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*Irish State infrastructural investment: an analysis of
past patterns, and an outline of a future Integrated
Systems of Systems evaluation methodology*

Thesis presented by

Mary Moloney

For the degree

Doctor of Philosophy

May 2015

TABLE OF CONTENTS

Table of Contents	i
Index of Figures	vi
Index of Tables.....	ix
Declaration	i
Acknowledgements	ii
Abstract	iii
Acronyms used in this Thesis	v
1.0 Introduction	1
1.1. The significant contribution of this research to the body of knowledge	1
1.2. Aims and Objectives of this research	3
1.3. Thesis Structure	6
1.4. Publication plan.....	7
2.0 Review of the literature	9
2.1. The Alternative forms of Infrastructure	9
2.1.1. Importance of Infrastructure and the Influence of FDIs and SMEs	12
2.1.2. Infrastructure: Ireland's International Rankings	13
2.1.3. Has Ireland invested enough?.....	14
2.2. Existing infrastructure decision-making in ireland	15
2.2.1. Ireland's ineffective National Spatial Planning	16
2.2.2. The Irish Planning Hierarchy & Infrastructure development.....	18
2.2.3. Political Interference in the Planning process.....	22
2.2.4. Government Evaluation of Infrastructure Projects.....	23
2.2.5. Fragmented Infrastructure Investment Responsibility	24
2.2.6. Engaging with stakeholders: Use of NVivo and Qualitative research	25
2.3. Sustainable infrastructure and its importance to a nation's economy	26
2.3.1. Sustainable Development	26
2.3.2. Sustainability Criteria and Evaluation.....	29
2.4. Strategic Infrastructure Planning – International practice	31

2.5.	Systems of systems approach to infrastructure decision making: Evidence based decision making.....	32
2.5.1.	The Importance of Data in SoS	33
2.5.2.	International Application of SoS and National Infrastructure delivery	35
3.0	Quantifying Ireland's Infrastructural Deficit	37
3.1.	Abstract	37
3.2.	Introduction	38
3.3.	Infrastructure: physical networks that support economic activity.....	39
3.4.	Infrastructure and Economic Growth	40
3.5.	Ireland – A Developed Economy or Developing?	41
3.6.	Ireland's historical infrastructural investment	44
3.7.	Ireland's present infrastructure investment levels.....	45
3.8.	Ireland's required infrastructure investment.....	46
3.9.	Ireland's Infrastructural Deficit – Conclusions.....	47
4.0	Analysis of investment decisions in Irish state infrastructure	48
4.1.	Abstract	48
4.2.	Introduction	49
4.3.	Infrastructure networks and their importance.....	50
4.4.	Drivers for investment in productive Infrastructure	50
4.4.1.	Legislation and policy stimulants	51
4.4.2.	National government policy and housing	51
4.4.3.	National government policy and housing	52
4.4.4.	The border, mid-land and western region	53
4.4.5.	Government influence through the use of tax incentives ('Section 23' tax reliefs).....	54
4.4.6.	Review of impact of drivers on the county of Leitrim	55
4.4.7.	Funding mechanisms for capital investment in infrastructure and Ireland's local government structure.....	57
4.4.8.	Data collation and review of water, wastewater and roads network capital investment distribution across the 26 counties: local authority and government records.....	59
4.4.9.	Roads capital investment distribution	59

4.4.10. Water and wastewater investment distribution across the 26 counties..	62
4.5. Analysis of capital investment.....	62
4.6. Analysis of capital investment.....	65
4.6.1. Results of analysis: water and wastewater capital investment	68
4.6.2. Results of analysis: roads capital investment	68
4.7. Conclusions and recommendations.....	70
5.0 The Distribution of Capital Investment in Ireland's Road Network	
2003-2009.....	72
5.1. Abstract	72
5.2. Ireland's Economic Activity 2003 to 2009	73
5.3. Productive Infrastructure and it's importance.....	74
5.4. Ireland on the International stage- its performance	75
5.5. Access to Records	79
5.5.1. Capital Stock.....	79
5.5.2. Local Authorities Annual Financial Statements.....	79
5.6. Ireland's Road Investment	80
5.6.1. The National Distribution of this Investment	81
5.7. Possible drivers to investment.....	84
5.7.1. Section 23 Tax Reliefs.....	84
5.7.2. Methodology and Analysis of investment data	87
5.7.3. Housing Vacancy Rates	87
5.7.4. Political Influence	89
5.8. Conclusions.....	90
6.0 Stakeholder engagement as a means of assessing the state of	
Ireland's infrastructure	92
6.1. Abstract	92
6.2. Introduction	92
6.3. Research methodologies in engineering research and the challenges	94
6.4. Use of CAQDAS - Computer assisted qualitative data software and NVivo.....	95
6.5. The research methodology for this work.....	96
6.6. Identifying the interviewees	99

6.7.	The Interviews & development of Survey questions.....	103
6.8.	Importing the interviews and the process of coding and developing the nodeS	106
6.9.	The analysis and results	109
6.9.1.	Statistical analysis of NVivo results	111
6.10.	Discussion and Conclusions.....	114
7.0	Infrastructure Gap Analysis for Ireland.....	116
7.1.	Abstract	116
7.2.	Introduction	116
7.3.	Irelands Industrial makeup	117
7.4.	Infrastructure and industries locating in a region.....	118
7.5.	Methodology	119
7.5.1.	The Survey Format.....	119
7.5.2.	Qualitative analysis process	122
7.6.	Observations from the data	124
7.6.1.	Industries locating within a region	124
7.6.2.	Political Element	126
7.7.	Infrastructural Gaps	127
7.8.	Key findings from the interviews and Quantitative evidence of identified infrastructure gaps.....	130
7.8.1.	Communications Connectivity	130
7.8.2.	Water capacity and Quality.....	132
7.9.	Conclusions & Recommendations	136
8.0	Systems-of Systems Architecture for Ireland's Infrastructure	139
8.1.	Abstract	139
8.2.	Infrastructure – a critical National Asset	139
8.3.	Historic investment patterns	141
8.3.1.	The National Spatial Strategy and Political Influence	141
8.4.	The need for change	143
8.5.	A systems-of-systems approach to Irish State infrastructure investment – is it possible?	147
8.5.1.	What is SoS?.....	147

8.6.	Systems of Systems as an evidence base for decision makers.....	148
8.6.1.	International developments in Systems-of-Systems.....	149
8.6.2.	An Irish SoS Framework for infrastructural investment.....	151
8.6.3.	Stage one: Development of constituent systems models	153
8.6.4.	Stage two: Development of infrastructure drivers and scenarios	156
8.6.5.	Stage 3: National Infrastructure Development Platform.....	157
8.6.6.	Stage 4: The Output	158
8.6.7.	How could it contribute to Irish infrastructure investment decisions? .	159
8.7.	Case Study: Village X in County Cork would have been different if SoS had been used.....	161
8.8.	Conclusions and recommendations.....	165
9.0	Conclusions and recommendations of this research.....	167
9.1.	Ireland's unsustainable investment in it's physical infrastructure	167
9.2.	The impact of government policy on infrastructure delivery	169
9.3.	Systems of Systems: integrated spatial planning and infrastructural delivery	171
9.4.	Limitations of this Research	172
9.5.	Future Research	173
10.0	References	175
11.0	Appendix A – Copies of Published Papers	196

INDEX OF FIGURES

Figure 1-1: Research aims aligned with the publication plan of this thesis	4
Figure 2-1: Comparison of the sectors considered ‘productive’ infrastructure by the Irish Government in 2008 and 2011	10
Figure 2-2: Comparison of the sectors considered ‘economic’ infrastructure by the Irish Government in 2008 and 2011, with a new category of Environmental Infrastructure	11
Figure 2-3: The Inter-relationship between spatial planning and infrastructure development	19
Figure 2-4: Figure illustrating origin of capital development projects.....	21
Figure 2-5: Chambers et al Resource Funnel Metaphor (Chambers <i>et al.</i> , 2009)	27
Figure 2-6: Representation of Sustainability.....	28
Figure 2-7: Parkins representation of sustainable development with infrastructure (Parkin, 2003).....	28
Figure 2-8: Relationship between evidence and policy making.....	34
Figure 3-1: World Economic Forum Global Competitiveness Report 2009 – Ireland’s GDP / capita ranking alongside selected global economies and their overall Infrastructure Score (Schwab, 2009)	42
Figure 3-2 : World Economic Forum Global Competitiveness Report 2009 – Ireland’s Infrastructural ranking alongside the nearest ranking countries in overall quality of infrastructure scores and their relative GDP per capita (US\$ 2008) ⁵	43

Figure 3-3: Ireland's GDP versus its % GDP investment in Productive Infrastructure from 2002 to 2008; Source: (Department of Finance, 2010a, Irish Government, 2008)CSO, 2010.....	45
Figure 4-1: Census statistics on national housing stock, households and housing vacancy rates. Source: Central Statistics Office census data (CSO, 1996, 2002, 2006, 2011) and authors' own calculations	53
Figure 4-2: Development-related income for some local authorities, expressed as a percentage of their total capital income. Source: Appendix 5 of the annual financial statements (DoECLG, 2003–2009)	58
Figure 4-3: Total capital investment in roads 2003–2009 by local authority, National Roads Authority (NRA) grants and new kilometres of motorway in each local authority/county.....	61
Figure 4-4: Selection of counties: aggregated capital investment for water and wastewater investment for 2003–2009. # denotes a BMW county.....	64
Figure 5-1: Plot of WEF 2011-12 best road quality and infrastructure quality for a selection of EU counties, also showing stage of development as per WEF	77
Figure 5-2: Capital Investment in Roads 2003 to 2011 (out-turn values) and 2012 (projected investment) Authors own calculations and NRA annual reports (National Roads Authority, 2003, 2004, 2005, 2006, 2007, 2008, 2009).....	80
Figure 6-1: The stages in this research.....	97
Figure 6-2: Criteria for selecting interviewees - Corporate Decision Makers (CDs)	100
Figure 6-3: The NVivo process of data input and coding.....	107
Figure 6-4: The Node tree in NVivo.....	107
Figure 6-5: Screen illustration of the coding strips and coding density in a section of a source interview	108

Figure 6-6: Overall survey structure illustrating main discussion topics, with % of policy makers (PMs) and corporate decision makers (CDs) that discussed the topic.....	110
Figure 7-1: Overall survey structure illustrating main discussion topics, with the total number of sources and references for each topic.....	123
Figure 7-2: Key infrastructural gaps, weighted from interviews	129
Figure 7-3: National population distribution and employment in the ICT sector in selected counties, as recorded in 2011.....	131
Figure 7-4: Counties on the RAL listing and the investment that has been undertaken in each of the counties during the period 2003-2009, in water and wastewater.....	135
Figure 8-1: The integration of policy, constituent models and change scenarios	148
Figure 8-2: Proposed framework for Ireland.....	151
Figure 8-3: Preliminary systems-of-systems architecture for Ireland's infrastructural methodology.....	152
Figure 8-4: Metadata compliance with INSPIRE (EU Directive) for spatial data (European Union, 2007, INSPIRE, 2014)	154
Figure 8-5: Permanent private households by year built, in Village X.....	162

INDEX OF TABLES

Table 2-1: The Irish Public Spending Code - Required appraisal type for capital project costs (Central Expenditure and Evaluation Unit, 2013b).....	23
Table 4-1: Case review of households in Leitrim connected to local authority water and wastewater schemes 2002–2011 (source: CSO and authors’ own calculations).....	56
Table 4-2: Results of correlation analysis of capital investment against selected determinants (selected BMW counties of Cavan, Donegal, Longford, Monaghan, Mayo, Sligo, Roscommon, Leitrim and Galway).....	67
Table 5-1: Key national economic statistics of the period 2003 to 2009.	73
Table 5-2: Ireland’s WEF performance	76
Table 5-3: Development Contributions as a percentage of Local Authority (local government) capital income – some examples.....	82
Table 5-4: Total Capital Investment (CI) in roads 2003-2009 by Local Authority, NRA grants and new Kms of motorway.....	83
Table 5-5: The percentage of Section 23 certificates issued per county as a proportional of the national total, 2000-2009.....	86
Table 5-6: Correlation coefficients of Roads, investment and housing development, population distribution	88
Table 6-1: Profile of the 6 Policy Makers (PMs) and the 9 Corporate Decision Makers (CDs) interviewed for this research	102
Table 6-2: Sequence of interviews, coding and number of nodes and references per interviewee	105
Table 6-3: Nodes discussing what determines/inhibits industries locating in a region	112

Table 6-4: Calculated p-values for specific discussion topics.....	113
Table 7-1: Profile of Interviewees, illustrating their positions within their organisations and geographical locations (Munster- southern counties; Leinster – counties around Dublin; Connacht –western counties).....	121
Table 7-2: Key infrastructural gaps identified in survey (Note: Broadband ¹ , speed, availability & cost; water ² , capacity and quality).....	128
Table 8-1: Profile of interviewees.....	144
Table 8-2: Availability of datasets for constituent systems	155
Table 8-3: A traditional form of decision making versus a SoS approach.....	160
Table 8-4: Infrastructure upgrades to support growth of Village X.....	164

DECLARATION

I declare that this thesis has not been previously submitted as an exercise for a degree at the National University of Ireland or any other University and I further declare that the work embodied in it is my own, or else noted.

Mary Moloney

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Thank you to all of the interviewees and many people that provided information, data and guidance during this study. These included various members of government departments, local authorities and FDI companies. Without their participation and generous provision of time and data this work could not have been completed.

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I dedicate this thesis to Kevin, Mark and Ruth

ABSTRACT

The literature clearly links the quality and capacity of a country's infrastructure to its economic growth and competitiveness. This thesis analyses the historic national and spatial distribution of investment by the Irish state in its physical networks (water, wastewater and roads) across the 34 local authorities and examines how Ireland is perceived internationally relative to its economic counterparts. An appraisal of the current status and shortcomings of Ireland's infrastructure is undertaken using key stakeholders from foreign direct investment companies and national policymakers to identify Ireland's infrastructural gaps, along with current challenges in how the country is delivering infrastructure. The output of these interviews identified many issues with how infrastructure decision-making is currently undertaken. This led to an evaluation of how other countries are informing decision-making, and thus this thesis presents a framework of how and why Ireland should embrace a Systems of Systems (SoS) methodology approach to infrastructure decision-making going forward.

In undertaking this study a number of other infrastructure challenges were identified:

- significant political interference in infrastructure decision-making and delivery
- the need for a national agency to remove the existing 'silo' type of mentality to infrastructure delivery
- how tax incentives can interfere with the market; and their significance.

The two key infrastructure gaps identified during the interview process were: the need for government intervention in the rollout of sufficient communication capacity and at a competitive cost outside of Dublin; and the urgent need to address water quality and capacity with approximately 25% of the population currently being served by water of unacceptable quality.

Despite considerable investment in its national infrastructure, Ireland's infrastructure performance continues to trail behind its economic partners in the Eurozone and OECD. Ireland is projected to have the highest growth rate in the euro zone region in 2015 and 2016, albeit that it required a bailout in 2010, and, at the time of writing, is beginning to invest in its infrastructure networks again. This thesis proposes the development and implementation of a SoS approach for infrastructure decision-making which would be based on: existing spatial and capacity data of each of the constituent infrastructure networks; and scenario computation and analysis of alternative drivers eg. demographic change, economic variability and demand/capacity constraints. The output from such an analysis would provide valuable evidence upon which policy makers and decision makers alike could rely, which has been lacking in historic investment decisions.

ACRONYMS USED IN THIS THESIS

AFS	Annual Financial Statements
BCRI	Bridge and Concrete Research Ireland
BEA	Building Environmental Assessments
BRE	British Research Establishment
BMW	Border, Midland and Western counties
CAQDAS	Computer Aided Qualitative Analysis Software
CBA	Cost Benefit Analysis
CD	Corporate Decision-maker
CEA	Cost Effectiveness Analysis
CEEU	Central Expenditure Evaluation Unit
CSO	Central Statistics Office
DoECLG	Department of the Environment Community and Local Government
ECB	European Central Bank
EU	European Union
FDI	Foreign Direct Investment
GCI	Global Competitiveness Index
GDP	Gross Domestic Product
GFCF	Gross Fixed Capital Formation
GNP	Gross National Product
ICE	Institution of Civil Engineers
ICT	Information and Communication Technologies
IDA	Industrial Development Authority
IMF	International Monetary Fund
LA	Local Authority
LAPs	Local Area Plans
MAN	Metropolitan Area Networks
MCA	Multiple Criteria Analysis
MNC	Multi-National Corporation
NDP	National Development Plan
NIDP	National Infrastructure Development Platform
NPV	Net Present Value
NRA	National Roads Authority
NSS	National Spatial Strategy
O&M	Operation and Maintenance
OECD	Organization for Economic Co-operation and Development
PCP	Public Capital Program
PM	Policy Maker
SLA	Service Level Agreement
SME	Small and Medium Enterprises

SoS	Systems of Systems
USGBC	United States Green Building Council
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
WB	World Bank
WEF	World Economic Forum

1.0 INTRODUCTION

There can be little doubt that infrastructure quality and capacity is linked to a country's economic health and growth (Allard and Everaert, 2010, Aschauer, 1990, Morgenroth, 2014b, Schwab, 2014). There is considerable evidence that public infrastructure investment increases a nation's economic output in both the short and long term, particularly during periods of economic slack (Abiad *et al.*, 2014). So as Ireland emerges from a deep recession and financial bailout, and slowly starts to invest once more in its physical infrastructure networks, it is imperative that the investment is of the correct type, capacity and in the most appropriate location to meet present and future needs. This imperative poses many challenges and thus the focus of this work.

Through an investigation and analysis of Ireland's historic investment in its infrastructure networks, the quantification of its infrastructural deficit, and using input from high level stakeholder interviews, this thesis proposes that decisions regarding future investment in Ireland's infrastructure networks should be informed by analysis using a systems of systems approach, with a methodology presented in Chapter 1.0 of this thesis.

1.1. THE SIGNIFICANT CONTRIBUTION OF THIS RESEARCH TO THE BODY OF KNOWLEDGE

This thesis presents an analysis, which has not previously been undertaken, of the national investment and the spatial spend on physical infrastructure. While national infrastructure investment figures have been published, there is a gap in the literature on how this investment has been spatially distributed, at a regional and local authority level. An appraisal of the national spend during the period 2002-2008, and thus a quantification of the deficit in infrastructure spend is presented in Chapter 3.0. This period was selected to analyse the national investment, as these were the years that detailed data was available for at the time of undertaking the research.

There are no published analyses of the capital investment in physical infrastructure across the 34 local authorities and 80 town councils. Indeed, Morgenroth suggests that analysis at a national level tends to be biased, thus necessitating the need for an evaluation at a regional and local level (Morgenroth, 2014a). Part of this research analysed the investment in the water, wastewater and road networks across the 34 local authorities (including the constituent 80 town and urban councils, which have now been abolished). These networks were selected as they are the only ones fully financed by government funds, and thus the detailed data was publicly available. The study period of 2003 to 2009 was chosen as electronic records were not available prior to 2003, and 2009 was the last audited year of records when undertaking this study in 2012.

The results of this analysis identified the impact of Government construction tax incentives, 'section 23 properties', in the housing construction boom, and the resultant need for and construction of enabling infrastructure of water, wastewater and roads. Such an analysis has not been previously undertaken relative to each local authority area, due to the recording of these properties, not by the county they are located, but rather by the county of residency of the owner (Department of Finance, 2011).

Having analysed this historic investment and appraised the continuing poor performance of Ireland in international assessments of infrastructure quality, it was evident that a gap analysis of the country's infrastructure should be undertaken. A number of papers have used key stakeholder interviewers to analyse locational determinants for FDI companies. But none appear to have addressed the significance of physical infrastructure to industries locating in a region, and thus interviews were undertaken with 15 high level stakeholders in industry and policy-making to evaluate and prioritise Ireland's infrastructure gaps.

