes social, economic and urban regeneration outcomes as well as direct outputs in terms of service supply. International comparison has illustrated how the development of business models from niche to established mainstream models reflects the regulatory, political and socio-economic context.⁵⁶ For example, the success of municipal decentralised energy supply in Denmark and subsidy-supported business models for local energy supply in the UK.

Figure 5: Conceptual Framework of Local Infrastructure Business Models



Source: Bryson et. al (in review).

Developing and implementing alternative approaches provides some benefits, but as noted above, our infrastructures are increasingly interconnected and some of the most promising opportunities are from thinking about delivering what people really require i.e. warmth, light, mobility etc. rather than electricity, gas, roads. This can help identify business models that deliver efficiencies across multiple 'traditional' sector boundaries. A rapidly emerging interdependence is between electricity and transport infrastructure – most notably uptake of electric vehicles (EVs). Coupled analysis of energy and transport systems models, has demonstrated that distribution networks could accommodate higher growth in electric vehicles than previous studies have suggested. Exploiting the geographic spread and different timings of EV charging can limit the impact on power infrastructure. Distribution network

⁵⁵ Currently online here: <http://ceg-research.ncl.ac.uk/ibuildDemo/> (URL subject to change when site goes fully live).

⁵⁶ Bryson, J. R., Mulhall, R., Song, M. Loo, and Dawson, R. J. (in review) 'Conceptualising Local Infrastructure Business Models: The Spatio-Temporal Fix', *Research Policy*.

operators should collaborate with new market players, such as charging infrastructure operators, to support the roll out of an extensive charging infrastructure to make both networks more robust.⁵⁷

A well-established demonstration of the value of integrated infrastructure thinking applied to an industrial park – now an industrial ecosystem – is the closing of material and energy loops locally with integrated infrastructure in Kalundborg, Denmark. Since 1972, this industrial park has evolved from a single power station into a cluster of companies that exchange materials and energy for mutual benefit as by-products from one business are often inputs for others. For example, treated wastewater from a refinery is used to cool a power station which in turn provides steam for the refinery and a pharmaceutical plant. Surplus heat from the power station is also used for warming nearby homes and businesses. This has led to substantial annual savings of resources and costs – for example, a reduction in water consumption of 3.3million m³/year, savings of \$15m from resource sharing and far larger savings by sharing infrastructure have been reported – highlighting how integrated infrastructure business models can produce substantial savings.^{58,59}

There are many potential ways of organising and regulating such interactions to create efficiencies. For example, in 1887 in Indianapolis, local civic leaders established a natural gas company as a Public Trust, with an aim to “create the greatest long-term benefit for customers and communities”. Today, the Citizens Energy Group owns and operates a large portfolio of physical infrastructure assets that deliver multiple services including energy, water and wastewater for 800,000 people and thousands of businesses in the Indianapolis area. This has provided community services that are entirely compatible with good financial management. The group was awarded a top rating (MIG 1) by Moody’s credit rating agency in 2014, a reflection, in part, of the strength of the company’s infrastructure business model.⁶⁰ By recognising the opportunities from the interdependencies of modern infrastructure, and explicitly designing this into our energy and other systems, this not only offers opportunity for new business models, but it can also be used to deliver flexible infrastructure systems that can enhance resilience.⁶¹

⁵⁷ Neaimeh M, Wardle R, Jenkins A, Hill GA, Lyons P, Yi J, Huebner Y, Blythe PT & Taylor P (in press) ‘A probabilistic approach to combining smart meter and electric vehicle charging data to investigate distribution network impacts’, Applied Energy.


⁵⁸ Chertow MR & Lombardi DR (2005) ‘Quantifying Economic and Environmental Benefits of Co-Located Firms’, Environmental Science & Technology, 39(17):6535-6541.

⁵⁹ Chopra SS & Khanna V (2014) Understanding resilience in industrial symbiosis networks: Insights from network analysis, Journal of Environmental Management, 141:86-94.

⁶⁰ www.moody.com/research/Moodys-Concludes-Review-and-Confirms-MIG-1-on-Indianapolis-Indiana--PR_302963

⁶¹ Khoury M, Bullock S, Fu G, and Dawson RJ (2015) ‘Improving measures of topological robustness in networks of networks and suggestion of a novel way to counter both failure propagation and isolation’, Infrastructure Complexity, 2(1):1-20.

Table 5: Infrastructure Funding and Financing Practices⁶²

Temporality	Type	Examples
<p>Established 'Tried and Tested'</p>  <p>Newer 'Innovative'</p>	Taxes and fees	Special assessments; User fees and tolls; Other taxes.
	Grants	Extensive range of grant programmes at multiple levels (e.g. federal national, province, state, supranational)
	Debt finance	General obligation bonds; Revenue bonds; Conduit bonds; National Loans Funds (e.g. PWLB).
	Tax incentives	New market/historic/housing tax credits; Tax credit bonds; Property tax relief; Enterprise Zones.
	Developer fees	Impact fees; Infrastructure levies.
	Platforms for institutional investors	Pension and Insurance infrastructure platforms; State infrastructure banks; Regional infrastructure companies; Real estate investment trusts; Sovereign Wealth Funds.
	Value capture mechanisms	Tax increment financing; Special assessment districts; Sales tax financing; Infrastructure financing districts; Community facilities districts; Accelerated development zones.
	Public private partnerships	Private finance initiative; Build-(own)-operate-(transfer); Build-lease-transfer; Design-build-operate-transfer.
	Asset leverage and leasing mechanisms	Asset leasing; Institutional lease model; Local asset-backed vehicles.
	Revolving infrastructure funds	Infrastructure trusts; Earnback and Gainshare

⁶² Strickland, T. (2015) Infrastructure Funding and Financing, unpublished PhD thesis, Newcastle University: Newcastle upon Tyne.

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