A PROSPEROUS FUTURE: INVESTING IN THE INFRASTRUCTURE SECTOR

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Who Should Read This White Paper?

The target audience for this white paper is cross sector or interdisciplinary.

- Economists can use the idea and methodology behind this paper to analyse infrastructure investments in a new way (costs fall to one sector but benefits arise in another sector).
- Policy makers can use the results of our model to rank infrastructure investments, enabling decisions to invest in the right infrastructure.
- Industry partners can possibly follow similar techniques to build business models that help identify the right avenues of investment to maximise returns.

Key Messages from the White Paper

- Infrastructure investments can be structured to take advantage of the interdependencies between infrastructure sectors.
- The wider economic/social benefits of infrastructure investment are not always accrued by the sector/stakeholders making the investment.
- Constraining investment options within current pre-defined infrastructure sector boundaries prevents the emergence of innovative business and investment models.
- Capturing the value of interdependency between infrastructures makes it possible to leverage alternative and additional financial sources for investments.

Abstract

Infrastructure represents the economic backbone of every country, and nowadays, in a global economy where goods and services are interdependent with one another, so too are infrastructure systems. However, in order to realise additional gains from investment in infrastructure sectors, it is important to understand their structure of interdependence. Compared to several other developed economies, the UK has underinvested in its infrastructure system and must now dedicate significant funds to properly upgrade its infrastructure system to cope with increasing economic, environmental and social challenges. Although the failure of one infrastructure can inflict cascading deleterious effects on other interdependent infrastructures, we suggest that the aggregated value of infrastructure can be potentially increased with the correct type of investment. A new paradigm in infrastructure investment is therefore proposed here, one in which the methodology seamlessly can connect economics and finance with technological advances and environmental and social aspects. We discuss an Input-Output model combined with financial index and define investments which allow us to confirm that the interdependency among infrastructures indeed represents a value-added feature.

Keywords:

Infrastructure interdependency; Input-output analysis; Infrastructure investments; Value-added

Connections to Other ICIF White Papers

- The Potential Benefits of Outcome Based Assessments of Infrastructure Performance
- Capturing the value of Resilience: Can we make the business case for investment?
- Emerging approaches and issues in regulation and governance of infrastructure based services
- Evidence for the Value of a Systems Approach to Infrastructure Planning, Delivery and Operation
- Smart Infrastructure – Benefits and Pitfalls?

Where Can I Find Out More?

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A Prosperous Future: Investing in the Infrastructure Sector

1 Introduction

The estimated cost of damages across Cumbria, parts of Lancashire and the Scottish Borders caused by storm Desmond in December 2015 stands at a staggering £500m (Treanor et al., 2015), but after storm Frank, costs spiraled upwards to £1.5bn (PwC, 2015). At the time of this writing, rain was still pouring down in the north and northwest, incurring further damage and economic standstill in the affected regions (Fig. 1). Technical assistance for reconstruction and building resilience was quickly made available. In December 2015 in the current Parliament, Prime Minister Cameron pledged £2.3 bn for flood defence during a major review of flood prevention strategy.

Figure 1. The UK flood crisis 2015. Damages to households and local businesses, land transport infrastructure, and the environment. [i]

However, despite the influx of funding, this crisis – as with many events where we observe the vulnerability of our infrastructure – once again magnifies the limitations and faults inherent in standard investment strategies and financial mechanisms. But interestingly, it also underscores a potential solution, which is to coordinate actions where the planning approach is more wide-ranging, and to connect the different social and critical infrastructures through financial leveraging on the interdependency of infrastructures.

Infrastructure investments are often considered as having a dual role in the social and economic development of countries: a direct role through growth and improvement, which consequently strengthens both private and public sector initiatives; and an indirect role as a

stimulus for further investment and enhanced economic growth and social welfare at different spatial scales (Andersson, 2012; Ahfeld and Feddersen, 2010; Baldwin et al., 2005). If, however, the different scales of the impacts of infrastructure investments are apparent, the various sources of finance often used to support these investments are quite opaque. As Chakrabarti (2014) has observed, in many countries infrastructure investments are traditionally financed through grants and transfers from central government, but "these financial sources are no longer sufficient to cater to the increasing requirements of infrastructure investments." Instead, a new paradigm in infrastructure investment is called for, one in which the methodology seamlessly connects economics and finance with technological advances and environmental and social aspects.

Central to infrastructure operations, and thus necessary to infrastructure investment, is to account for the interdependency between infrastructure systems. We argue that we can no longer apply a silos approach to infrastructure finance by investing within pre-defined infrastructure boundaries, thereby perpetuating the same business and investment model. The challenge in a turnaround strategy is to unlock latent economic and financial potential by capturing infrastructure interdependency as a value-added in order to leverage additional financial resources for investment.