The spatial investigation of investment across the 34 local authorities, and the gap analysis of the country's infrastructure networks showed the clear need for change in how projects are currently identified and assessed. Ireland has

developed many plans, which will be discussed in this thesis; however current decision-making uses static appraisal, with evaluation based on a single project. There is growing support for evidence based decision making and using a systems approach, in particular a systems of systems (SoS) methodology to infrastructure decision making. This has not heretofore been explored for implementation in Ireland. This thesis investigates the use of this dynamic methodology, and identifies the merits and potential issues with implementing such a Systems-of-Systems methodology.

1.2. AIMS AND OBJECTIVES OF THIS RESEARCH

This analysis of Irish State infrastructure investment in productive/physical networks consists of 4 sub-projects. Figure 1-1 below lists the main research aims, with the associated publication plan.

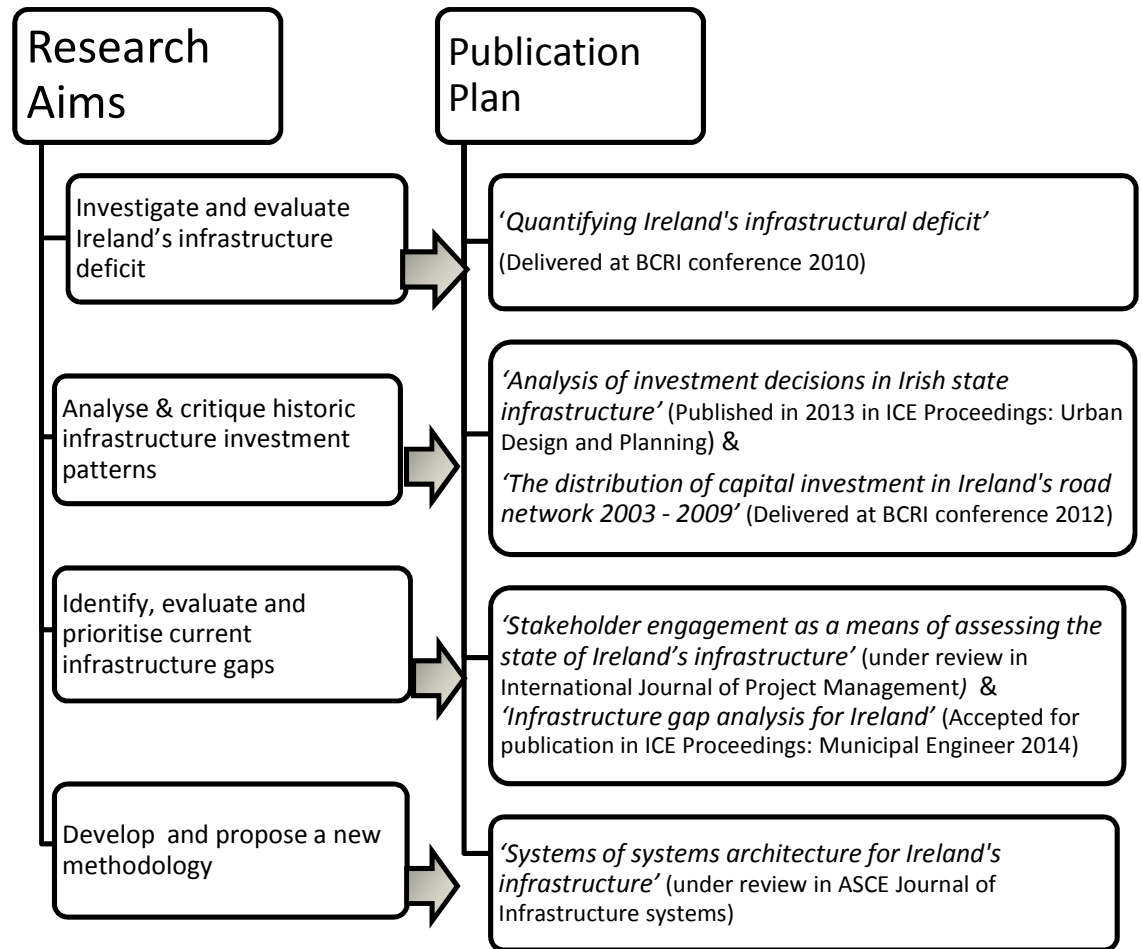


Figure 1-1: Research aims aligned with the publication plan of this thesis

The study, with its four sub-projects, each has specific aims:

1. Investigate and evaluate Ireland's infrastructure deficit (Chapter 3)
 - What are the definitions of infrastructure and what categories are included using the term: the scope of this research thesis is physical infrastructure networks
 - Assess Ireland's external image, as a measure of the quality of its infrastructure
 - Evaluate Ireland's investment in physical infrastructure networks and appraise if this has been sufficient
 - Estimate and suggest what Ireland's level of investment should be annually in physical infrastructure

2. Analyse and critique historic investment patterns to identify what or who were the drivers to state infrastructure investment decisions; and particularly how it has been spatially distributed across the different local authorities (Chapter 4 & 5)
 - Collate and analyse state investment in physical infrastructure across the 34 local authorities
 - 2003 to 2009 is the study period, as this includes the steep growth in Ireland's economy during what has now become known as the 'Celtic Tiger' period; and the years up to Ireland's economic collapse, leading to a bailout from the EU and IMF
 - Quantitatively analyse and assess the aggregated investment during the study period against possible drivers

3. Identify, evaluate and prioritise current infrastructure gaps, through a series of interviews with key stakeholders, to better inform decision-making going forward. (Chapter 6 & 7)
 - Interview top level corporate decision-makers and policymakers to identify Ireland's infrastructure gaps and explore other perceived infrastructure issues
 - Using qualitative analysis, with the use of NVivo (a qualitative data analysis software package), prioritise these gaps, substantiating the findings with published literature
 - Appraise other concerns with infrastructure delivery in Ireland
 - Understand the impacts of poor infrastructure delivery in industries locating in a region

4. Explore the current issues with infrastructure decision-making, with a view to developing a new methodology (Chapter 8)
 - Evaluate alternative decision making tools currently used to address infrastructure issues identified during the interview process
 - Prepare a methodology architecture, with justification
 - Appraise the challenges with the introduction of such a methodology in Ireland

1.3. THESIS STRUCTURE

The thesis contains nine chapters, a list of references and appendix. This chapter outlines the aims and objectives of the research while Chapter 2 contains an overview of the literature pertinent to the research questions.

Chapter 3 explores and aims to quantify Ireland's infrastructure deficit and how Ireland is perceived externally in relation to its infrastructure. It aggregates and appraises the national investment during the period 2002 to 2008 in the physical networks. Chapter 4 presents a detailed analysis of Irish state infrastructural investment during the years 2003 to 2009, across the 34 Local Authorities, for the water, wastewater and roads investment, with Chapter 5 providing a deeper analysis of the investment in the road network during this period.

Chapter 6 outlines the methodology used in undertaking interviews with key stakeholders through the use of qualitative research and software, NVivo in this case. Chapter 7 presents the results of the gap analysis undertaken to identify Ireland's infrastructural shortcomings. Chapter 8 proposes a Systems of Systems architecture for Ireland's infrastructure, and explores the challenges to Ireland adopting such a methodology.

Chapter 9 presents the main conclusions from this research thesis and explores areas of future research. This is followed by the reference list and appendix, which includes the published papers from this thesis.

1.4. PUBLICATION PLAN

This thesis is a compilation of published work over the past four years, with the final two papers currently under review, as indicated in Figure 1-1. There follows a list of each publication, not in chronological print date was rather in the sequence that it appears in this thesis, with its title, author and co-authors; along with the Journal or publication in which the work has been or may be disseminated. It will be noted that Mary Moloney, the author of this thesis, has been the primary author on all publications. This work has been based on a research question developed by Mary Moloney under the guidance of Dr. Eamon McKeogh, primarily. Prof. Karsten Menzel was a co-author of the first publication, and Mr. Kevin Fitzgibbon has contributed to the systems of systems architecture paper.

1. *'Quantifying Ireland's infrastructural deficit'*. This paper was presented at the Bridge and Concrete Research of Ireland (BCRI) conference in Cork in September 2010. The proceedings of this conference have been published and the ISBN number is 978-0-9542973-3-6. The authors were Mary Moloney, Karsten Menzel, and Eamon McKeogh
2. *'Analysis of investment decisions in Irish state infrastructure'*. This paper has been published in the ICE Proceedings - Urban Design and Planning in 2013 (E-Pub date 17th December 2013). The DOI reference code is 10.1680/UDP.13.00009. The authors of this work were Mary Moloney and Eamon McKeogh
3. *'The distribution of capital investment in Ireland's road network 2003 - 2009'*. This paper was presented at the BCRI conference in Dublin in 2012, and the proceedings have been published with an ISBN number of

ISBN 978-0-9573957-0-1. The authors of this work were Mary Moloney and Eamon McKeogh

4. *'Stakeholder engagement as a means of assessing the state of Ireland's infrastructure'*. This has been submitted and is currently under review in the International Journal of Project Management. This work was submitted in February 2015. The authors of this work were Mary Moloney and Eamon McKeogh.
5. *'Infrastructure gap analysis for Ireland'*. This has been accepted for publication in the ICE Proceedings - Municipal Engineer. This work was submitted in August 2014, with the proof manuscript approved in February 2015. Mary Moloney and Eamon McKeogh were the authors of this work.
6. *'Systems of systems architecture for Ireland's infrastructure'*. This has been submitted and is currently under review with the ASCE Journal of Infrastructure Systems. This work was submitted in December 2014. The authors of this work were Mary Moloney, Kevin Fitzgibbon and Eamon McKeogh.

2.0 REVIEW OF THE LITERATURE

2.1. THE ALTERNATIVE FORMS OF INFRASTRUCTURE

The Oxford dictionary defines Infrastructure as:

‘the basic physical and organizational structures and facilities (e.g. buildings, roads, power supplies) needed for the operation of a society or enterprise’

(Oxford Oxford University Press, 2008)

In the broader sense, the term ‘infrastructure’ has generally come to include three main categories: productive infrastructure which includes physical networks of roads, water, wastewater, power and communications; social infrastructure such as hospitals and schools; and economic infrastructure which would include research and science innovation institutions. The Irish Government has ‘rebranded’ the sectors within these infrastructure categories over the study period, thus making it challenging to compile a coherent set of investment figures in e.g. productive infrastructure, as evident in Figure 2-1 below.

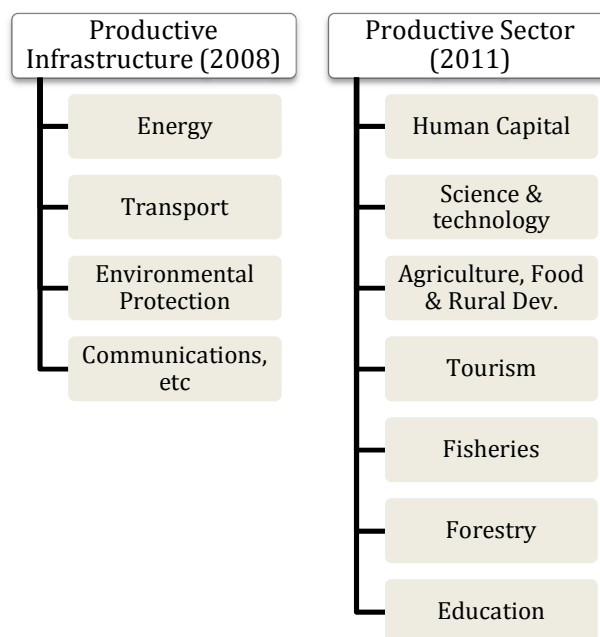


Figure 2-1: Comparison of the sectors considered ‘productive’ infrastructure by the Irish Government in 2008 and 2011

Source: Developed from Irish Government Capitals programs (Department of Public Expenditure and Reform, 2011, Irish Government, 2008)

It is a similar situation with economic infrastructure as illustrated in Figure 2-2 below. The 2011 Capital plan included a new category of Environmental Infrastructure, which would previously have been included under the category of productive infrastructure (Department of Public Expenditure and Reform, 2011).

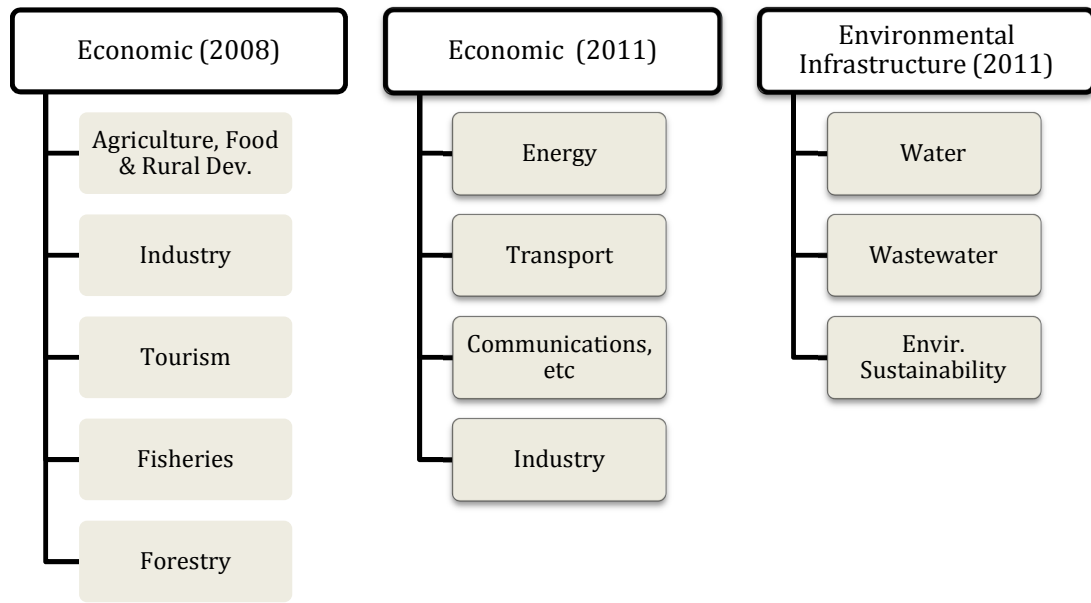


Figure 2-2: Comparison of the sectors considered ‘economic’ infrastructure by the Irish Government in 2008 and 2011, with a new category of Environmental Infrastructure

Source: Developed from Irish Government Capitals programs (Department of Public Expenditure and Reform, 2011, Irish Government, 2008)

Therefore to clarify: the research presented in this thesis focuses on ‘*physical networks*’ (ESRI, 2006, Ter-Minassian *et al.*, 2008), which appear under both productive and economic infrastructure. These will include: water; wastewater; transportation; power; and communication networks. Investment figures analysed in Chapter 3.0 were compiled based on defining the terms of the sectors included in ‘productive infrastructure’, ie. physical networks.

This is very much in line with Tredgold’s definition of civil engineering, and on which the charter of the Institution of Civil Engineers is based:

*‘... being the art of directing the great sources of power in Nature for the use and convenience of man, as the means of **production** and of traffic in states, both for external and internal trade, as applied in the construction of roads, bridges, aqueducts, canals, river navigation, and docks, for internal intercourse and*

exchange; and in the construction of ports harbours, moles, breakwaters, and lighthouses, and in the art of navigation by artificial power, for the purposes of commerce; and in the construction and adaptation of machinery, and in the drainage of cities and towns'

(Institution of Civil Engineers, 1870)

2.1.1. Importance of Infrastructure and the Influence of FDIs and SMEs

The literature overwhelmingly supports the theory that good infrastructure is crucial to a country's economic growth and competitiveness (Allard and Everaert, 2010, Aschauer, 1990, Forfas, 2012, Kessides, 2004). The OECD clearly links Foreign Direct Investment (FDI) with good quality infrastructure (OECD, 2006c). The Irish Government recognised this in their supporting documentation for the 2000-2006 National Development Plan, when discussing the significant influence to FDI locating in the country, while also accepting that the spatial pattern of quality infrastructure has a bearing on the economic growth and health of the regions (Department of the Environment Community and Local Government, 2000). This view was repeated in further national development plans, strategies and capital investment programmes (Department of Communications, 2012, Department of Finance, 2010a, Department of Finance, 2010b, Department of the Environment Community & Local Government, 2006, Government, 2002). The Department of Public Expenditure and Reform went so far as to state that '*Economic recovery in Ireland will be enterprise-driven and export-led*' (Department of Public Expenditure and Reform, 2011).

The positive impact of SMEs and FDIs on a country's and regional economic growth is without doubt, and thus engagement with these stakeholders is crucial in understanding the needs of specific industries and furthermore identifying what they perceive as gaps. Gunnigle undertook stakeholder interviews, and while his primary research objective was to understand the impact of labour issues on US multinationals (MNCs) locating here in Ireland, this work also identified the importance of good quality infrastructure

(Gunnigle and McGuire, 2001). This was also the case in Hannigan's survey of Multi-National Corporations (MNC), with telecommunications infrastructure 4th and air and sea transport 8th in the top 10 most important factors for their companies competitiveness (Hannigan, 1999). This is further emphasised by Quinlan in his review of the US-Ireland relationship where he cites on the one hand the enormous level of US investment in Ireland and on the other noting the on-going upgrade of the nation's infrastructure as a challenge. He very clearly states that for Ireland to remain competitive in the sectors of tomorrow, it must work harder at improving and upgrading its physical infrastructure (Quinlan, 2012). This is reinforced by Forfas, the Government agency who commissioned a report on the main infrastructure issues for enterprise (Forfas, 2012). They identified high speed broadband as the main priority, as was the finding of the work in this thesis (which is detailed in Chapter 7.0).

2.1.2. Infrastructure: Ireland's International Rankings

With all these plans and visions, there has been a lack of substantive progress across the country in the quality of physical infrastructure, which is apparent in Ireland's ranking in various global reports. The United Nations Conference on Trade and Development (UNCTAD) identifies infrastructure as one of the critical elements to productive capacity-building of an economy (UNCTAD, 2012), while the World Bank (WB) includes the key components of physical networks in its assessment of World Development Indicators.

The World Economic Forum (WEF) measures 12 pillars, in evaluating each of the circa 150 countries' competitiveness. The WEF includes 4 basic pillars in its analysis, with one being infrastructure. So while Ireland currently ranks 25/144 in overall competitiveness in the 2013-14 World Economic Forum Global Competitiveness report, the quality of infrastructure places it 36/144, with Transport infrastructure 35/144; Quality of roads 25/144; air transport infrastructure 23/144; port infrastructure 29/144; and railroad infrastructure 31/144. The quality of the electricity supply is evaluated at 17/144. Overall this is not a great global image for a country that was once 22nd in the global competitiveness score (2007-08), while never achieving greater than 36th on the

overall quality of infrastructure (Schwab, 2007, Schwab, 2008, Schwab, 2009, Schwab, 2010, Schwab, 2011, Schwab, 2013, Schwab, 2014).

The recent OECD economic survey illustrated that Ireland ranks poorly relative to some of its fellow OECD countries. In evaluating structural levers to lift sustainable and inclusive growth, Ireland ranked 30/34 in Government involvement in infrastructure; OECD electricity transport and communications Product Market Regulations (PMR) overall 28th out of 34; with the publication of administrative data sets 22/34. All this would suggest that Ireland has some way to go in infrastructure development as well as in meeting its data publication obligations (OECD, 2013).

2.1.3. Has Ireland invested enough?

Ireland's economy has been through an extraordinary cycle from boom to bust over the study period of this work (2003-2009), resulting in an International Monetary fund (IMF) and European Union/European Central Bank (EU/ECB) bail out in 2010. Ireland successfully exited the bailout programme in late 2013, the 1st of the 4 bailed out countries to do so. However the fact remains that Ireland's GDP per capita remains very high relative to some of its European counterparts.

