Infrastructure, Interdependency and Systems

John Beckford

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'No Man is an Island'

We happily now talk of infrastructure in terms of interdependency, and in the same breath, of 'systems'. Before we go too much further it is perhaps time to think about what we mean by each of those words. The aim is to help us be more precise in our conversations and render them more productive.

That the UK infrastructure is a 'network of networks' (CST, 2009) is beyond doubt. Each network relies on, at least, one other network for its continued operation whether that be electricity to pump gas, oil or water and run trains and lighting systems or telecommunications (wired and wireless) required to operate and control those systems. A failure in one, notwithstanding redundant and failover capacity in the depended upon systems, eventually leads to disruption, delay, compromise or failure in another.

For the purposes of this part of the discussion I am including in the infrastructure 'network of networks': energy, telecommunications, water (inc drains), transport and waste.

Dependency exists where one element relies on another for its continued functioning. Dependency is uni-directional: THIS depends upon THAT. Dependency may exist within a network as well as between networks.

Interdependency exists where the reliance is multi-directional: THIS depends on THAT AND THAT depends on THIS. Interdependency exists between (at least two) networks and, particularly with the use of automation and remote devices for control, is increasing. For example, water pumping relies on electricity (the generation AND distribution networks) and on telecommunications (for transmitting and receiving both data and voice messages) through wired and wireless devices. Telecommunications, in turn, relies upon electricity supply and is quite likely to have a significant geographic spread. This implies external (non-infrastructure network) geophysical interdependency and, of course, weather interdependency (short term) and climate interdependency (long term).

In addition to those functional interdependencies there is also the need for inter-operability, the various devices on the various networks need common language and/or interface devices which allow them to communicate effectively. So we also have an inter-operability interdependency, i.e. a 'control language' or set of interfacing transducers which enable those things to talk to each other.

Adding further complication, at the level of the network (or significant portions of it) there is operational interdependency. This exists where the performance

of one network impacts on the performance of another network (or networks). For example, when an airport experiences disruption to flights, for whatever reason, that impacts on associated or adjacent transport systems. Trains may be fully laden or empty, roads and motorways jammed or empty, because passengers are delayed arriving and leaving. Equally, there may be impact from coinciding peak loads in interdependent networks, when demand for electricity is high, and that for gas (to generate electricity) is also high. These peak loads, whichever networks they affect first, impart operational challenges to the others.

With ever increasing inter-connectivity of networks and the different types of interdependency the complexity of designing, building and sustaining them is, probably, growing exponentially. The challenges of any one cannot be resolved in isolation from the others on which it depends. Examples of this can be seen in the plans for new rail termini, additional runways, and 'managed motorways'. In every case, the intentions for the target project have implications for and make demands on each of the others.

These interdependencies (of all types) have significant implications not just for the design and construction of the infrastructure itself but also for the cost and value arising from them. They will be more expensive and consequently they need to generate greater value than would be the case for an 'independent' asset (should such a thing exist).

The upshot of this is a further type, infrastructure network economic interdependency. This exists where the 'business case' for investment in one network can either impart cost to another network or add value by reducing cost or increasing revenue, or both. For example, building a new (or extended) runway requires investment within the airport campus (terminal, control systems, access roads etc.) but will also require investment in the surrounding infrastructure: electricity provision, drainage, water supply, roads, rail, telecommunications. Not only must the business case for the runway stack up, so must all the other investments necessary to support it. Alternatively shared investment through co-location of facilities (e.g. strategic infrastructure pathways) could reduce the investment cost of delivering new/renewed infrastructure by spreading basic costs (land acquisition, ground works, some structures) across multiple networks, delivering benefits to all.

A Question of Purpose

What is valuable about an infrastructure network is what it does (or enables). What is costly about it is its assets and operating model. To have a meaningful conversation about this, we need to understand what infrastructure is for, what is its purpose.

The infrastructure ‘network of networks’ can be thought of as a value enabling system. A system is conceived as a complex whole, a set of inter-connected things working together to achieve a purpose. That it is value enabling means that it is not purposeful in its own right, it is purposeful only to the extent that it contributes to some other system.

That other system, one which relies on the first absolutely for its functioning, exploits it to generate value. This value generating system is made up of (not exhaustively): commerce, education, civil administration, healthcare, defence. It can be argued that the value generating system is an emergent property of the value enabling system. An emergent property is one which belongs to the system as a whole and not to any of its individual parts. For example, flight is an emergent property of the interaction of an airframe, propulsion system and control system, it cannot be found in any of the parts!

Here it gets a little more complex. The value generating and value enabling systems rely on each other. The value generating system places demand on the value generating system, but the value generating system, at least, provides the funding (whether through taxation, subsidy, fees, service charges or whatever other means) to support its existence. This is systems interdependency, the symbiotic relationship of one system with another. The higher order system that contains it all we can call society.