However, market forces alone are not capable of carrying out this deep transformation towards sound financial planning for infrastructures. Market forces act by moving investment toward the most productive infrastructure with the highest financial returns. They operate in an incremental fashion, and in doing so, hinder the acceleration mechanisms of innovation which are essential for infrastructures. Without doubt, governments must act as catalyst in this change to stimulate the redesign of financial solutions which address the real economy. This means mobilising finance using different forms of capital, and not only involving bank finance but also risk-sharing portfolio guarantees, securitisation products, hybrid products (debt and equity), subordinated loans, grants, and crowd funding.

Moreover, within the infrastructure's spectrum of repair, construct, operate, renewal, and reinvention, it is also crucial to engage and empower the people who will develop, use and maintain these infrastructures. It is thus essential to impart, through information and new communication technologies, how the infrastructure investment process needs to happen *with people and not to them* in order to address real needs and challenges. Taking a bottom up approach now and into the future will lead to increases in innovative financial mechanisms

where collaborative production and consumption will be based on the cognitive surplus created through shared information and improved communication. And indeed this will incentivise and unite infrastructure sectors to re-consider how to create the conditions for sustainable long-term allocations of investment. In the next sections we briefly demonstrate how, if interdependency is regarded as the pivotal point for innovative financial planning, new economic value creation will inevitably emerge.

2 The Interdependency of Infrastructure

After the Somerset floods crisis in 2013-2014, the extensive damage repairs were assessed and tackled by the different agencies and departments at local and national level in the UK. The Environment Agency is the national public body in charge of repairing and restoring the flood defence assets (UK Environment Agency, 2015). However, on the specific occasion of the Somerset flood, the budget available to the Environmental Agency to repair the damages would have only partially addressed the required capital investment. On the other hand, agencies such as the Highways Agency and Network Rail, respectively responsible for UK road and rail systems, had available budgets for raising rail and road ballasts so as to avoid future service disruptions due to flooding (Figure 2). For instance, £22.3 million was given to Somerset as Department of Transport grants to repair damages and raise roads and rail ballasts (BBC, 2014).

Given our focus here, would it not have been more effective financially, in terms of investment reduction, and operationally, in terms of zero disruption costs, to have pooled the financial resources from the different agencies all together and invested in flood defences rather than to have imagined road and rail on 'stilts'?

Figure 2. The 2013-2014 Somerset flood crisis. Damages: the land transport infrastructure and the environment; Repairs: pumping water back into the rivers. [ii]

The real life stories and follow-up concerns are often part of the general framework when we examine infrastructure investments. Sectoral approaches have their roots in established budget allocations and investment plans implemented by each of the different agencies and departments of local and national governments; as a result, sectoral approaches often shut out opportunities to deliver leaner, more effective investment plans.

When we examine problems such as systemic risk and resilience operations which are at the core of infrastructure interdependency, we notice that optimal and effective solutions have been studied thoroughly in the context of engineering and technical approaches. For many years however, the engineering solutions were very specific, and this level of specialisation allowed for the best performance of the single techniques. Unfortunately, specific solutions have been determined at the cost of losing sight of the overall picture, and it is for this reason that in the context of engineering and technical innovative solutions there is a decisive shift towards designing and integrating the overall system. This approach is significant, particularly in the construction of new infrastructures because the net effect of a new infrastructure is strongly related to the existing infrastructure system. For example, the system approach is at the forefront of IT infrastructure, which is wholeheartedly adopting the Big Data paradigm for the purpose of ongoing monitoring of our critical infrastructures in preparation for rapid responses, for instance, to disasters, to adapt new technologies, and to respond to the demand from consumers. It is clear, however, that such a system approach cannot be effective without appropriate economic/financial modelling.

Given our understanding of interdependency of infrastructures, we can now think about how to capture the economic value of this interconnected infrastructure system. Policy makers require a modelling framework capable of estimating losses and gains, defining investment priorities and capturing financial and non-financial impacts.

The issue with the frameworks currently in use is that they do not tackle problems related to the interdependency of infrastructures. The case of the Tōhoku undersea earthquake off the coast of Japan in 2011 is certainly known as a Black Swan event: an unfortunate and rare incident. Nonetheless, it is a perfect prototype of a catastrophic domino effect; and although the magnitude of the event caused average direct losses, the indirect losses due to this

earthquake have been estimated as among the highest in recorded history. In the Japanese earthquake the significant indirect costs were rooted in the misevaluation of the interdependency of infrastructure such as the global supply chain. To some extent, our aim to account for interdependency in infrastructure systems is to correct this misevaluation by using existing modelling approaches but with a different emphasis.