Kamps has demonstrated that Ireland underinvested in its infrastructure networks between 1990 and 2000 (Kamps, 2004, Kamps, 2006). The level of investment increased considerably over the period 2000 to 2010. There are varying opinions on whether it invested sufficiently or in the right assets during this period, but what is clear is that Ireland has quite some distance to go, in terms of the actual quality of its infrastructure. An IMF paper identified structural reform as a gap that needed to be addressed, as far back as 2010 (Allard and Everaert, 2010). Ireland continues to perform poorly in the ratings and rankings of the OECD, IMF and the WEF, as previously discussed. On the other hand, Morgenroth has illustrated that Ireland's investment of general government gross fixed capital formation (GFCF) has been in line as a percentage of its GDP with its European counterparts (Morgenroth, 2014b). So

while the investment in infrastructure was considerable, one has to question why it did not improve the country's infrastructure rating and ranking as it should have.

Gramlich argues that the most important question in looking at infrastructural investment is not on whether there has been a shortage but rather whether government policy has been appropriate, and thus investment of the correct type and location (Gramlich, 1994). This thesis argues that while Ireland may have invested significantly in its physical infrastructure during the Celtic Tiger period, much of the investment was wasted due to a combination of: inflated construction costs; monies invested to support vacant houses; oversizing of infrastructure; and invested in the incorrect locations (Irish Academy of Engineers, 2011, Moloney and McKeogh, 2013, Morgenroth, 2014b).

2.2. EXISTING INFRASTRUCTURE DECISION-MAKING IN IRELAND

Gramlich discusses four drivers of infrastructure investment. He identifies these as: an engineering assessment which identifies an infrastructure need; political influence granting infrastructure to a particular area to ensure winning votes; an economic measure or evaluation on the rate of return; and econometric estimates of the possible productivity impacts of a piece of infrastructure (Gramlich, 1994). This thesis argues that Ireland's emphasis was heavily skewed, i.e. that certain drivers were given excessive weight; while little or no regard was had for others, with the resulting negative consequences of wasted investment in particular. This is discussed in more detail in Chapter 9.

Furthermore, while a cost-benefit analysis was selectively used in Ireland to help justify a particular investment, there is a growing quantity of literature questioning how economic evaluations are being undertaken in the appraisal of infrastructure projects. There are many assumptions and unknowns in evaluating both the cost and the benefits of a piece of infrastructure; not least the variability on the use of the discount rate, the expected life span of the asset

and the estimation of productivity factors (Aschauer, 2011, Gramlich, 1994, Morgenroth, 2013, Munda, 1996, Munnell, 1990a).

2.2.1. Ireland's ineffective National Spatial Planning

The Irish Government commissioned a review of planning legislation in 1997. This process led to the adoption of a national spatial planning methodology, culminating in the first National Spatial Strategy (NSS) in 2002 (Irish Government, 2002); along with the National Development Plan (NDP) 2000, with a review and update of the NDP in 2006 (Department of the Environment Community & Local Government, 2006, Department of the Environment Community and Local Government, 2000, Government, 2002). The vision of the NSS was to focus development and growth in particular towns and cities that were identified to become Gateways and Hubs. It aimed to deliver more regionally balanced social and economic development. A hierarchy of National, Regional and Local Development planning was set up, aiming to achieve policy consistency at all levels.

These were then accompanied by capital programmes issued by the Department of Finance, primarily (Department of Finance, 2010a, Department of Finance, 2010b, Irish Government, 2008, Irish Government, 2010, Irish Government, 2013b).

However, from the outset, the aspiration of the Government to embrace a coherent national strategic planning approach was undermined by weak implementation, political interference and vote getting. The NSS plan was given no legislative basis and was seen as merely a framework document (Meredith and Egeraat, 2013). To date it has not been revised or updated, despite the dramatic changes in conditions in Ireland in the intervening period. This lack of legislative basis, along with the fact that it was very much a static document, led to the belief that the NSS was flawed. Targets were set in the plan, but no regime was established to ensure on-going monitoring and evaluation of how each region, gateway and hub was performing relative to the target. Thus, for example, an excessive amount of land zoning and resultant development went

uncounted and unchecked. According to Cussen, 44,000 hectares of land were zoned under the NSS by 2009, as compared to the 12,000 hectares identified requirement (Cussen, 2012).

Furthermore, during this time the Irish Government announced a major decentralisation of government departments across 53 locations around the country. These locations were not in line with the NSS, and decentralisation was seen as very much a political process, interfering and '*completely undermining*' the vision of the NSS (Grist, 2012). This further undermined the envisaged national spatial planning process.

In addition, the legislation outlining a hierarchy of national, regional and local development plans met a legal challenge in 2003, when the High Court adjudicated that local authorities did not have to comply with the regulations, but merely give them 'reasonable consideration'. This ultimately led to the flood of land rezoning identified above (Grist, 2012), as elected local councillors exercised their reserved functions, frequently ignored their own executives' recommendations, and voted to rezone land liberally, often without any consideration of the wider context or the implications for infrastructure expenditure.

A further illustration of the counter-drivers to a coherent approach to national planning is the example of the heavy reliance of many local authorities on financial planning contributions during this period. When land was zoned and planning granted by local authorities, a financial 'planning contribution' was (and still is) levied as one of the conditions attached to the grant of planning permission. These contributions were very significant during the Study Period 2003-2009. Some counties received in excess of 20% of their annual capital budget from planning contributions (Local Authorities, 2003 to 2009). The significance of these contributions from zoning land should not be underestimated. This issue is part of a larger context of the very narrow fundraising power that local authorities held at that time; so it is difficult to avoid the view that the potential to raise considerable sums of finance may have incentivised some local authorities to continue rezoning lands and granting

planning permissions: the more land zoned, the more development permitted, and the greater the capital budget. While these contributions practically disappeared during the recession, Cussen suggests that the newly introduced property tax may remedy the impact of loss of planning contributions on capital budgets, and thus be a positive influence on the implementation of strategic planning policies (Cussen, 2012).

2.2.2. *The Irish Planning Hierarchy & Infrastructure development*

The National Spatial Strategy was written in 2002 and has not yet been replaced/revised. Such a study cannot remain valid, as for example, demographics and economic circumstances change over the Plan's projected 18 years. Previous work by Moloney et al. (Moloney and McKeogh, 2013) has identified how housing construction quickly overshot projected numbers, but construction still continued in specific towns and regions. This led to in excess of 2800 ghost estates (Department of the Environment Community & Local Government, 2011) during the economic downturn. Unfortunately many of these houses have been constructed in locations that are highly unlikely to attract a corresponding level of economic growth, and thus will remain vacant; while at the same time housing shortages are emerging in the large urban centres e.g. Dublin and Cork. The 2011 survey revealed that the 2800 ghost estates had 18,638 housing units complete but vacant (many without supporting services connected), and 7,000 units nearly complete. The survey estimated another 10,000 housing units are varying levels of early construction.

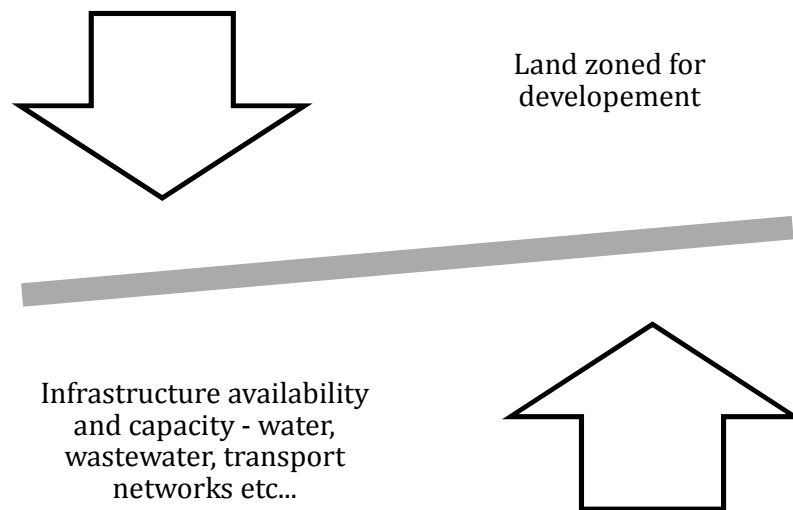


Figure 2-3: The Inter-relationship between spatial planning and infrastructure development

However, the need to develop and/or expand infrastructural assets is clearly interrelated with planning and development as illustrated in Figure 2-3 above, and as described earlier. As land is zoned, and planning permissions are granted for construction, the immediate implication is a need for infrastructure to be provided, i.e. water, wastewater and transport links. Therefore in understanding decision making for infrastructure development, one also needs to understand how planning occurs in Ireland. Figure 2-4 below shows the overall planning hierarchy, along with where and how capital infrastructure development arises in Ireland. The Department of the Environment would envisage that it should be a top down type of planning program i.e. a national vision, percolating down to local level, as illustrated in Figure 2-4. There are various initiators of infrastructural projects: Ireland's 2002 NSS and the various National Development Plans (NDP) (Department of the Environment Community & Local Government, 2006); individual government departments identifying specific infrastructural needs and grant aiding the development of these to local authorities or undertaking the projects themselves (as indicated in the case of a motorway in Figure 2.4); and individual local authorities

developing a County and Local Area Plans (LAPs) for development (Department of Environment, 2000). These plans can in themselves give rise to the 'need' for infrastructure, ie. a water supply scheme to support the development of a village or town as illustrated in Figure 2.4. The county and Local Area Plans initiate a process of land to be zoned and developed for housing and industry; thus the need for the land to be serviced with infrastructure networks.

The case of two these types of projects are illustrated in Figure 2.4, and can be demonstrated as follows in line with the numbers in the flow chart boxes, with ample opportunity for political and ministerial input/interference in the process.

A new motorway project – these type of projects are generally initiated as part of a national programme, ie. the Department of Transport in this instance (11 & 12), or may have been part of the National Development Plan (14 &15). The relevant department applies to the Department of Public Expenditure and Reform's Central Evaluation Unit (CEEU) where the project is appraised (17 & 18). If the project is approved (16) the relevant Government department gives permission to the agency, in this instance the National Roads Authority (NRA) to commence the design process, and its various stages (13). Some of the work for the project may be given to the relevant local authority to undertake (10). The construction, operation and maintenance (O&M) of the motorway will then be undertaken, with the NRA managing and being responsible for each process (8 & 9).

Water Supply for a village –the need arises for a new water supply to support land that has been zoned for development (7). This would be in line with the regional, county and local area plans (4, 5 &6). Some or all of the financing for its construction will be from the Department of the Environment (10), with the O&M element financed by local charges. This was the case till 2014, but now Irish Water is responsible for the construction, maintenance and operation of these facilities. The O&M is through SLA with the relevant Local Authority, and will likely be financed by the new water charges which commence in April 2015 for domestic users.

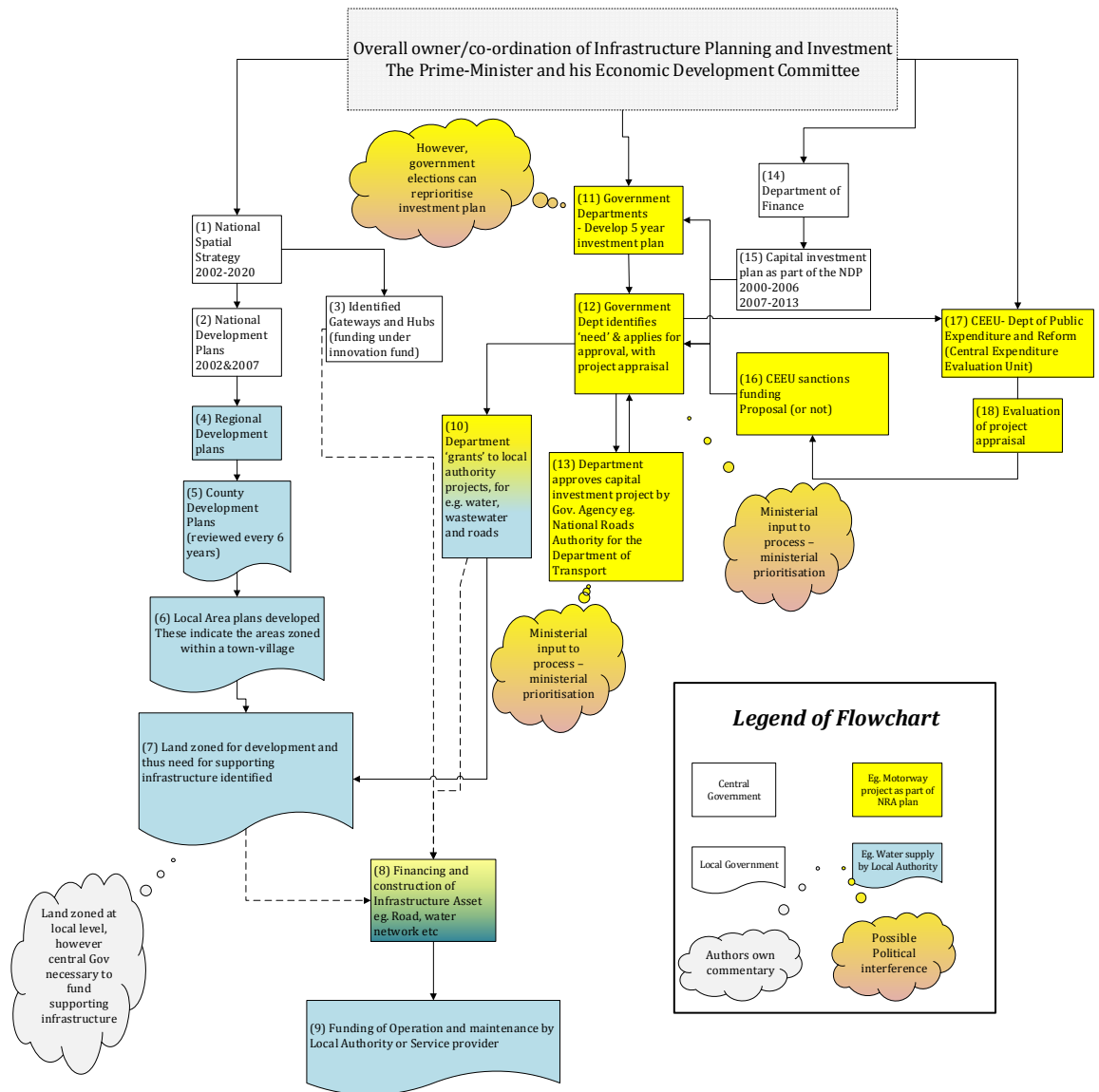


Figure 2-4: Figure illustrating origin of capital development projects

Source: Prepared by author from various documents (Department of Enviroment, 2000, Government, 2002, Government, 2009)

However, this thesis provides evidence of how in many cases planning and development has been a bottom-up type process, i.e. local counsellors and developers lobbying at a local level to get land rezoned for housing, thus driving a need for infrastructural support for these housing developments, as reported by Cussen (refer to section 2.2.1)

2.2.3. *Political Interference in the Planning process*

The exceptional extent of land zoning for development, in the villages and towns of Ireland, has resulted in items of infrastructure having been oversized, and in many cases redundant. A case study of a small village in North County Cork is presented in Section 8.7. Morgenroth suggests that while at a national level Ireland may have spent a considerable amount of capital on its infrastructure over the 2002-2010 period, it may not have been of the correct type and the most appropriate location (Morgenroth, 2014b). The Comptroller and Auditor General, in a review of the expenditure on the water services sector from 2002-2007, identified a lack of improvement in the overall quality and performance of water relative to the vast investment, by grant aid to local authorities (Comptroller and Auditor General, 2009). He suggested that the Government should have had a separate body responsible for the overseeing of the grants to local authorities to ensure that the expected improvement in water quality would be in line with Exchequer expectations, ensuring that prioritised schemes remained a priority and that there was adequate maintenance of the infrastructure. This aligns with the findings of this research: the need for a 'National Infrastructure Agency'. It should also be noted that capital investment decisions are subjected to the political cycle, a maximum of 5 years for each Dail sitting. New Ministers reprioritise projected investment plans in their particular departments. Ireland is currently in its 31st Dail, with an average of 3 years per sitting since 1919 (with 3 Parliament sessions in the years 1981 and 1982) (Irish Government), all potentially exposing infrastructure decision making to short term appraisal, if any.

Flyvberg writes extensively on the input and impact of political influence in decision making for infrastructural projects (Flyvberg, 2007, Flyvberg, 2009,

Freudendal-Pedersen, 2014). He provides clear evidence of political influence having negative impacts on the sizing and pricing of infrastructure projects.

2.2.4. Government Evaluation of Infrastructure Projects

So while capital development projects can originate through a number of different routes as outlined in Figure 2-4 above, there would appear to be a lack of centralized thinking and management of these projects. This is discussed further in Chapter 6.0, with the findings of a study of key stakeholders and their opinions with regard to infrastructure decision-making. Ireland's Prime Minister chairs the Economic Subcommittee of cabinet ministers, and this is the central coordinating group. Applications for capital investment are evaluated in the central expenditure valuation unit (CEEU), within the Department of Public Expenditure and Reform (Central Expenditure and Evaluation Unit, 2013b). Here they are subject to Ireland's public spending code, developed by the Department of Finance, which outlines to each department how they should undertake the identification and appraisal of projects. Different levels of financial investment require alternative forms of appraisal (Central Expenditure and Evaluation Unit, 2013a), as outlined in Table 2-1 below.

Estimated Budget	Form of Financial Appraisal
< €0.5 million	simple financial assessment
€0.5 million to €5 million	a single appraisal incorporating elements of a preliminary and detailed appraisal
€5 million and €20 million	MCA should be carried out at minimum
> €20 million	Cost Benefit Analysis (CBA) or Cost Effectiveness Analysis (CEA)

Table 2-1: The Irish Public Spending Code - Required appraisal type for capital project costs (Central Expenditure and Evaluation Unit, 2013b)

However, what is of concern is that one project might make financial sense in itself when evaluated using these methodologies, and may give a good internal rate of return or cost to benefit ratio; but such an analysis fails to assess the impact or need, positive or negative on other systems with which it is interdependent (Flyvberg, 2007).

2.2.5. *Fragmented Infrastructure Investment Responsibility*

In overall terms, the landscape for infrastructure investment decision making was highly fragmented and lacking in policy consistency throughout the study period, and remains so.

Local authorities undertook spatial planning on a county by county level, as described above, within an ineffective national planning framework. Meanwhile, the government moved to regionalise and centralise the management of the main road network, through the National Roads Authority (NRA) which was formally established as an independent statutory body in 1994.

Water and wastewater provision remained at local authority level, with oversight and grant aid for capital works from the Department of Environment, Community and Local Government (DoECLG). These water sector assets have now transferred to a new semi-state company called Irish Water, in January 2014, but will be operated and maintained by the responsible local authorities under Service Level Agreements (SLAs) (Department of the Environment Community and Local Government, 2012). The original vision for Irish Water was that it would be a financially independent organisation, raising funds through the metering of domestic water and on the open bond market, to carry out a significant programme of capital investment without adding to the national debt. Indeed, the research in this thesis clearly quantifies the great need for investment in water infrastructure (Chapter 7.0 in particular) (Moloney and McKeogh, 2014). However, in recent months the proposed domestic water charging regime met with enormous social unrest, resulting in the Government rowing back and introducing a fixed charge, independent of the number of people in the house and the quantity of water used (Oireachtas,

2014). To date Ireland is the only country in the EU that does not charge for water, and the introduction of a fixed charge removes the incentive for users to reduce their water usage. More significantly, this change of domestic water charging policy undermines the basis of Irish Water's financial plan, since it considerably reduces the amount and certainty of this source of revenue. Gramlich (Gramlich, 1994) would describe such turn-arounds as based on '*vote getting*'.

The telecommunications sector was privatised by the Government in 1999 (Palcic and Reeves, 2007). Except for the 94 Metropolitan Area Networks (MANs) in towns and cities, the communications network is privately owned and operated (ENet).