We propose in our work the Input-Output model created by the Nobel Prize winner Leontief (1966). The model is an elegant, simple, and yet powerful tool for macroeconomic analysis of economic interactions between industry sectors and firms at both regional and national level. The starting point for these models is a matrix of flow of goods between economic actors (firms, industries or industry sectors) that accurately captures their interdependence. We use a combination of the Input-Output modelling approach and the financial Return on Investment (ROI) measurement to determine the best strategy for investment in infrastructure. In particular, we are interested in knowing how *combinations of investments* are able to maximise returns on investment for infrastructure (For an extensive analytical discussion of the model see Medda and Patel, 2016).

3 Calling for coordinated investment between infrastructure sectors

To clarify our model, let us use as an example the UK infrastructure sewerage sector. We imagine a situation where a negative event has damaged the infrastructure. As a consequence, the sewerage sector cannot operate at 100%. We then assume that the sewerage sector does not have the financial capacity to invest in its infrastructure to restore its full operation. But sewerage operations have high levels of interdependency with other UK infrastructures, and indeed the loss of sewerage certainly impacts negatively on other infrastructures. At this juncture, can we identify an infrastructure willing and able to invest in the sewerage infrastructure to restore it to 100% of operation?

Using our model, we can verify which infrastructure(s) are willing to invest in the Sewerage sector, allowing it to again reach full capacity. Figure 3 depicts a range of levels of lost capacity, (Epsilon from 0.001% to 5%) shown in the horizontal axis which correspond to different Returns on Investment (ROI) (in the vertical axis) from the selection of infrastructures.

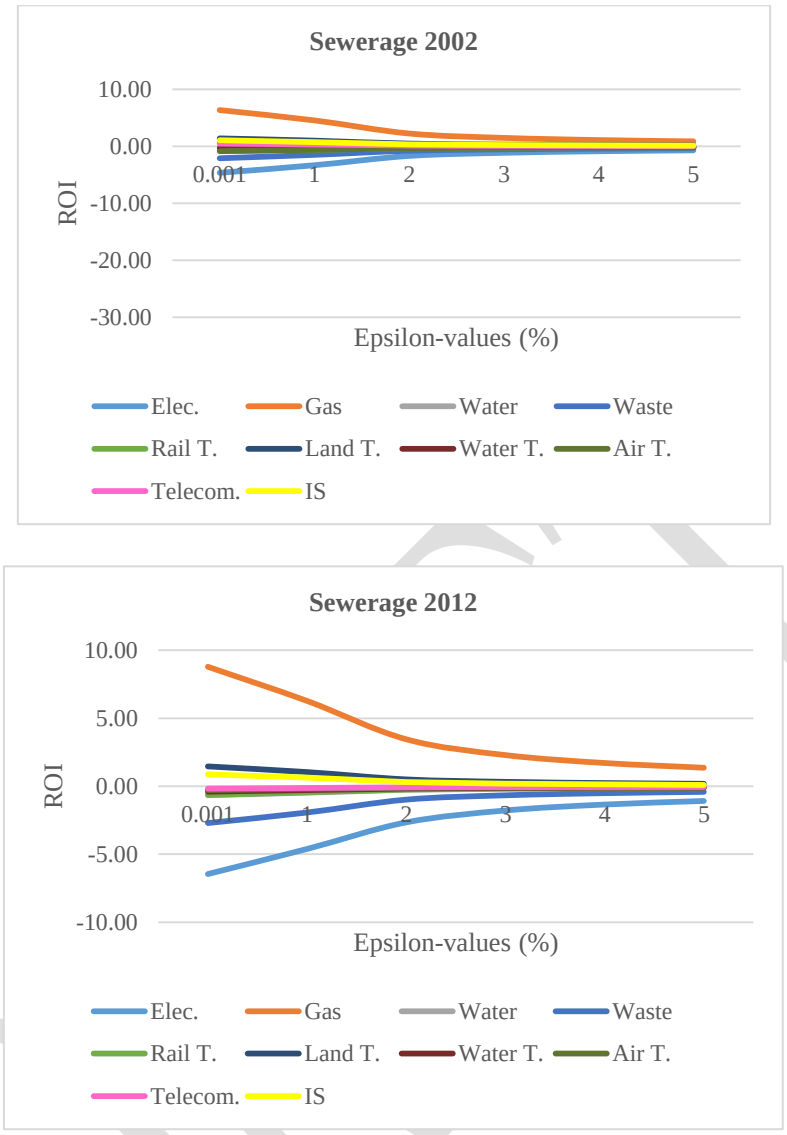

Figure 3. Comparison of 2002 and 2012 ROI in the Sewerage sector when production capacity between 0.001% and 5% is lost.