2.2.6. *Engaging with stakeholders: Use of NVivo and Qualitative research*

Stakeholder engagement is crucial to the infrastructure decision making process, which is a long term investment. It is clear that current planning and decision making is focused at best on the mid-term but primarily on the short term. Morgenroth's recent brief to the Department of Public Expenditure and Reform sets out some high level principals which he considers important in the decision-making process for public capital expenditure. He goes so far as to suggest that advice on specific infrastructure assets should

'be based on thorough background research, which has often been lacking in public investment decision making in the past. Such background research costs little relative to massive sums involved in an investment programme but it can significantly improve the impact and effectiveness of new investment'

(Morgenroth, 2014b)

The use of stakeholders in understanding and exploring policy and structural issues is a much used process (Brookfield *et al.*, 2013, Garrod *et al.*, 2013, Gunnigle and McGuire, 2001, Hannigan, 1999). However the challenges of analysing numerous interviews can be a very labour intensive and cumbersome

task, with a possible loss of data (Bringer *et al.*, 2004, Denardo, 2002, Hutchison *et al.*, 2009, Saunders *et al.*, 2014). The use of computer aided qualitative data analysis software (CAQDAS) supports the transparent coding, integration and analysis of interviews (Bazeley and Jackson, 2013, NVivo, 1999-2013). One such analysis package was used for this research and is discussed in Chapters 6.0 and 7.0.

2.3. SUSTAINABLE INFRASTRUCTURE AND ITS IMPORTANCE TO A NATION'S ECONOMY

There is extensive literature on the need for development to be carried out in a sustainable way. It has been a key principle within the OECD, the WEF, EU and the UN to name a few. The word '*sustainability*' is much used and maybe not always in the correct context (Pearce *et al.*, 2012). One much accepted definition of sustainable development is as follows:

'sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs'

(Brundtland, 1987)

In a recent address to the UN, Ban Ki Moon suggested that sustainably development is the best chance we have of reversing climate change.

'Climate change is destroying our path to sustainability. Ours is a world of looming challenges and increasingly limited resources. Sustainable development offers the best chance to adjust our course'.

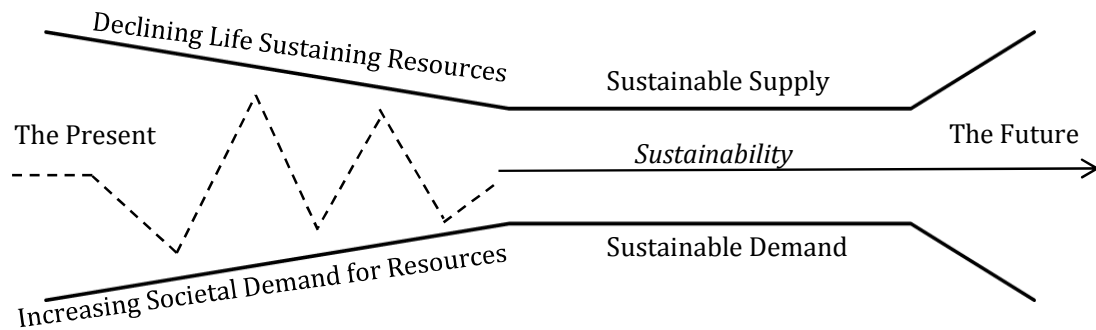
(Ban, 2012)

2.3.1. Sustainable Development

Brundtland argues that the environment is where we live and development is what we do to improve where we live and how we live, and thus that both are inseparable (Brundtland, 1987). And of course the challenge is in how we develop in a sustainable manner minimizing the impact on the environment.

This is a very well presented in Chamber et al's resource funnel metaphor as illustrated in

Figure 2-5 below.



The Resource Funnel

Figure 2-5: Chambers et al Resource Funnel Metaphor (Chambers *et al.*, 2009)

This funnel lying on its side represents the increasing pressure over time of our demands on the planet's resources. The Earth's capacity to provide for the population as represented by the top surface of the funnel is diminishing, as the Earth's population demands increase, as represented by the bottom surface of the funnel. Chambers et al calls on people to avoid the squeeze of the funnel and to open up the walls (Chambers *et al.*, 2009). This can obviously only be done by thinking and acting in a more creative and innovative way, thus reducing our demand of the Earth's natural resources, with the challenge of how to deliver sustainable infrastructure.

Engineering infrastructure provides the critical interface between society and the environment. People can only survive and live and operate economically in a location which has infrastructure to allow them to go about their daily lives. There are differing opinions on how to represent sustainable infrastructure and these are illustrated below. The familiar triple bottom line diagram (Figure 2-6 below) would suggest that sustainability is an equal balance of social, economic and environmental issues.

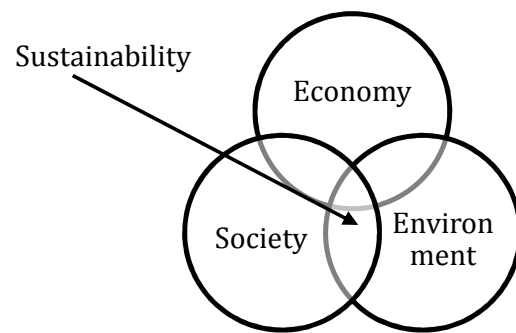


Figure 2-6: Representation of Sustainability

Ainger and Fenner prefer Parkin's (Parkin, 2003) representation of the relationship as like three nested components with infrastructure the link between society and the environment (Ainger and Fenner, 2014).

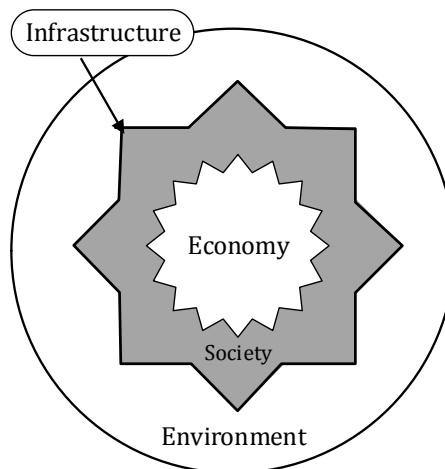


Figure 2-7: Parkins representation of sustainable development with infrastructure (Parkin, 2003)

Brundtland's commission discusses how technology and society can be both managed and improved. They suggest that

'sustainable development is not a fixed state of harmony, but rather a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are made consistent with future as well as present needs'

(Brundtland, 1987)

With the enormity of the task and the complexity of addressing how to deliver sustainable development, many are blinded by numbers and options. There is compelling evidence of the necessity to reduce our carbon footprint and incorporate the potential impact of climate change when undertaking infrastructure projects. The challenge for engineers is how this can be delivered.

2.3.2. Sustainability Criteria and Evaluation

The issue of sustainable development does not fall within any one discipline of engineering, and thus is difficult to identify and measure. There have been many frameworks developed over the past decade to assist engineers to evaluate if their design is sustainable. There are extensive sets of indicators which are documented by Brandon and Lombardi (Brandon and Lombardi, 2010). They propose the adoption of a holistic and integrated framework based on the philosophy of Dooyeweerd's theory of the 'Cosmonomic idea of reality'. The framework proposes a list of 15 modalities, which address 3 specific aspects of sustainable development: urban and infrastructure development; environmental and physical quality; education and scientific development; social and economic development; and governance.

There are many building environmental assessment (BEA) tools, which have been well documented by Haapio and Viitaniemi (Haapio and Viitaniemi, 2008).

While these BEA tools address a buildings environmental performance many have been adapted/developed further to look at the development within the greater context of economic performance, and the sustainability of the development in the proposed location eg. BREEAM communities (BRE, 2015). Existing evaluation methodologies such as BREEAM and LEED are based on a set list of criteria and targets, however these could result in a very high scoring sustainable development, but in the incorrect location from the perspective of users (BRE, 2015, USGBC). These also allow developers and designers to satisfy corporate sustainability requirements/responsibilities and reporting. On the other hand the Halstar assessment methodology is based on a systems approach, which allows for a holistic and integrated assessment of a development within: the short, medium and long term; within a global, regional, local and client context; evaluating natural, social, human, manufactured, financial aspects (Pearce *et al.*, 2012).

Panagiotakopoulos et al also propose the use of a systems approach in assessing sustainability (Panagiotakopoulos and Jowitt, 2008). Their work suggests that existing methodologies allow for a simple rating to be calculated at the expense of '*context-driven*' requirements. It should be noted that Ireland has presently not adopted a sustainability assessment methodology. The aspiration for national spatial planning, with the numerous associated reports discussed the many elements of physical infrastructure, but none outlined how to ensure a sustainable infrastructure delivery that would be in line with spatial planning. Many used the term sustainable, but none showed how to actually demonstrate or deliver sustainable infrastructure, sustainably (Government, 2002, Government, 2009, Irish Government, 2002)

The evidence presented in this thesis on Ireland's past infrastructural investment will demonstrate how truly unsustainable it was, particular the investment in Ireland's water and wastewater networks, as demonstrated in Chapters 3.0 and 5.0. There is a growing body across Europe and the US looking at SoS as a mechanism for infrastructure delivery and appraisal (DANSE

Consortium, 2014, Hall *et al.*, 2013, Thissen and Herder, 2009, Young and Hall, 2014). Jowitt, in his Presidential Speech of the ICE, encourages decision makers

‘to take a long term view and not a view where the future is discounted and where major decisions on infrastructure are thwarted by blind obedience to the Treasury discount rate’

(Jowitt, 2009)

He suggests that engineers need to take a systems view at a spatial and temporal scale. And thus a systems of systems approach to Ireland infrastructure analysis is proposed in this thesis.

2.4. STRATEGIC INFRASTRUCTURE PLANNING – INTERNATIONAL PRACTICE

There is growing consensus that countries need to take a long term view of national infrastructure planning and delivery. A number of them have set up infrastructure agencies, authorities or commissions. There are varying structures as to how these are managed, their time scale and statutory position.

The Labour Party commissioned Sir John Armitt to undertake a review of long term planning and delivery of infrastructure in the UK, on which he reported in 2013 (Armitt, 2013). The Armitt review examined international practices in this regard, and recommended the implementation of an ‘Infrastructure Commission’ which would have statutory independence and achieve cross-party consensus, to ensure that the identified projects could be delivered. His vision is that the Commission would convene each decade to undertake evidence-based assessment of the UK’s infrastructure needs for the following decade, and ensure that there would be no shift in Government policy in implementing its recommendations. Armitt also envisaged annual reviews to monitor and review implementation of the overall strategy.

The Armitt review diagnosed the current issues of infrastructure delivery to be linked with the front end planning and two key issues were identified: the lack of strategic planning for future needs on the one hand; with policy uncertainty being the second main issue. Jowitt would define this as a 'decision-making crisis', where he cites infrastructure projects getting bogged down, deferred or cancelled (Jowitt, 2013). He suggests that these can be as a result of political pressures, impending elections and thus it being easier to do nothing till after the 'next election'.

The United Kingdom Government has established a dedicated infrastructure planning unit (Infrastructure UK) within the HM Treasury Department. This unit has published a number of infrastructure plans, the most recent in 2014 (HM Treasury, 2014). Section 2.2.2 of this thesis outlines the many capital plans that Ireland has published; these have not had a strategic focus on the infrastructural networks, but have included, *inter alia*, schools, social housing etc. Ireland does not have a 'single' agency or authority that overviews infrastructure; rather each department develops its own plans in isolation. Internationally, Australia, New Zealand, and Singapore have infrastructure authorities or agencies that plan for the long term, and generally sit within the Financial Department/Ministries (Armitt, 2013).

Internationally, there is much evidence of the need for, and a transition to, a single infrastructure planning and decision-making body within a country, that uses evidence-based approaches, in a system-of systems manner, to chart its infrastructure spending.

2.5. SYSTEMS OF SYSTEMS APPROACH TO INFRASTRUCTURE DECISION MAKING: EVIDENCE BASED DECISION MAKING

SoS is an integration and analysis of constituent systems, incorporating input from policy makers and decision makers. There is growing interest in the methodology for the evaluation of national infrastructure networks. Current

decision making evaluations are generally based on ‘static’ and historic information. Current and up to date information and data input can only be sourced for dynamic modelling if the data is collected and used in a live model. This is currently not the case in many of Ireland’s networks, other than power and gas distribution and a number of road traffic counters. The development of a national infrastructure development platform (NIDP) is proposed in this thesis in Chapter 1.0 and supports the call by many for dynamic analysis in infrastructure decisions making: which would take account of spatial distribution; and varying levels of economic change and demand/capacity in the networks (ITRC, 2013, Jowitt, 2009). In *‘Using Evidence to Inform Policy*, a group of researchers in Ireland’s Economic and Social Research Institute (ESRI) argue the merits of using evidence in policy making and the complexity of the issues between evidence and policy making (Lunn and Ruane, 2013a). They conclude that

‘good evidence is likely to result in better policy making, but good policy cannot be deducted from good evidence alone’

(Lunn and Ruane, 2013b)

They advocate the use of a ‘system model’ between policy makers and evidence providers, such that there is a flow of information in both directions, with feedback loops, thus leading to a systems approach with researchers/evidence providers; policy makers and key stakeholders all engaged in the dynamic process. Obviously such a process would need accurate, available and dynamic data of the infrastructure assets, usage and capacity.

2.5.1. *The Importance of Data in SoS*

The EU INSPIRE directive requires member states to report on the availability and accuracy of an extensive list of datasets (INSPIRE, 2014). Ireland has a moderate conformance with publication of these datasets, approx. 60% as presented in section 8.6.4. Thus the initial challenge to adopting a SoS approach will be the availability and accuracy of data. Lunn and Ruane call on the

relationship between evidence and policy to be a dynamic one, with evidence generated on an ongoing basis, to be effective.

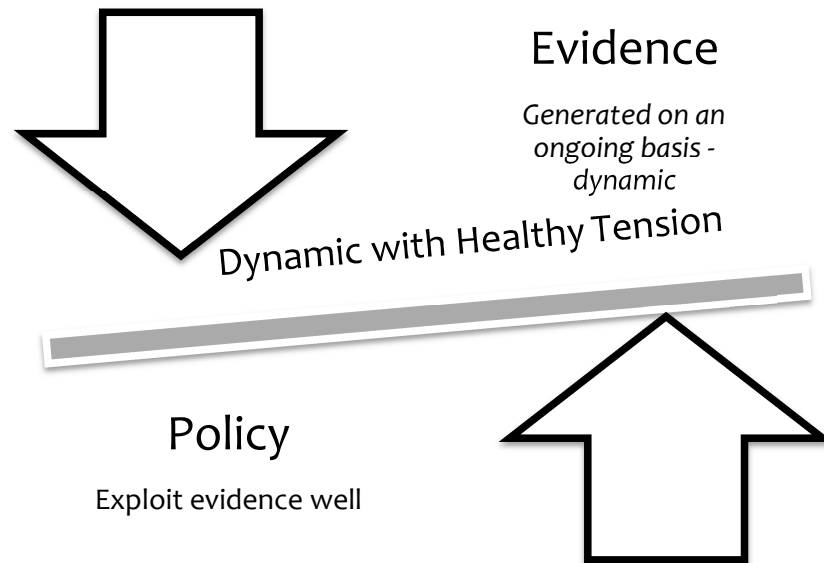


Figure 2-8: Relationship between evidence and policy making

Adapted from Lunn and Ruane (Lunn and Ruane, 2013a)

SoS supports the development of sustainable infrastructure evolution based on the integration of social, environmental and economic principles, through evaluating constituent system models for varying demands and constraints.

A review of the literature gives many (often complex) definitions for 'Systems of Systems'; Jamshidi's definition (Jamshidi, 2009) is the one preferred by this author.

'Systems of systems are large-scale integrated systems that are heterogeneous and independently operable on their own, but are networked together for a common good'

2.5.2. *International Application of SoS and National Infrastructure delivery*

There is growing interest in the SoS approach to national infrastructure planning, and indeed in further using the models and simulations to assess critical national infrastructure (Alderson, 2012, Barr, 2012, Hall *et al.*, 2013, ICE, 2013, OECD, 2006a, Young and Hall, 2014) systems.

The UK Infrastructure Transitions Research Consortium (ITRC) is a 5 year research programme, led by Oxford University which partners with 6 other Universities in the UK and numerous government departments, organisations, professional bodies, engineering consultants and contractors. They commenced their work in 2011 and through collaboration with policy makers and consultancies, have developed a number of discipline specific tools to evaluate impact of future climate change and assessment of critical infrastructure from extreme weather events. They have produced a number of reports assessing the UK national infrastructure. The 1st report was a fast track analysis which presented the findings of scenario frameworks and analysis of long term strategies for physical infrastructure provision (ITRC, 2012). They evaluated capacity intensive; capacity constrained and decentralisation strategies against different drivers of population; and economic growth/change and the cost of energy. The impact of these drivers with the different strategies for short, medium and long term growth were examined. The water, wastewater, transportation, solid waste, ICT and energy sectors were assessed in the FTA report.

The EU require each member state to prepare a critical infrastructure and response plan (European Union, 2008). Rinaldi *et al* identified 6 key dimensions for describing infrastructural interdependencies, based on: infrastructure characteristics; how the system is operating; interdependency types; environmental dimensions; the response behaviour of the systems; and the types of failure (Rinaldi *et al.*, 2001).

The SoS methodology models each constituent network; and identifies the interdependent nodes. This allows the impact that a change in one system has on another system to be identified, quantified and evaluated. One such example would be a water system: the water is abstracted from a source e.g. a reservoir ; this reservoir could also be a power source; the water abstraction is dependent on power for pumping; the water treatment plant is dependent on power and ICT for operation; and a road is needed to the water treatment plant for its operation. So while each of these power, water, ICT and road systems operate independent of each other there is interdependence for the resilience of their operation.

The following Chapters 3 to 8, present the analyses and findings of this research, as outlined in sections 1.2 and 1.3.

3.0 QUANTIFYING IRELAND'S INFRASTRUCTURAL DEFICIT¹

3.1. ABSTRACT

Ireland's construction output during the 'Celtic Tiger' years peaked at €38.4 billion in 2007. However, the extraordinary fact is that less than 20% of this was put into public physical infrastructure. Across the euro zone the Republic of Ireland was quoted as being a 'wealthy' country. However, nearly 65% of construction output during the period 2000 and 2007 was invested in the combined sectors of private residential (housing and apartments) and private non-residential construction. These assets have now depreciated by between 30% and 50%; many lie idle and cannot be sold. Ireland's Construction Industry contributed 24.7% of the country's GNP in 2006. The latest estimate for 2009 is that this figure was 14.5%, which is still above the average in the EU and US. Since 2009, there has been a lack of publications, due to the severe slowdown in the Irish Construction Sector. During the time of great apparent prosperity Ireland did not invest sufficiently in its public infrastructure. Roads investment is the one category that bucks this trend. It is well recognised and widely published that for a country to maintain sustainable growth and prosperity it must invest in its infrastructure. Ireland failed to invest sufficient funds in public infrastructure during this time of peak construction output. The pace at which Ireland emerges from the current recession will depend in part on finding innovative funding mechanisms to finance infrastructural development.

¹ Presented and published in Bridge, Infrastructure and Concrete Research in Ireland (2010)

This thesis defines the term productive infrastructure and identifies the sectors that should be included in its scope, i.e. physical networks for power, rail road. It measures the investment that has occurred during the period 2002 – 2008 in Productive Infrastructure. It examines the global norms for investment in Productive Infrastructure and identifies Ireland's investment shortfall.

3.2. INTRODUCTION

The OECD in its Economic Survey in 2006 noted that Ireland had undergone very rapid economic growth but that its infrastructure had not kept pace (OECD, 2006b). This chapter discusses the relevance of infrastructure to a country's growth, and identifies Ireland's global ranking in terms of the quality of its infrastructure and associated expenditure. The paper estimates how much should be spent to bring Ireland's infrastructure in line with its global position as a developed and innovation driven country as per the WEF (Schwab, 2009).

The paper reviews government expenditure figures for 2002 to 2008 (Department of Finance, 2010a, DKM, 2009, Irish Government, 2008) and demonstrates that rather than increase investment, the country has decreased its investment in key aspects of infrastructure that would support economic activity. Therefore, the question is by how much, and in what way is Ireland deficient in its current infrastructure?

Furthermore, how much does Ireland need to invest to bring it in line with its OECD partners?

3.3. INFRASTRUCTURE: PHYSICAL NETWORKS THAT SUPPORT ECONOMIC ACTIVITY

There are many services, facilities and sectors that can be included under the general heading of 'infrastructure'. It is necessary to define the term 'Infrastructure' as it will be used in this chapter and to do so a number of publications were referenced.

An International Monetary Fund (IMF) working paper defines 'infrastructure' as "the physical networks that support economic activity" (Ter-Minassian *et al.*, 2008). The IMF considers that infrastructure networks are transport, water, sanitation, power and telecommunications sectors. Also the World Economic Forum in its Global Competitiveness reports (Schwab, 2009) identifies infrastructure as being transport, communications and energy systems.

The Irish Government has used three sub-headings to define its infrastructure investment: productive, socio and economic, as outlined in section 2.1 previously. In its 2007-2008 Public Capital Programme (PCP) (Irish Government, 2008), the sub-heading of Productive Infrastructure includes the sectors of Energy, Transport, Environmental Protection and Communications. This Irish Government sub-heading closely matches the apparently accepted international definition of 'infrastructure', being the 'physical networks that support economic activity'. Therefore, in undertaking comparative reviews of what countries should spend on 'infrastructure' and measuring Ireland's performance, the relevant sectors under the Irish Government's 'Productive Infrastructure' sub-heading are included, namely power and energy, transport, environmental protection and communications. In international terms, the expenditures included under the other Irish Government sub-headings, namely socio and economic, are not considered to be 'infrastructure', per se. Therefore, the terms 'infrastructure' and 'productive infrastructure' are used interchangeably to mean the physical networks as outlined above, for the remainder of this thesis.

3.4. INFRASTRUCTURE AND ECONOMIC GROWTH

There have been a number of studies undertaken which clearly indicate that the quality of a country's infrastructure is intrinsically linked to its economic growth and that infrastructural investment is vital to maintain and improve a country's competitiveness and growth (Briceno-Garmendia *et al.*, 2004, OECD, 2006b, Schwab, 2009, Ter-Minassian *et al.*, 2008). These studies found a positive relationship between the stock of infrastructure assets and the rate of economic growth and prosperity.

Ter-Minassian and Hajdenberg identified that the impact that public investment had on an economy's growth depended on a number of factors. These included: the source of funding (increased taxation, government borrowings and/or private competition); the availability of other complementary investment in social areas of development; and the institutional context and quality of governance in which investments are made. The quality of the project evaluations and prioritisation, and the regulatory and operational framework within which infrastructural projects and services are provided – be they public or private investment or indeed in partnership, also have an effect on the level of growth derived from investment.

The World Economic Forum (WEF) (Schwab, 2009) also commented on the relationship between infrastructure investment and economic growth when it published its 2009 Global Competitiveness Report. This stated that extensive and efficient infrastructure is an essential and vital driver to a country's competitiveness. The WEF maintains that Productive Infrastructure determines the centre of economic activity and joins regions and countries together. The WEF went further, stating that the quality and effectiveness of infrastructure networks significantly impacts on a country's economic growth.

3.5. IRELAND – A DEVELOPED ECONOMY OR DEVELOPING?

The WEF defines three stages of development for global economies. In increasing order of development, these are:

- factor driven
- efficiency driven
- innovation driven.

The WEF identifies the stage of development from a country's GDP per Capita (US\$) and its score in the WEF Global Competitiveness Index (GCI).

Since 2005 the World Economic Forum has measured the competitiveness of countries using a Global Competitiveness Index. This index is based on what the WEF considers are the 12 pillars of competitiveness. Infrastructure is included as one of these pillars. In measuring this pillar a number of infrastructural sectors are measured and surveyed. These are the quality of the: overall infrastructure; roads; railway infrastructure; port infrastructure; air transport infrastructure, including the available air seat kilometres; quality of electricity supply; and connectivity to telephone lines.

Ireland was a global economic phenomenon in the period 2000 – 2008. Ireland's GDP per capita ranked it among the top 10 global economies in 2007-2009 as illustrated in Figure 3-1 below (Schwab, 2007, Schwab, 2008, Schwab, 2009).

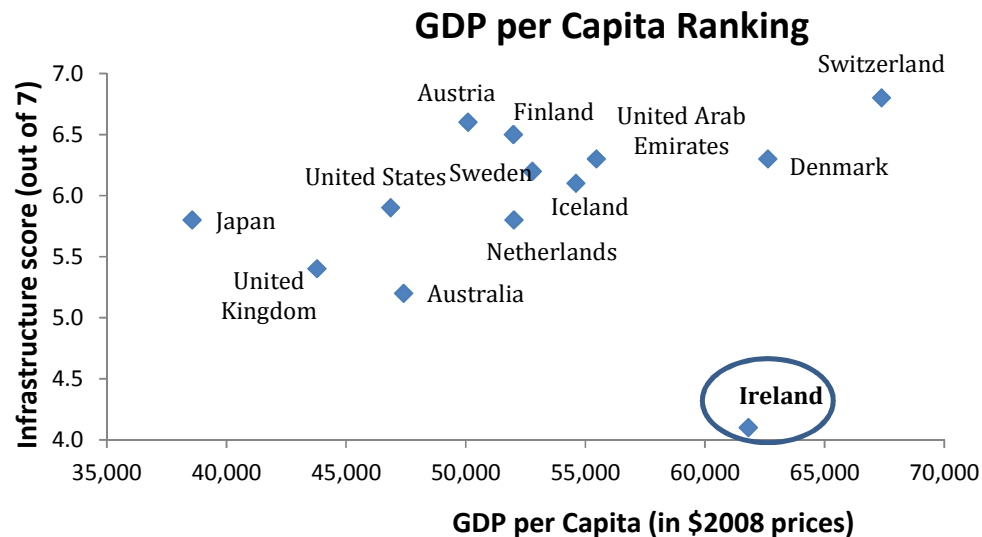


Figure 3-1: World Economic Forum Global Competitiveness Report 2009 – Ireland's GDP / capita ranking alongside selected global economies and their overall Infrastructure Score (Schwab, 2009)

However, in the WEF Competitiveness Report 2009, Ireland has slipped from an overall country ranking of 22nd in 2008 (Schwab, 2008), to 25th. This drop in overall country ranking was contributed to by the poor score for Ireland's infrastructure. The report ranked Ireland's infrastructure 65th out of the 133 countries assessed. The 2009 result is no exception; in each of the previous two reports, Ireland is positioned midway in the 133 countries for its quality of infrastructure. In GDP per capita terms, Ireland is ranked 6th, close to countries such as Switzerland and Denmark as illustrated in Figure 3-1 above.

However, Ireland's rating for the overall quality of its infrastructure places it alongside Sri Lanka, China etc; see Figure 3-2 below.

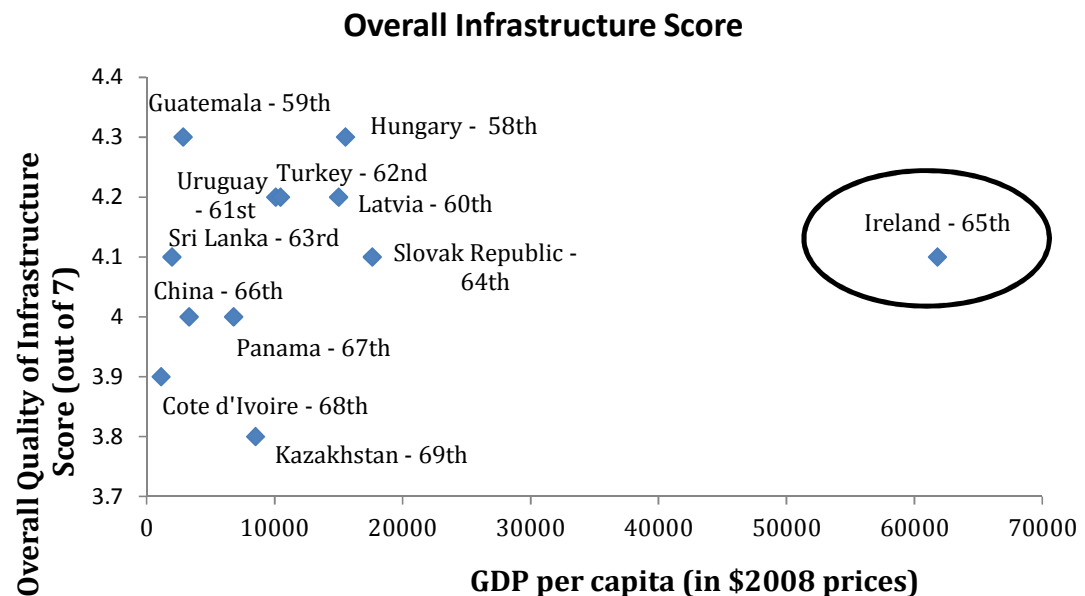


Figure 3-2 : World Economic Forum Global Competitiveness Report 2009 – Ireland's Infrastructural ranking alongside the nearest ranking countries in overall quality of infrastructure scores and their relative GDP per capita (US\$ 2008)⁵

Therefore, from the perspective of overall quality and effectiveness of infrastructure, the WEF findings would suggest that Ireland would be more correctly considered as an efficiency driven economy; or at best an economy in transition between being efficiency driven and innovation driven. This conclusion is in stark contrast to Ireland's GDP per capita ranking.

The World Economic Forum 2009 report (Schwab, 2009) suggests that if an economy is very competitive, it will deliver a higher standard of living to its population. Also, the more productive the country the higher the level of return obtained by investments in that country's economy. Therefore Ireland should be striving to improve its standard of infrastructure, to increase its Global Competitiveness Index, boost its productivity and ultimately lead to a more sustainable growth rate in the economy.

In 2004, Kamps (Kamps, 2004), examined Ireland and 21 other OECD countries to ascertain the Nett Capital Stock. The paper looked at three years - 1980, 1990 and 2000 and ranked the 22 countries according to the level of investment in percentage GDP per capita at 1995 prices. Ireland had ranked 5th of the 22 in both 1980 and 1990. However, in 2000 Ireland ranked 22nd – last of the 22 countries examined. The report showed that Ireland's ratio of Government Capital Stock to GDP was 75.9 in 1980, 66.8 in 1990 and 35.2 in 2000. The 2006 OECD economic survey of Ireland, also identified the country as having one of the lowest stocks of public capital per head in the OECD (OECD, 2006b). Both the OECD and Kamps suggest that Ireland's public capital stock per person in 2000 was 10% below its 1987 levels (Kamps, 2004, OECD, 2006a).

As the above discussion has demonstrated, the WEF competitiveness indices demonstrate continued under-investment into the period of 2001 to 2009. The question is by how much has the under-investment been; and how much is required to address the deficit?

3.6. IRELAND'S HISTORICAL INFRASTRUCTURAL INVESTMENT

In assessing the required future investment in infrastructure, the recent historical context is very informative. Kamps has demonstrated that the relative ratio of investment in infrastructure in Ireland nearly halved between 1990 and 2000 (Kamps, 2004, Kamps, 2006).

The 2006 OECD (OECD, 2006b) country survey reported that the Irish Government was set to invest up to 5% of the national income in infrastructure. The OECD report projected that this level of 4-5% would have to be maintained from 2010 onwards, to bring Ireland's infrastructure up to standard with its OECD and Global partners.

However, the actual figures both before and since then have been considerably different. As Ireland's GDP rose during the period 2002 to its peak in 2007 as outlined in Figure 3-3, the country's relative investment in productive infrastructure decreased. Prior to 2006 the investment level was

in the range of 3.25% to 3.5%; between 2006 and 2008 the level was in the region of 3.0% – 3.25%.

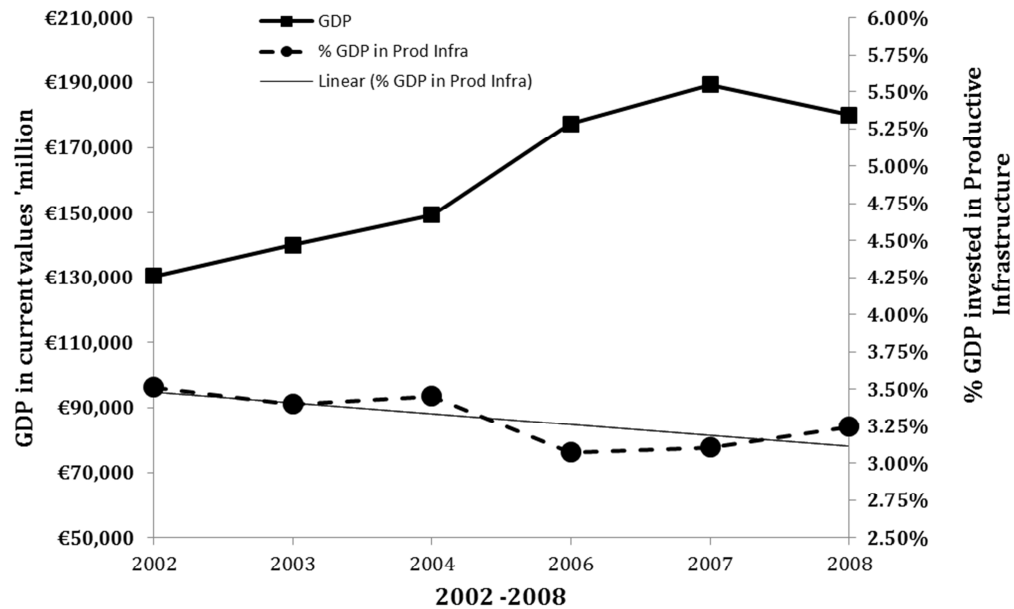


Figure 3-3: Ireland's GDP versus its % GDP investment in Productive Infrastructure from 2002 to 2008; Source: (Department of Finance, 2010a, Irish Government, 2008)CSO, 2010

The projected 5% investment level has never been reached. Clearly, the level of infrastructure investment has been inadequate over a long period, a conclusion borne out by the successive WEF Reports and discussed above.

3.7. IRELAND'S PRESENT INFRASTRUCTURE INVESTMENT LEVELS

Detailed Irish Government investment figures up to and including 2008 have been used in the preparation of this chapter. Due to economic crisis, the Irish Government did not publish a capital investment programme until 2010. For this chapter, capital investment figures were obtained from the Irish Department of Finance for 2009 outturn and 2010 estimated investment programme (Department of Finance, 2010a). However, these do not include 2009-2010 figures for non-exchequer, semi-state investment. Therefore the

analysis included in this chapter is up to and including 2008. These figures have been charted in Figure 3-3 above, which clearly demonstrate that Ireland's investment in infrastructure has not kept pace with its economic growth.

These 2009-2010 Department of Finance figures do not use the category of 'Productive Infrastructure' but rather a grouping titled 'Economic/Productive Infrastructure'. Sectors that were previously included under social infrastructure have been moved to this sector, e.g. the schools investment programme. This does not display a true image of how much is being invested at present in productive infrastructure, as defined internationally, as discussed in sections 2.1 and 3.3 previously.

3.8. IRELAND'S REQUIRED INFRASTRUCTURE INVESTMENT

A literature review of a number of articles (Briceno-Garmendia *et al.*, 2004, Ter-Minassian *et al.*, 2008) suggests a clear link between the general income level of a country, its state of development and its ongoing investment needs. The latter would suggest that a low middle-income developing economy with a developing infrastructure should generally invest 5.5-7% of GDP in its productive infrastructure. A higher middle-income developing country would require circa 3% of GDP as on-going infrastructure investment.

However, while the GDP of Ireland rose, the level of infrastructure investment remained static in percentage of GDP terms, at a level close to 3%. The 5% target referred to in the 2006 OECD Report was not achieved, despite the significant and growing productive infrastructural deficit. Therefore, even though Ireland has a high income per capita level, due to its present deficit of vital productive infrastructure, there remains a strong case for maintaining an elevated level of infrastructure investment in Ireland, similar to that of a low-middle income developing economy.

If 2006 is taken as a baseline for investment targets, then to address the widening infrastructure gap in the interim, and assuming modest growth of

2% over the period to 2020, it is estimated that investment would be required at a rate closer to 6.25% to redress the balance.

Thus it is the conclusion of this chapter that Ireland should now invest 5.5%-7% of GDP in physical networks, on a consistent basis, to improve its competitiveness and complete the transition to a true innovation-driven economy.

3.9. IRELAND'S INFRASTRUCTURAL DEFICIT – CONCLUSIONS

The World Economic Forum (WEF) identified that extensive and efficient infrastructure is an essential and vital driver to a country's competitiveness - the quality and effectiveness of infrastructure networks significantly impacts on a country's economic growth (Schwab, 2009). This chapter has identified a number of issues with Ireland's level of investment in productive infrastructure over the past decade.

It is estimated that Ireland under invested, by up to 30%, in productive infrastructure over the past 10-15 years. There should have been in the region of 1.5% to 2.5% additional GDP invested during the boom years of 2002 to 2007.

Ireland's ranking in the category of productive infrastructure sets it with developing or emerging economies. An appropriate level of infrastructure investment is now between 5.5% and 7.0% of GDP, considering the significant time lost over the period 2002-2007.

Further work will be carried out to identify what specific productive infrastructure projects need to be undertaken and prioritised. A methodology will be prepared to identify how these projects should be prioritised, so as to remove the 'bottle-neck' identified as far back as 2006 (OECD, 2006b) in Ireland's infrastructure.

4.0 ANALYSIS OF INVESTMENT DECISIONS IN IRISH STATE INFRASTRUCTURE²

4.1. ABSTRACT

Ireland was the envy of Europe and indeed the world with its apparent economic success, during what was termed the 'Celtic tiger' years. Nevertheless, it is now evident that despite the considerable monies invested in physical infrastructure, Ireland still ranks poorly in its state of infrastructure internationally. This chapter identifies that government investment in physical infrastructure was clearly stimulated and influenced by the housing boom that Ireland experienced in the period 2000–2008. The physical infrastructural networks analysed in this chapter are the water, wastewater and roads networks, as these are entirely funded by government/public monies. This chapter uses correlation analysis to investigate the relationship between investment (2003–2009) and a range of determinants, and draws a number of conclusions: water and wastewater and to a lesser extent roads capital investment was driven by the house construction industry, which in turn lacked monitoring of housing numbers and their spatial distribution; and government tax incentives further fuelled the housing industry and thus infrastructure investment. The evidence in this chapter clearly identifies the need for a comprehensive and holistic planning framework at national and regional level to ensure that future investment in Ireland's infrastructural networks contributes to Ireland's recovery and growth.

² Published in ICE Proceedings: Urban Design and Planning (2013)
<http://dx.doi.org/10.1680/udap.13.00009>

4.2. INTRODUCTION

It is internationally recognised that investment in physical infrastructure is vital to improve and maintain a country's growth and competitiveness (Arslanalp *et al.*, 2011, Aschauer, 1989, Briceno-Garmendia *et al.*, 2004, Harchaoui *et al.*, 2004, Ter-Minassian *et al.*, 2008). A recent International Monetary Fund (IMF) paper (Allard and Everaert, 2010) identified Ireland's infrastructure as a structural reform gap that needed to be addressed, despite considerable investment in the past decade. This chapter will review Ireland's state (excluding semi state) investment in its productive infrastructure (ESRI, 2006) (physical networks of water, wastewater and roads) between 2003 and 2009. This period has been selected for a number of reasons. For example, Ireland experienced the steepest growth phase and the start of the 'bust' phase of the economy during this time range and electronic local government financial records are not available before 2003. The review will present the spatial distribution of the investment in these networks across the 26 counties and undertake an analysis of the possible drivers to productive infrastructural investment throughout the country. In light of Ireland's construction industry representing upwards of 20% (DKM, 2009) of the annual gross domestic product over the study period, an in-depth review of the industry and in particular the housing construction sector is undertaken. A central thesis of this chapter is that, in effect, the housing boom that Ireland experienced in the period 2003–2009 created a distortion in the spatial distribution of investment in productive infrastructure, to a significant degree. The paper discusses the importance of infrastructure to an economy, reviews the relationship between the construction industry and productive infrastructure and identifies possible drivers and undertakes an in-depth correlation analysis of the investment with these drivers.