As shown in Fig. 3, the Gas sector has the highest Returns on Investment (ROI) in relation to the other sectors when it invests in Sewerage and this is due to the Gas sector ability to capture its interdependency financial value with the Sewerage sector. And this is particularly evident when we compare the changes in ROI between 2002 (first graph) and 2012 (second graph). With the advent of new technologies in recent years, the Gas and Sewerage sectors have become increasingly interconnected, particularly due to their strategic investments such as biogas generation through sewage sludge, using anaerobic digestion (Defra, 2012); and this explains the increase of ROI of the Gas sector towards Sewerage by 2012.

Our methodology can also be a powerful tool when we want to create a portfolio of investment where several infrastructures invest in the same infrastructure. We consider four transport sectors (Air, Rail, Land and Water) and for each sector we assume, as before, a loss of 1% of production/output.

Air Transport		**Rail Transport**		**Land Transport**		**Water Transport**	
Sector	ROI(e1%)	Sector	ROI(e1%)	Sector	ROI(e1%)	Sector	ROI(e1%)
Telecom	4.22	Land T.	5.05	Gas	5.31	Rail T.	4.6
IS	2.35	Gas	3.83	Telecom	3.64	Land T.	4.19
Gas	2.09	Sew.	1.88	IS	1.08	IS	2.92
Sew.	1.17	Telecom	0.13	Waste	0.65	Sew.	1.27
Water	0.63	Elec.	-0.51	Rail T.	0.35	Waste	1.24
Waste	0.24	IS	-0.55	Sew.	0.34	Gas	1.05
Water T.	-0.96	Water	-0.92	Air T.	-0.07	Telecom	0.92
Elec.	-1.39	Water T.	-2.43	Water	-0.16	Elec.	-0.15
Land T.	-1.8	Air T.	-3.22	Water T.	-0.42	Air T.	-0.19
Rail T.	-4.96	Waste	-3.46	Elec.	-3.69	Water	-0.63

Table 1. 2012 rankings for the 10 UK sectors investing in the affected transport sectors that have lost 1% production capacity.

In Table 1 we show the different infrastructure sectors (in the shaded area of the Table) that will yield a positive Return on Investment by investing in the transport sectors. The results, which we have developed for all of the infrastructure sectors in the UK, can be used to build a portfolio where several infrastructure sectors invest in a specific infrastructure. In other words, if before we have seen which infrastructure has the highest ROI in investing in sewerage, we can also identify the different infrastructures having a positive ROI and which therefore can coordinate their contributions/investments for the needed infrastructure. For instance, in the case of Air Transport if we consider the sectors Telecom, Information Technology (IT), Gas, Sewerage, Water, and Waste, all have a positive ROI and can therefore contribute with different shares of investment in Air Transport.

Our results using Input-Output modelling and ROI in the process of building an infrastructure portfolio confirms that we can leverage infrastructure interdependency as an added financial value. Importantly in doing so, we decrease the financial risk for public and private investors by anchoring investment in one specific infrastructure to the other interconnected infrastructure sectors.

4 Conclusion

New advances in technologies for road driving, renewable energy sources and information economics are just a few of the trends that should convince us to adopt the interdependency infrastructure perspective which is already emerging. Opportunities to recognise and take advantage of the high level of connectivity between infrastructures are now ripe for the taking. The interdependency that we recognise, as in a supply chain, can be the source of added value compared to single infrastructure benefit baselines because infrastructures can be linked to opportunity of the investments, e.g. value creation and value capture of investment costs.

We agree with Moss Kanter (2015), who recently remarked that "to avoid getting stymied by silos reorganisation …. A compelling vision needs to connect actions to a clear set of goals." If the lens through which we design, intervene, maintain and finance infrastructures is their interdependency, we are now able to use available financial resources to leverage infrastructure projects to achieve sustainable and bankable investments.

Across the present economic landscape we notice that the effects of the economic and financial crisis of 2008 are still reverberating across the UK. A significant global tightening of credit has altered the roles of governments and the private sector and has also greatly impacted on infrastructure investment. We have discussed how the established models and investment decision making for infrastructure are becoming increasingly ineffective. But solutions are possible, especially if financial channels are widened and flexible financial options for infrastructure investments are achieved. Trends such as information economics and innovation technologies have spurred the redefinition of a new financial model of infrastructure investment. Our work addresses the interdependency between infrastructures and suggests a methodology to add value by taking advantage of the inextricable links among infrastructures. An improved paradigm for infrastructure finance is ready and waiting, making now the right time to invest in infrastructure.

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[i] Source: The Daily Mail, the BBC, respectively.

[ii] Source: The Guardian, the Daily Mail, the BBC, respectively.