4.3. INFRASTRUCTURE NETWORKS AND THEIR IMPORTANCE

There is little doubt that infrastructure, and in particular productive or physical infrastructure, is vital to the growth and competitiveness of an economy (Arslanalp *et al.*, 2011, Aschauer, 1989, Briceno-Garmendia *et al.*, 2004, Harchaoui *et al.*, 2004, Shen *et al.*, 2011, Ter-Minassian *et al.*, 2008). Del Bo and Florio, in their review of the relationship between infrastructure and economic growth in the EU area, concluded that the quality and accessibility of a region's transportation network had a positive influence (Del Bo and Florio, 2012). Znidaric *et al.* described road infrastructure 'as strategic and vital' to the sustainable trade and thus economic growth of member states within the EU (Znidaric *et al.*, 2011). Kamps also reported the positive impact of infrastructure public capital on economic growth (Kamps, 2005). Indeed, the IMF, in a review of Ireland in 2000, attributed Ireland's economic success at that time to the significant structural funds that had been received from the EU since 1989 (International Monetary Fund, 2000). It noted in particular that the upgrading of 'physical infrastructure' had helped to support economic demand and boost potential growth. The report also suggested that the improved infrastructure made Ireland more attractive to foreign investment. However, Ireland has rapidly decreased its infrastructural investment due to the present economic climate. It can thus be concluded that if Ireland does not return to reasonable infrastructural investment, it will be in a position of constrained infrastructure once the current economic crisis eases.

4.4. DRIVERS FOR INVESTMENT IN PRODUCTIVE INFRASTRUCTURE

Investment in productive infrastructure occurs due to an existing shortfall in infrastructure or due to the expansion of a region, necessitating the development/expansion of productive networks. This can be said of Ireland, which witnessed considerable growth and investment during the period 2000–2006, and then a rapid decline. The government's capital investment peaked in 2008 with an investment of €13.6 billion, while the projected/allocated budget

for capital investment in 2012 is €4 billion: a very considerable 70% reduction (Department of Public Expenditure and Reform, 2011, Irish Government, 2010). During this period, construction output peaked at €38 billion in 2007, in excess of 20% of the national gross domestic product (CSO, 2006, Department of Finance, 2010a), with direct employment in the industry peaking at 13.5% of the national workforce.

4.4.1. *Legislation and policy stimulants*

Capital infrastructural projects are identified and prioritised within central government departments and through individual local authorities. In general, and in Ireland specifically, capital investment in productive infrastructure projects can arise as a result of an identified engineering need; political decisions and evaluation based on voting outcomes – for example, seats in the next local and general elections; external influences of European directives and regulations; and national government policy.

4.4.2. *National government policy and housing*

A number of aspiring national plans were prepared – for example, the first national development plan (NDP) 2000–2006, which was issued in 1999; the national spatial strategy (NSS), which was launched in 2002; and the NDP for 2007–2011, (Department of the Environment Community & Local Government, 2006, Government, 2002) . During the study period, Ireland prepared a number of ambitious capital investment programmes, which were broadly aligned with the NDP and NSS. These plans were the template for infrastructure investment for the following decade. The NSS identified a potential housing shortage by 2010 based on the housing stock of 2002, and it is now apparent that this identified housing need led to excessive housing construction, and consequently influenced the infrastructural investment plan.

4.4.3. National government policy and housing

To understand the impact of the Irish government development policy and housing, it is important to distinguish between housing units or housing stock and households. The number of households in the state is calculated based on the number of housing units that are occupied, or whose occupants are reckoned to be only temporarily absent on census night, whereas the housing stock figure is the total number of units available for habitation in the state on census night. The vacancy figure is calculated based on units fit for habitation, which includes holiday homes. Over the period 1996–2011, there was a considerable increase in the national housing stock (up 62%), with an overall increase of 6% in the housing vacancy rate over the period.

The NSS, in 2002, estimated that it would be necessary to provide some 500 000 additional dwellings to meet likely demand for houses up to the period 2010 (Irish Government, 2002). At the time the UK had 435 units per thousand population and the EU average was 450 per thousand. The Department of the Environment, Community and Local Government (DoECLG) had responsibility for the implementation of the NSS, and set a target of 400 housing units per 1000 population by 2010. The evidence from Figure 4-1 below indicates that Ireland had 437 units per thousand by 2011. However, for zero vacancy in 2011, Ireland required only 373 units per thousand. Therefore, it is concluded that Ireland had sufficient units constructed by 2002 to satisfy the population of 2011, as is clear in Figure 4-1 below.

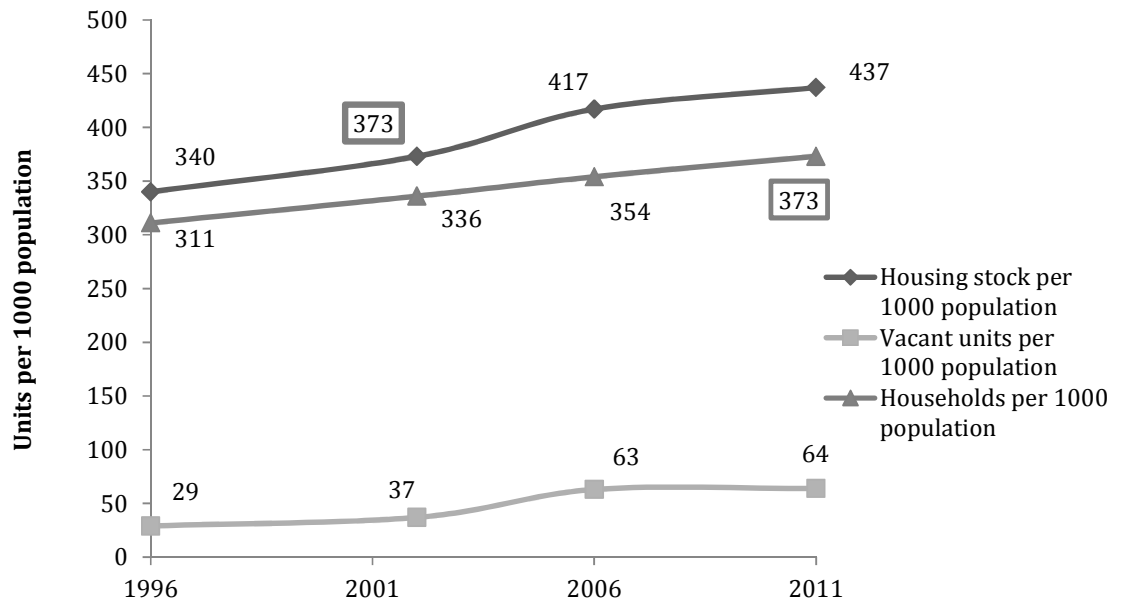


Figure 4-1: Census statistics on national housing stock, households and housing vacancy rates. Source: Central Statistics Office census data (CSO, 1996, CSO, 2002, CSO, 2006, CSO, 2011) and authors' own calculations

4.4.4. *The border, mid-land and western region*

The NSS put a particular emphasis on the development of the border, mid-land and western counties (13 in total). This chapter focuses on nine in particular, hereafter referred to as selected BMW counties. These are Cavan, Donegal, Longford, Monaghan, Mayo, Sligo, Roscommon, Leitrim and Galway County. The evidence of this policy is examined in sections 4.5 and 4.6 of this chapter, but the census data clearly identify that there is a large percentage of vacancy rates in the BMW counties, which is not represented by holiday homes (CSO, 2006). For example, Sligo has a 23.1% vacancy rate, of which 77% are vacant housing units. In the two censuses of 2006 and 2011, Ireland has a national vacancy rate of 15%, and spatially there are counties with 30% vacancy.

There are a number of counties with a greater than 20% unit vacancy rate such as Clare, Kerry, Leitrim, Sligo, Galway, Roscommon and Cavan, of which 36% or less are holiday homes. Therefore, there is a very large number of vacant/ghost/empty units in these counties since 2006. We now know that this situation has

deteriorated even further. Wexford has a very high percentage of holiday homes, 52% of the vacancy rate. This is likely to be due to its proximity to Dublin.

Donegal also has a particularly high number of holiday homes. It is now clear that the basis of the estimate, included in the 2002 NSS, for 500 000 additional housing units, was flawed and has contributed to the housing boom with a record number of housing completions over the period 2003–2009. This ‘perceived’ need drove the market to build, while there was no apparent measurement and check to assess when and where construction should have been halted. It is now evident that 531 215 housing units were constructed from 2002 to 2009 inclusive. This situation of over-supply, and the lack of monitoring, highlights the significance that government policy documents can have on a market, and the importance of continuous monitoring and measurement. Consequently, physical networks were constructed/upgraded to ‘service’ these housing units, primarily funded by central government grants and planning contribution funds. Based on 2011 census figures, it could be concluded that only 50% of these units were necessary (considering the 293 202 vacancy units less the 59 395 holiday homes, resulting in a net vacancy of 233 807), and how much of the supporting infrastructure is redundant?

4.4.5. Government influence through the use of tax incentives (‘Section 23’ tax reliefs)

The Irish government, in 1981, introduced and maintained a number of property and construction-related tax incentive schemes (Department of Finance, 2011), commonly referred to as ‘Section 23’ schemes. The nominal rationale for such schemes was generally to stimulate regeneration of a region, city quarter or town. They were also used to incentivise for specific uses – for example, the ‘living over the shop’ scheme, student accommodation and holiday home developments. These gave capital tax allowances to the developer, against the capital investment costs of the schemes. While the original concept of ‘Section 23’ was to deliver specific types of development in highlighted

geographical locations, the overall quantity and spatial distribution appears to have lacked clear management – for example, there was no central database recording the number of and location of Section 23s. The author received data from the DoECLG (Department of the Environment Community & Local Government, 2010) which allows the pattern of Section 23 properties to be mapped across the country, with 87% of the properties located in just ten of the 26 counties: Dublin 16.03%; Longford 13.63%; Leitrim 13.44%; Roscommon 11.12%; Sligo 10.51%; Limerick 6.17%; Cork 4.39%; Waterford 4.31%; Cavan 3.94% and Galway 3.60% (all but Dublin, Cork and Waterford are BMW counties) (Moloney and McKeogh, 2012, Moloney and McKeogh, 2013).

Furthermore, a Department of Finance paper suggests that 74 003 housing units were constructed under this scheme; this figure represents an average boom year's construction of housing, or 17.5 units per thousand population equivalent to approximately 15% of the housing construction of the period (Department of Finance, 2011). This impact is very significant, and there is little doubt that these 'Section 23' units contributed to the oversupply of housing and thus fuelled the demand for productive infrastructure. What is now clear is that a large proportion of these units, and thus the infrastructure supporting them, is redundant.

4.4.6. Review of impact of drivers on the county of Leitrim

The county of Leitrim is a very interesting study. Leitrim spent the highest amount on water and wastewater investment per capita in the period 2003–2009. One would thus expect a remarkable increase in the number of houses connected to a local authority water and wastewater network. The investment in Leitrim resulted in an increase of 12.6% increase in the number of housing units connected to a local authority water scheme and a 9.4% increase in the number connected to wastewater treatment facilities, as indicated in Table 4-1 below.

CSO Census	Population	% increase in population since last census	House Holds	Housing Stock	Number of vacant units	Type of water supply: Public mains	LA public mains and group scheme	% of house holds on public water scheme*	Type of sewerage facility: Public scheme	% of house holds on public Waste Water scheme
2002	25,799	3.0%	9,279	11,858	21.75%	3,953	6,199	66.8%	2,646	28.5%
2006	28,950	12.2%	10,541	15,282	29.30%	5,243	8,144	77.3%	3,708	35.2%
2011 preliminary results	31,778	9.8%	12,693	18,237	30.40%	6,405	10,082	79.4%	4,815	37.9%

Table 4-1: Case review of households in Leitrim connected to local authority water and wastewater schemes 2002–2011 (source: CSO and authors' own calculations)

Indeed, further analysis of the figures would suggest that some of the new housing units constructed over the period 2003–2009 have no connection to local authority water and wastewater services, despite the level of investment in Leitrim being so considerable. During the period 2000–2009 it had the highest housing completion number per thousand capita in all of the non-urban districts.

There was an significant increase in the housing stock in the 2000–2009 period, as indicated in Table 4-1. This enormous increase does not correlate with the census population figures. The population of Leitrim increased by 23% from 2002 to 2011, with a 41% increase in housing stock over the same period. However, 30.4% of all housing units in Leitrim are vacant. This figure of vacant houses is in line with the 2006 census figure of 29.3% vacant units. One would have to question the rationale for building additional housing units from 2006, with such a large number vacant. The 2006 housing stock of 15 282 units would still be sufficient to house the 2011 figure of 12,693 households, with 17% vacant for future population growth. This again clearly illustrates that there was no ‘monitoring’ of the construction of housing units, relative to population growth and distribution.

4.4.7. Funding mechanisms for capital investment in infrastructure and Ireland’s local government structure

The Irish local government structure consists of 80 different borough and town councils, grouped into 34 local authorities. Each local authority has budgetary responsibility for the operation of their geographical areas of authority and prepares an annual financial statement. An extensive review of these reports was undertaken, during the data collation for this chapter, in particular Appendix 5, which itemises the local authority capital income account and Appendix 6, which itemises the capital investment (Local Authorities, 2003 to

2009). Budgetary funding for local authority capital investment plans is raised at a national level, from central government grants, and locally from sources such as disposal of assets, tenant purchase or rental income, and car parking fees. In addition, a considerable source of income during the study period was as a result of developers' planning permission application fees and development contributions. These arise when a local authority grants planning permission for a development; planning conditions are added to each permission, which specify the necessary infrastructural contributions for water, wastewater and roads, which must be paid before the start of construction. Figure 4-2 shows the extent of such private sector development-related income for some local authorities (as a percentage of their total capital income), in excess of 20% in some instances.

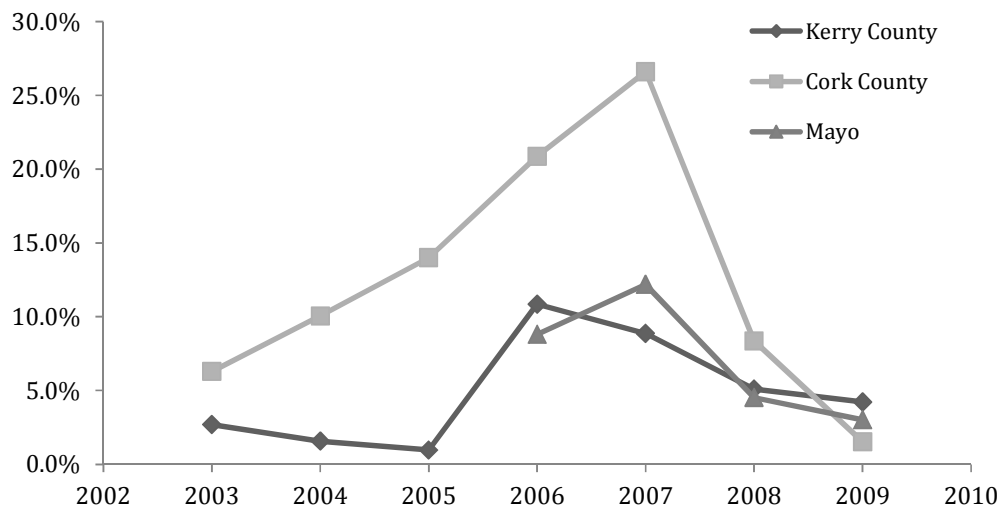


Figure 4-2: Development-related income for some local authorities, expressed as a percentage of their total capital income. Source: Appendix 5 of the annual financial statements (Local Authorities, 2003 to 2009)

It could be concluded that there is a correlation between the extent of land zoned for development, the extent of permissions granted and the development contributions received by local authorities. Therefore, the more land zoned, the

greater the number of planning permissions granted, and the greater the infrastructural contributions received by the local authority.

4.4.8. *Data collation and review of water, wastewater and roads network capital investment distribution across the 26 counties: local authority and government records*

Central and local government records are the main sources of data for the analysis in this chapter. In general, the collating of data presented a number of challenges: an overall lack of ‘standardisation’ of the format of the reports across the local authorities; water (the provision of drinking water) and wastewater investment were recorded as a single figure called ‘water services’, rendering it impossible to assess the national picture on the actual split between waste and wastewater investment; and the DoECLG capital investment grants to each local authority do not distinguish between water and wastewater investment (Department of the Environment Community and Local Government, 2010). Annually, the department grant aided in the region of €0.6 to €0.9 billion nationally. This represented an average of 52% of the overall annual investment in water and wastewater infrastructure. Conversely, road investment has always been recorded as a separate item in the local authority capital investment account, and therefore these records were reasonably accessible, with National Roads Authority (NRA) annual reports publicly available, containing the spatial distribution of its grant investment (National Roads Authority, 2003, 2004, 2005, 2006, 2007, 2008, 2009).

4.4.9. *Roads capital investment distribution*

Ireland has invested €10.9 billion in capital projects for the overall road network over the period 2003–2009. Capital investment in Ireland’s road network is funded through central government grants, by the NRA and local government funds. The NRA grants invested by county are dependent on applications by local authorities for roads funding and the national roads

development plan. Figure 4-3 shows the profile of a number of counties' road capital investments.

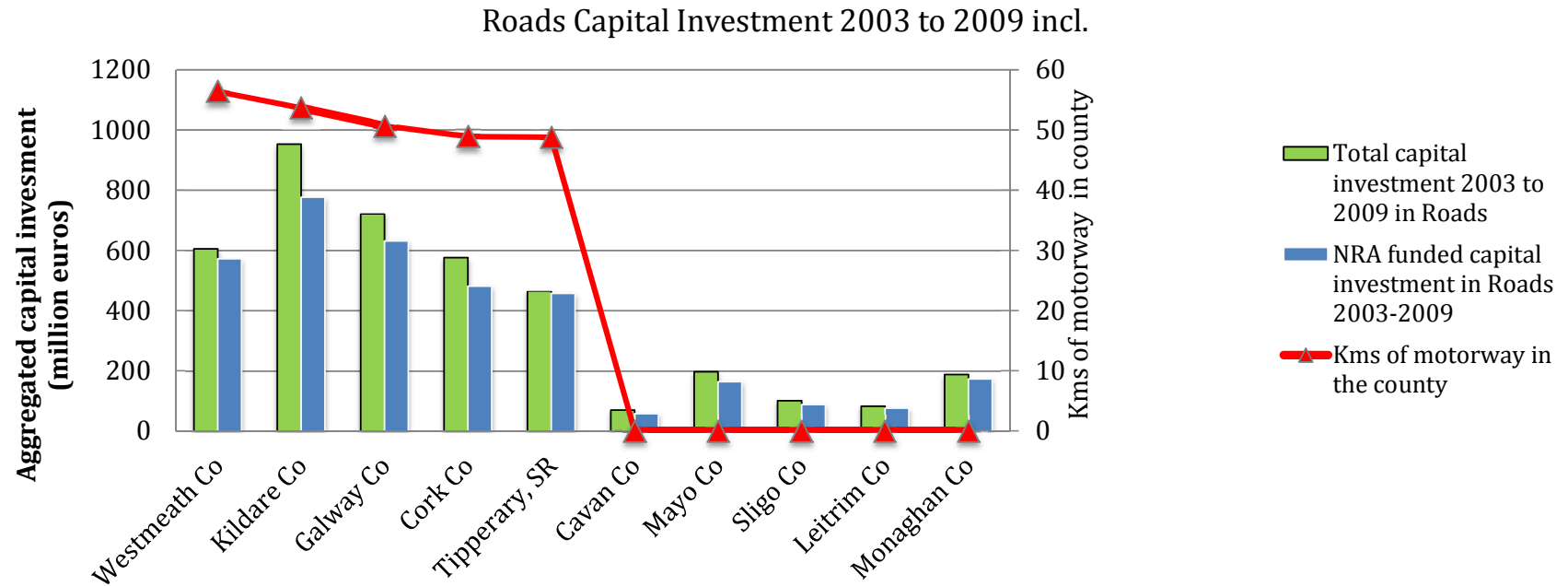


Figure 4-3: Total capital investment in roads 2003–2009 by local authority, National Roads Authority (NRA) grants and new kilometres of motorway in each local authority/county.

Source: Local Authority Annual Financial Statements (Local Authorities, 2003 to 2009), NRA annual reports (National Roads Authority, 2003, 2004, 2005, 2006, 2007, 2008, 2009) and authors' own calculations (Moloney and McKeogh, 2012)

These counties are the top five counties per kilometre of motorway constructed, and the five counties with no motorway, but the highest percentage of capital investment funded by the NRA. During the study period, 74.2% of the total funds spent nationally on road capital projects were channelled through the NRA.

The counties that have higher than average investment are counties along the motorway routes from Dublin to Cork, Limerick, Galway and Waterford, which is to be expected. A total of 662 km of motorway were constructed during the period. However, there are a number of counties that had a higher than average investment by the NRA, in particular Leitrim, Mayo, Cavan, Monaghan and Sligo, Roscommon, Donegal and Longford, all of which are BMW counties. This again demonstrates the influence that the NSS had on the infrastructural investment programme over the period.

4.4.10. Water and wastewater investment distribution across the 26 counties

A total of €4.93 billion was invested in the water and wastewater networks over the period 2003–2009. It was not possible, as part of this study, to state accurately the division between water and wastewater capital investment, due to the type of records maintained by local authorities and the DoECLG (as previously discussed).

4.5. ANALYSIS OF CAPITAL INVESTMENT

The DoECLG and local authority investment figures were collated for each local authority, and the total aggregate capital investment was calculated for water and wastewater per county and city across the country. This investment value has been evaluated against a number of variables, and the results of this analysis are included in Section 6 of this chapter. Figure 4-4 shows the

investment per capita across a selection of the 26 counties, with a mean investment per capita of €1,346 for water and wastewater investment, over the period 2003–2009. The data reveal that all the BMW counties analysed had far in excess of €1,346 per capita, except Monaghan at €1,342 and Longford at €1,121 per capita. Leitrim had €2,859 per capita invested in the water and wastewater networks, more than twice the national average (as discussed in 4.4.6).

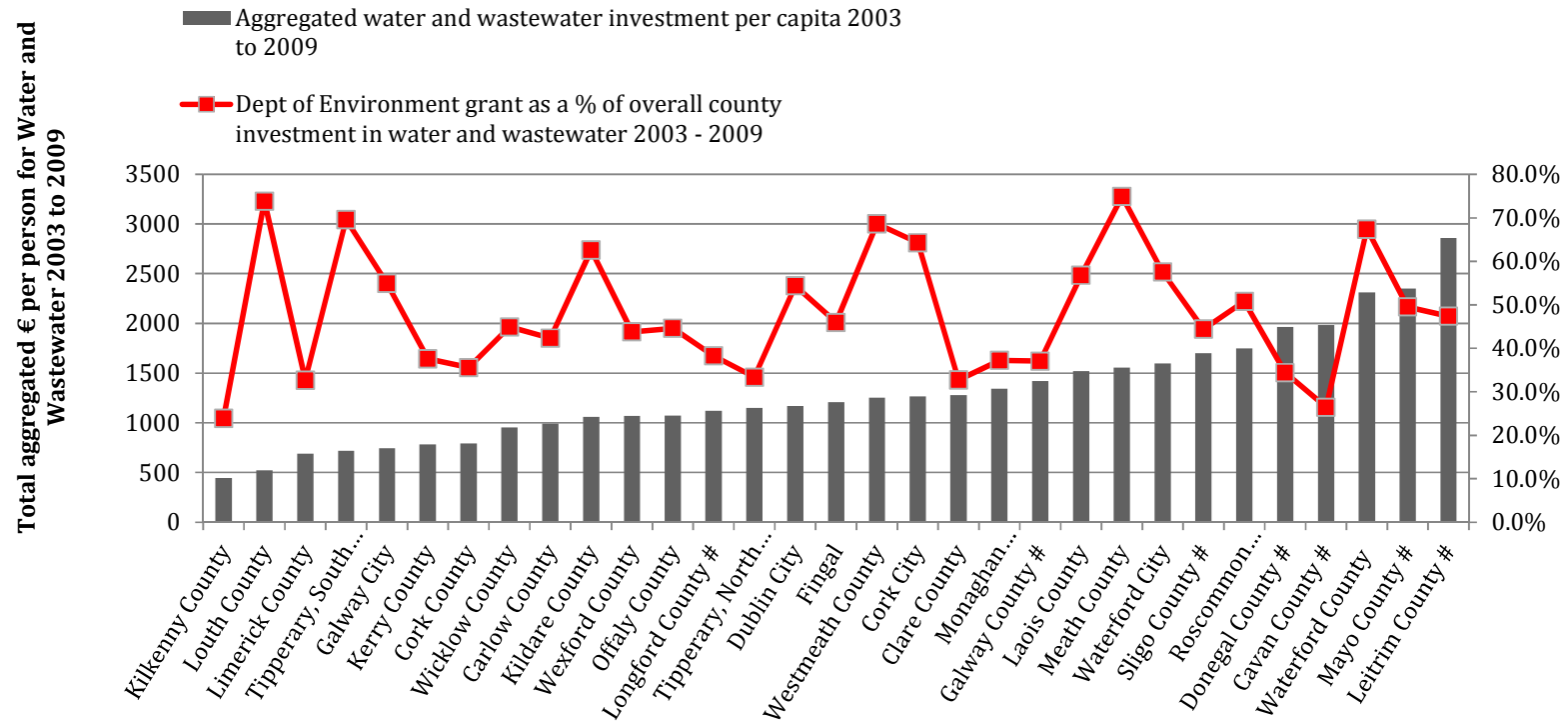


Figure 4-4: Selection of counties: aggregated capital investment for water and wastewater investment for 2003–2009. # denotes a BMW county

Source: Local Authority annual financial statements (Local Authorities, 2003 to 2009) and Department of the Environment, Community and Local Government records (Department of the Environment Community and Local Government, 2010)

Figure 4-4 also illustrates the DoECLG grant as a percentage of the total county investment. This was generally higher in more densely populated areas, as would be expected. However, it is also worth noting that the BMW counties studied in this chapter have an average or lesser DoECLG grant for the water and wastewater network investment. This would indicate that the capital investment was funded at 50% or greater by local authority funds, presumably sourced from local rates and development contributions. This again suggests that the housing boom in these low population density counties funded infrastructure investment. However, bearing in mind the up to 30% housing vacancy rate in the BMW counties, the question again arises as to whether this infrastructural investment has been constructed in the appropriate locations. How much of this infrastructure is now redundant? An evaluation of the extent of redundant infrastructure will be analysed in future research.

4.6. ANALYSIS OF CAPITAL INVESTMENT

A correlation analysis of the capital investment and its possible drivers was undertaken for the period 2003–2009. A number of datasets were collated to test what possible correlations there are with state capital investment. These correlations are a test of the linear relationship between a set of values, with a correlation coefficient of 1, demonstrating a perfect match in the two datasets, while -1 indicates a perfect negative linear relationship. The aggregated capital investment in roads and ‘water services’, that is, water and wastewater network investment, has been analysed against selected determinants

- population size of the county
- population density based on the population size in the 2006 census
- the number of unoccupied units, known as ‘ghost’ units
- the county housing stock, based on the 2006 census; these are the total number of completed housing units available to be occupied

- housing vacancy rate
- the aggregated number of housing units completed during the period 2000–2009 and the number of units per 1000 population
- the overall area of the county (in hectares).

The 2006 census was chosen as it is mid-term in the study period. A number of correlation analyses were carried out on the roads investment and separately on the water and wastewater investment. Due to the variation in population density across the 26 counties, and also the significant findings of this chapter in relation to development in the BMW counties, an analysis was undertaken for three different scenarios: all counties; counties with a population density of less than ten persons per hectare; and the nine BMW counties listed (Section 4.4.2). The results of the analysis are presented in Table 4-2 below

Results of Correlation Analysis (2006 Census)		Population	Population density*	Ghost Houses	Housing stock 2006 census	Vacancy rate 2006	% change in vacant dwellings 2006-2011	Total Housing units completed 2000-2009	Total house units per 1000 capita	Hectares of county
Water and Wastewater network Capital investment	All counties	-0.02	0.15	0.51	0.82	-0.02	-0.20	0.58	0.30	0.22
	Counties with a population density < 10	-0.22	0.11	0.55	0.73	0.09	-0.20	0.64	0.45	0.58
	BMW Counties	0.01	-0.81	0.15	0.95	0.31	-0.13	0.86	0.69	0.93
Roads Capital investment	All counties	0.20	-0.14	0.48	0.57	-0.45	-0.50	0.26	-0.01	0.17
	Counties with a population density < 10	0.15	0.01	0.36	0.47	-0.51	-0.53	0.28	-0.01	0.18
	BMW Counties	0.45	-0.48	-0.18	0.71	-0.25	-0.45	0.14	0.02	0.74
	Kms of Roads	-0.29	-0.54	0.18	0.21	0.46	0.25	-0.19	0.24	0.97

Table 4-2: Results of correlation analysis of capital investment against selected determinants (selected BMW counties of Cavan, Donegal, Longford, Monaghan, Mayo, Sligo, Roscommon, Leitrim and Galway)

4.6.1. Results of analysis: water and wastewater capital investment

Across the 26 counties, the data indicates that water and wastewater investment was driven by the housing stock, as recorded in the 2006 census. When all counties are analysed the correlation is 0.82. There is a weaker factor of 0.58 with the total housing units constructed over the period 2000–2009 and the number of ghost houses is 0.51. There does not appear to be a relationship with investment and population, population density and the area of the county, with correlation coefficients of -0.02, 0.15 and 0.22, respectively.

Counties with a population density of less than ten persons/hectare show a close correlation with ghost houses (0.55), housing stock at the 2006 census (0.73) and total housing units completed in 2000–2009 (0.64). It is worth noting that these counties have a correlation of 0.58 with the area of the county. It is clear that water and wastewater investment in the non-urbanised counties/districts followed the housing stock.

The BMW counties show a very strong correlation between the water and wastewater investment in the county and the housing statistics, with correlation coefficients of 0.95 with housing stock figures and 0.86 with housing units constructed in 2000–2009. The correlation with the area of the BMW counties is 0.94, which suggests that the investment in the BMW counties was aligned with the area of the counties, with the larger counties in the BMW region benefiting. The data suggest there is an inverse relationship between ‘water services’ investment and population density, with a correlation of -0.81 for the BMW region. Therefore, the less dense the population, the higher the per capita investment in water and wastewater.

4.6.2. Results of analysis: roads capital investment

The analysis of the roads capital investment with the selected determinants indicates a number of patterns. The length of roads capital investment is in line with the area of the county, as would be expected (0.97). The kilometres of road

decrease with an increase in the population density (-0.54), as would be the case with urban centres.

Across all 26 counties, the roads investment is reasonably aligned with the housing stock, with a factor of 0.57 and a factor of 0.48 with the number of ghost houses. The low density districts have a poor correlation with population, population density and housing figures.

The BMW counties roads investment has a close correlation with the housing stock, with a factor of 0.71. This factor increases to 0.79 when the roads investment is analysed against the 2011 housing stock. There is a correlation factor of 0.74 with the area of the counties, as would be expected, considering the relationship between kilometres of road and area. The larger the area of the county, the more kilometres of road, and therefore the need for capital roads investment. The individual grants by the NRA to the local authorities were also analysed. There is a reasonable inverse correlation of -0.54 between the grant aid of the NRA to the BMW counties and the population density of the BMW counties. This indicates that the lower the population density, the higher the grant aid to the county.

The NRA provides varying grant assistance to local authorities. These grants have generally been in line with the location of the motorway investment. However, there is evidence that considerable grants have followed the house building trend, with a correlation coefficient of 0.44. This trend would suggest that Ireland, with an average house vacancy rate in excess of 15% (with some counties as high as 25–30% vacancy rate) may have invested in regional areas, where there is unlikely to be an economic return commensurate with the scale of investment.

4.7. CONCLUSIONS AND RECOMMENDATIONS

The extensive and varied datasets analysed in this chapter indicate that the capital investment in Ireland's water and wastewater networks was driven by the housing boom and therefore by land zoning, with roads investment to a lesser extent. With the extraordinary vacancy rates in some counties, the focus of this investment pattern was clearly unsustainable, and one has to wonder at the levels of redundant or oversized infrastructure, and thus the waste of money.

Government policy decisions and their subsequent impact on the national housing market went unmonitored and unmanaged over the study period. It is very clear that the extended 'Section 23' tax incentive schemes should have been halted or at least curtailed, with 'Section 23s' comprising an equivalent year's supply of housing over the boom period. During this study, there was no evidence of systematic on-going record keeping and evaluation of growth indicators carried out during the study period of 2003–2009. If available datasets had been monitored and missing data identified and collated, it is suggested that excessive house planning and construction would have been identified and could have been halted. This is evidenced when the BMW counties have 30% of the national vacant units with just 17% of the population. Furthermore, the house unit types have not matched the required needs, with a large number of apartments and three-bed semi-detached units now vacant. There were ample data available from the CSO and reports to indicate that there was an excess of housing in the 2006 census.

Development contributions had a large inflationary impact on local authority capital budgets over the study period (as high as 20% in some counties), which aided the development of productive infrastructure. This source of finance is not available at present to the local authorities, due to the substantial reduction in development contributions being received, and the overall national investment in physical infrastructure has reduced by upwards of 70%, since the peak of the 'Celtic tiger' years. The rating of Ireland's infrastructure, as measured by the World Economic Forum and the IMF, continues to perform

poorly relative to Ireland's economic peers. So this vast decline in investment will doubtless further reduce Ireland's international ranking, thus further slowing their economic recovery.

The level of infrastructural investment in Leitrim was extraordinary – the highest investment per capita for water services at twice the national average, with reasonably low improvement on the number of units connected to public water and wastewater services, and the highest national vacancy rate. These data beg the question of whether these investment decisions would withstand rigorous cost-benefit analysis?

This chapter clearly demonstrates the need for there to be a more holistic approach to the overall development of a county/ region. Future decisions to invest in housing, and infrastructure to support housing and other developments, need to be formulated based on in-depth analysis of regional population growth, census figures and so on. A sustainable socioeconomic analysis should be included in the first instance with development plan preparation and subsequently within all planning applications. Ireland does not currently have a standardised evaluation methodology for evaluating the sustainability of developments. Ireland, in the future, needs to ensure that investment in physical infrastructure is aligned with population growth and industry requirements, and will thus contribute to the economic growth of the country.

5.0 THE DISTRIBUTION OF CAPITAL INVESTMENT IN IRELAND'S ROAD NETWORK 2003-2009³

5.1. ABSTRACT

There has been considerable capital investment in Ireland over the past decade, by both Government and the private sector. There are conflicting opinions as to whether Ireland has invested sufficiently in its productive networks over the past decade. Ireland may have nationally invested considerably, but how has this been distributed across the country?

This chapter focuses on and reviews the overall investment that has occurred in the road network, and its distribution across the country. The level of investment is correlated with possible economic and political drivers, to examine if the investment has occurred in locations that will support the future economic development and growth of the country. The paper tests the correlation of the investment relative inter alia to population density, growth projections, and distribution of overall national construction activity. A study period of 2003 to 2009 was selected as this shows the steepest growth and drop in the nation's economic history.

Understandably, capital investment in Ireland over the past 3 years has been severely curtailed by the present national and international economic crisis. Ireland still performs poorly in the international measure of quality of infrastructure and quality of roads, as measured by the World Economic Forum and the International Monetary Fund. The country needs to ensure that where there is future investment in productive infrastructure, it must be targeted where it is most needed, and deliver the greatest return for the investment.

³ Presented and published in BCRI Conference Proceedings (2012)

5.2. IRELAND'S ECONOMIC ACTIVITY 2003 TO 2009

Ireland witnessed unprecedented growth and investment during the period 2000 to 2007. During this period Ireland's construction industry contributed in excess of 20% to the national gross domestic product (GDP). Direct employment in construction peaked at 13.5% and Ireland's economy was experiencing an extraordinary growth, in the construction sector in particular. This was one of the main factors in driving up property prices and other consumer goods. Table 5-1 below shows some of the key national economic statistics of the period 2003 to 2009.

	No of Employees in Construction (000)	Construction output as % of GDP	Gov Capital investment as % of GDP	Productive infrastructure investment as % of GDP
2003	191.4	17.01%	6.06%	3.08%
2004	206	18.39%	5.64%	2.94%
2005	242.2	19.46%	5.27%	2.64%
2006	268	21.78%	5.29%	2.57%
2007	264	20.38%	6.23%	3.20%
2008	216	18.11%	7.56%	3.67%
2009	137	11.31%	4.51%	2.84%

Table 5-1: Key national economic statistics of the period 2003 to 2009.

Source: CSO data (CSO, 2006) and author's own calculations

This activity peaked in 2007 and Ireland has experienced an extraordinary decline in GDP, GNP, construction activity and capital investment, since. Government capital investment peaked in 2008 with an investment of €13.6

billion, while the projected/allocated budget for capital investment in 2012 is €4 billion, a 70% reduction.

This severe cut in capital investment, despite reduced tendering costs, will certainly hamper and slow Ireland's growth in this particularly difficult phase. Certainly, Ireland invested considerably over the 'celtic tiger' period in productive infrastructure, as evidenced in Table 5-1 above. This chapter demonstrates how Ireland still performs poorly by international comparison, and how the driver for some of the investment during this period, has not improved Ireland's growth and competitiveness.

Much has been written on the overall national investment in Ireland's infrastructure; however, little analysis has been carried out on the distribution of this investment across the country and the resulting cost benefit and strategic importance. This chapter reviews how the investment has been distributed across the 26 counties of Ireland, and evaluates this against a number of possible drivers. The particular focus of this chapter is the national roads investment.

5.3. PRODUCTIVE INFRASTRUCTURE AND IT'S IMPORTANCE

National infrastructure investment in Ireland is generally classified by the Government into social, economic, and productive infrastructure (Department of Finance, 2010b). Sectoral economic infrastructure investment includes the agriculture, food, fisheries, tourism, forestry and industrial sectors. Social infrastructure includes such categories as: social housing; education and science; health; and government construction. In recent publications the Irish government has re-categorised education and science investment as productive/economic infrastructural investment. However, this chapter will continue to use the term 'productive infrastructure' as meaning physical networks (Moloney *et al.*, 2010), i.e. water and wastewater networks; electricity

infrastructure; connectivity and communications networks and roads which are the main focus of this chapter.

Infrastructure, and in particular productive infrastructure, has been internationally recognised as being vital to the growth and competitiveness of an economy. Gramlich (Gramlich, 1994) clearly identified the link between productivity, economic health and infrastructure investment.

5.4. IRELAND ON THE INTERNATIONAL STAGE- ITS PERFORMANCE

It is evident that Ireland has invested in productive infrastructure over the study period, with 3% to 4% of GDP, as outlined in Table 5-4 above. The question remains whether this was sufficient to improve the country's growth and competitiveness. The World Economic Forum (WEF) publishes an annual global competitiveness report which reviews more than 130 global economies. The WEF measures an economy's performance using 12 pillars of competitiveness (Schwab, 2007, Schwab, 2008, Schwab, 2009, Schwab, 2010, Schwab, 2011). Each country is categorised into one of 3 main headings; *basic requirements* which are key to factor driven (FD) economies; *efficiency enhancers* which are required for efficiency-driven (ED) economies and *innovation and sophistication factors* which are necessary for innovation-driven (ID) economies. Some economies are identified as being in transition between FD, ED and ID. The *basic requirement* pillars are institutions; infrastructure; macroeconomic environment; and health and primary education. The *efficiency enhancer* factors are higher education and training; goods market efficiency; labour market efficiency; financial market development; technological readiness; and market size. The *innovation and sophistication* (ID) factors are business sophistication; and readiness. Ireland's performance in the WEF reports over the past number of reports is outlined in Table 5-2 below, for overall competitiveness, infrastructure generally, and roads in particular.

Ireland's overall infrastructure score and ranking has improved from 49th position in the 2007-08 report to 29th in the 2011-12 report. However, overall

quality of infrastructure has seen only a small improvement from 64th to 53rd in the same period, and with the “quality of roads” ranking improving from 60th to 40th over the same period.

	Year of report	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15
Overall competitiveness	Ranking	22	22	25	29	29	27	28	25
Infrastructure Pillar	Ranking	49	53	52	38	29	25	26	27
Overall quality of infrastructure	Ranking	64	64	65	69	53	37	35	36
Quality of Roads	Ranking	60	70	59	52	40	28	29	25

Table 5-2: Ireland's WEF performance

Source: World Economic Forum Global Competitiveness Reports (Schwab, 2007, Schwab, 2008, Schwab, 2009, Schwab, 2010, Schwab, 2011, Schwab, 2013, Schwab, 2014, Schwab, 2015)

The 2011 WEF report was used to prepare Figure 5-1 below. This identifies Ireland as being in the innovation driven stage of its development (the phase of each country's growth is indicated). When Ireland's performance and ranking is compared to some of the European Union (EU) and accession countries, it does not perform well.

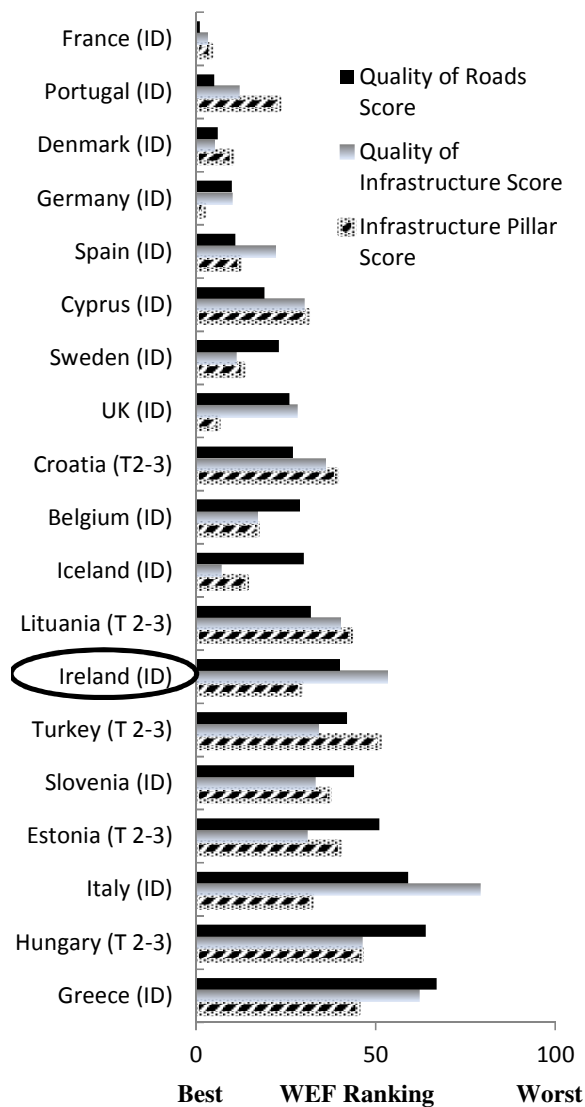


Figure 5-1: Plot of WEF 2011-12 best road quality and infrastructure quality for a selection of EU counties, also showing stage of development as per WEF

(Source: WEF Global competitiveness report 2011-12 (Schwab, 2011))

Yet, when Ireland's position is reviewed relative to some of the EU member and possible accession states, it sits alongside Lithuania and Turkey, both of which are in the transition zone between efficiency driven and innovation driven economies.

Some may argue that the Global competitiveness reports are very much based on 'perception' and 'opinion'. However, these reports are published annually amid much pomp and Ireland, now more than ever needs to improve its ratings and overall international image. This is clearly presented in an International Monetary Fund (IMF) report (Allard and Everaert, 2010) where structural reform gaps are identified, using a heatmap. Ireland has 'high' or red gaps in network regulation (a medium-term gap) and infrastructure (a long-term structural reform gap). The Irish Government in its latest book of estimates uses the 'improved' ranking of the quality of Irish roads, as published in the WEF reports, as justification for reducing its capital investment plans. This book of estimates however does not identify Ireland's poor position relative to its EU partner countries, as this chapter has done, in Figure 5-1 above. If Ireland wants to 'show its open for business' it must increase its overall capital investment.

A World Bank (WB) report notes that fast-growing countries are characterized by high levels of public investment in infrastructure, with values as high as 7% of GDP (Commission on Growth and Development, 2008). Ireland did invest this level in 2008, but was well short of this level in the study period. If Ireland should have invested 7% of its GDP on infrastructure, then it underinvested €13.6 billion over the years 2003 to 2009. Based on figures collated, this would equate to €7 billion deficit in productive infrastructure investment. Indeed, this WB report also highlights the great shortage or unavailability of data on infrastructure investment, globally.

5.5. ACCESS TO RECORDS

There are poor records for national capital stock and capital investment.

5.5.1. *Capital Stock*

Keeney identifies that Ireland does not have clear records of Government Capital Stock (Keeney, 2007). Indeed, in the preparation of this chapter and in reviewing investment patterns, it was evident that there was a lack of record-gathering over the study period and it was difficult to gain access to information. Investigating the national distribution of government capital investment across the county proved a very difficult task with a number of weaknesses identified.

5.5.2. *Local Authorities Annual Financial Statements*

In order to appraise the level of public investment in roads, the Annual Financial Statements (AFS) of each county and city were reviewed for the period 2003 to 2009 (Local Government Finance Section). These AFSs are submitted to the Department of the Environment, Heritage, and Local Government internal audit division, by the Local Authorities.

A number of observations can be made with regard to the accessibility and clarity of these records while researching for capital investment in productive infrastructure figures: there was a lack of 'standardisation' of the format, some counties recorded water and wastewater capital investment separately while others combined them under the heading 'water services'. Additionally, there is a considerable delay in the auditing of the draft accounts of the local authorities - audited accounts for 2010 have yet to be released at the time of writing this chapter in early 2012. This delay in information must make it extremely difficult for counties and indeed central government departments to plan, when they cannot use historic trends.

Some of the local authorities make the information available on their websites; while for others it proved extremely difficult and in some instances impossible to get access to the records.

However, road investment has always been recorded as a separate heading, in the capital investment account and therefore these records were reasonably accessible. Also, the National Roads Authority (NRA) publishes its annual reports on its website and this contains the national distribution of its grant investment to each county (National Roads Authority, 2003, 2004, 2005, 2006, 2007, 2008, 2009).

5.6. IRELAND'S ROAD INVESTMENT

The National Roads Authority (NRA) is responsible for the capital investment and maintenance of Ireland's motorway and national primary roads. In 2008 the NRA also became responsible for the secondary and local roads. Ireland's overall national investment is profiled in Figure 5-2 below.

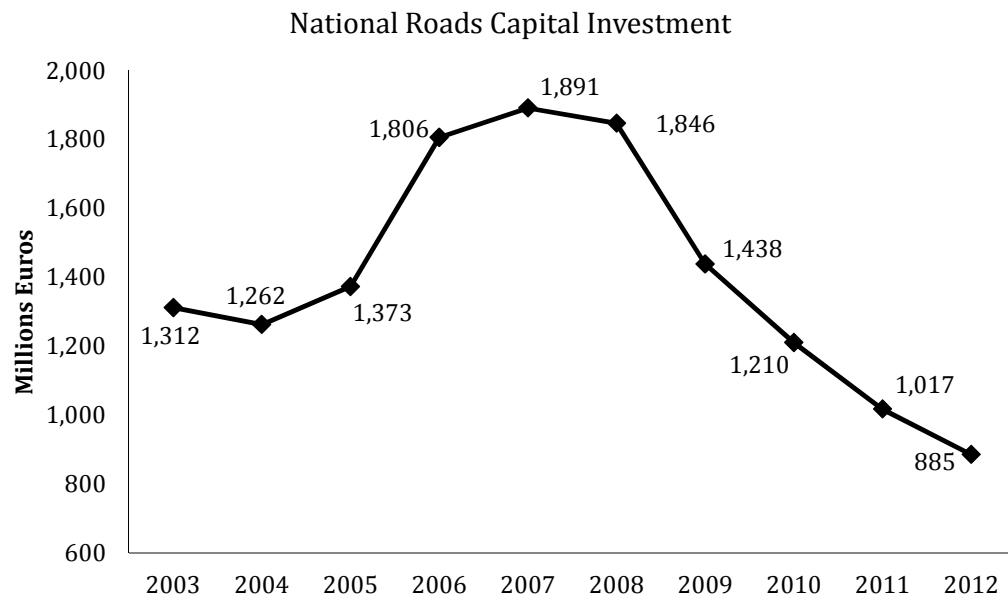


Figure 5-2: Capital Investment in Roads 2003 to 2011 (out-turn values) and 2012 (projected investment) Authors own calculations and NRA annual reports (National Roads Authority, 2003, 2004, 2005, 2006, 2007, 2008, 2009)

Figure 5-2 shows that Ireland has invested considerably in roads in the study period, and this resulted in Ireland's international rating for roads improving. However, the evidence in the WB report discussed above would indicate that Ireland should continue to invest heavily in its road network. Tender prices have decreased considerably over the period 2007 to 2012 and the impact of the reduced cost of delivering capital investment relative to how much Ireland should invest, to continue its improvement in international rankings will be further researched in a later paper.

5.6.1. *The National Distribution of this Investment*

Capital investment in Ireland's road network is funded through central government grants, via the NRA and Local Government funds. Local Government is funded through a variety of sources eg. from central government, road tax and rates. There is also a category of 'development contributions'. These contributions are levied on developers, as a condition of their planning permission. They are generally calculated based on €/m² of the building footprint. Each Local Authority (LA) has different rates and indeed some LAs charge an additional premium for eg close proximity to rail corridors. Table 5-3 below illustrates the considerable positive impact, in some cases in excess of 20%, that these development contributions had on local authority incomes over the study period (Local Government Finance Section). The AFS of the LA record their capital income separately from the revenue income.

	Kerry	Cork Co	Mayo
2003	2.69%	6.63%	n/a
2004	1.57%	10.06%	n/a
2005	0.97%	14.00%	n/a
2006	10.85%	20.87%	8.80%
2007	8.86%	26.61%	12.19%
2008	5.09%	8.37%	4.52%
2009	4.23%	1.54%	3.02%

Table 5-3: Development Contributions as a percentage of Local Authority (local government) capital income – some examples

Source: Local Authority AFS 2003-2009 (Local Government Finance Section), where available

Table 5-4 shows the profile of a number of counties road capital investments. The collective national average NRA grant was 74.2% of the national capital investment in the study period.

District	Total Capital Investment in Roads 03-09 €M	Total NRA Capital investment by County 03-09 €M	NRA as % of Total CI	Kms of MW* to 2009
Westmeath Co	6,055.30	572.7	94.60%	56.38
Kildare Co	9,525.90	777.1	81.60%	53.67
Galway Co	7,211.10	631	87.50%	50.69
Cork Co	5,765.40	483.5	83.90%	48.9
Tipperary, SR	4,650.70	457.1	98.30%	48.8
Cavan Co	700.3	58.1	83.00%	0
Mayo Co	1,979.60	164.8	83.20%	0
Sligo Co	1,013.80	88.4	87.20%	0
Leitrim Co	833.4	76.9	92.30%	0
Monaghan Co	1,893.00	174.6	92.30%	0

Table 5-4: Total Capital Investment (CI) in roads 2003-2009 by Local Authority, NRA grants and new Kms of motorway

Source: Local Authority AFS (Local Government Finance Section), NRA annual reports (National Roads Authority, 2003, 2004, 2005, 2006, 2007, 2008, 2009), author's own calculations (MW* - Motorway)

The counties selected in Table 5-4 are based on the top five counties per km of motorway constructed and the five counties with no motorway, but highest percentage of capital investment funded by the NRA.

If studied, the counties that have higher than average NRA grants are counties located along the motorway routes from Dublin to Cork, Limerick, Galway and Waterford, which is to be expected. A total of 662 km of motorway were constructed in Ireland during the period.

However, there are a number of counties that had a higher than average investment by the NRA, in particular Leitrim, Mayo, Cavan, Monaghan and Sligo. Roscommon, Donegal and Longford also had higher than average NRA grant assistance over the period. These counties are evaluated with a number of other variables in the following section.

5.7. POSSIBLE DRIVERS TO INVESTMENT

Gramlich, in his essay, identified a number of drivers for capital investment (Gramlich, 1994). These included engineering need, political decisions and econometric estimates and returns. The NRA has robust reviews of its projects, based on traffic surveys and therefore need. However, where there are projected increases in population and substantial areas zoned for housing, a 'need' for road improvements/upgrades result. There follows a discussion on some of the drivers for roads investment, all of which originated with the Government at the time and Central Government policy.

5.7.1. Section 23 Tax Reliefs

The Irish Government prepared a number of strategy plans during the 2000-2010 period. The National Spatial Strategy (NSS) was prepared in 2002 (Department of the Environment Community & Local Government, 2006, Government, 2002). It had a great vision, that Ireland would be a better place to live with a better quality of life for all and a better spread of job opportunities. It suggested that to enable this vision, a framework of hubs, gateways and other urban and rural areas act together. In line with this, the Government set in place a number of tax relief programmes, which have come to be known as Section 23s. These gave capital tax allowances to the developer and included a vast array of developments from rural renewal, to holiday cottages, hotels, private hospitals etc. It would appear that the original function of these tax reliefs was to halt rural decline, encourage economic regeneration and develop economic and social infrastructure. A review of these was undertaken in 2005 and a

number of recommendations were made, including halting the reliefs immediately, to giving a five year extension (Department of Finance, 2005). What is apparent now is that while some of these 2005 recommendations were acted on, the construction and completion of section 23 properties continued. While the original concept of the section 23 was to deliver specific types of development in highlighted geographical locations, the overall quantity and spatial distribution went somewhat unmanaged.

The Irish Department of Finance issued an impact assessment consultation paper in June of 2011 to review the impact of amending existing property tax reliefs (Department of Finance, 2011). This chapter presents the Section 23 reliefs linked to the residing county of the tax payer. This means that if the tax payer resides in Cork, they make their tax return to the appropriate Cork tax district of the Office of the Revenue Commissioners, the tax payer lists/documents their Section 23 property or properties for which they are claiming relief against their income tax. However, this tax return information does not register the address of the section 23 property.

Clearly, therefore, the Revenue Commissioners information does not identify the location of the Section 23 properties. From discussions with the Departments of Finance, there is no 'list' of where these properties are located. This Department of Finance consultation paper identified that there were 74,003 claims of tax relief for Section 23 properties (living accommodation only), over the period 2004 to 2009.

During the preparation of this chapter, previously unpublished records were received from the Department of the Environment, which identified the number of certificates granted for the purpose of claiming the tax relief. These certificates were issued by the Department of the Environment to each owner of a property. These certificates allow the pattern of Section 23 properties to be mapped across the country, as per Table 5-5 below. In total, from the records received, it would appear that there were 37,117 certificates of compliance issued. Some certificates are for a number of properties. Section 23 properties

included in Table 5-5 are for third level student accommodation, living over the shop scheme, sea-side resorts, town renewal and urban renewal.

County	As % of total Section 23 certificates issued in period 2000 to 2009	County	As % of total Section 23 certificates issued in period 2000 to 2009
Dublin	16.03%	Louth	1.03%
Longford	13.63%	Wexford	1.03%
Leitrim	13.44%	Carlow	0.99%
Roscommon	11.12%	Donegal	0.97%
Sligo	10.51%	Kildare	0.87%
Limerick	6.17%	Kilkenny	0.69%
Cork	4.39%	Clare	0.57%
Waterford	4.31%	Tipperary	0.53%
Cavan	3.94%	Meath	0.51%
Galway	3.60%	Laois	0.47%
Westmeath	1.98%	Offaly	0.38%
Kerry	1.32%	Wicklow	0.17%
Mayo	1.19%	Monaghan	0.16%

Table 5-5: The percentage of Section 23 certificates issued per county as a proportional of the national total, 2000-2009.

Source: Department of the Environment, Heritage and Local Government (previously unpublished numbers)

Table 5-5 shows the very large proportion of section 23 properties that have been constructed in the Border- Midlands –West (BMW) region, Longford at 13.6%, Leitrim 13.4%, Roscommon 11% and Sligo at 10.5%. There was also considerable section 23 development/activity in Cavan and Westmeath.

5.7.2. *Methodology and Analysis of investment data*

Considerable data has been collated in the preparation of this chapter. This included roads investment by local authority, NRA grants to each local authority. A number of data sets were collated and prepared to test if there was a correlation between roads capital investment and other variables. These correlations are a test of the linear relationship between a set of values, with a correlation coefficient of 1, demonstrating a perfect match in the 2 data sets. It was decided to test using area of the local authority, population, population density, Section 23 properties, housing stock, with a focus on some BMW counties.

5.7.3. *Housing Vacancy Rates*

With such construction activity, it was decided to focus on a number of BMW counties, to understand if there was a correlation between the level of road capital investment and the recent housing boom. The counties analysed were Cavan, Donegal, Galway, Leitrim, Longford, Mayo, Monaghan, Roscommon, Sligo. Bearing in mind that both Roscommon and Galway had considerable motorway investment as identified in table 4 above, a second scenario of excluding Galway County and Roscommon is analysed. Records of housing stock ie. the number of units existing and available to be lived in, the number of units occupied and the overall vacancy rates in these counties were analysed. The results are presented in Table 5-6 below.

Area in hectares AND kms of road, for all cities and counties	0.9
Population density AND kms road, for all cities and counties	-0.4
Hectares of County AND % of NRA as Capital Investment, for all cities and counties	0.5
Hectares AND NRA as % of all BMW counties	0.6
Pop density AND NRA as % of BMW counties	-0.5
Pop density AND %NRA of CI*, for all cities and counties	-0.6
No of Households and NRA roads CI	0.5
Total CI* in roads AND housing stock	0.8
Total CI* in roads AND housing stock, incl Roscommon and Galway Co (BMW region)	0.7
Roads CI per capita AND housing stock, excl Galway Co and Roscommon (BMW region)	-0.9
Roads CI per capita AND housing stock, incl Galway and Roscommon (BMW region)	-0.6

CI* - capital investment

Table 5-6: Correlation coefficients of Roads, investment and housing development, population distribution

This table shows a number of correlations. The kilometre of roads is in line with the hectares of the county as would be expected. There is reasonably close correlation of -0.4 between the population density of a county and the kilometres of road, as the population per hectare increases, the kms of road

decreases. There is a reasonable correlation of -0.5 inversely between the grant aid of the NRA to the BMW counties and the population density of the BMW counties. This indicates that the lower the population density, the higher the grant aid to the county.

There are very close correlations between the national capital investment in roads and the housing stock by county. Considering the high vacancy rates across the country, it would indicate that housing development influenced the investment in the roads network. The length of Ireland's road network is dependent on the hectares of the county (0.9 correlation) and the higher the population density the fewer kilometres of roads, as would be expected.

The National Roads Authority provides varying grant assistance to local authorities. These grants have generally been in line with motorway investment. However there is evidence that considerable grants have followed the house building trend, with a correlation co-efficient of 0.4. This trend would suggest that Ireland, with an average house vacancy rate in excess of 15% (with some counties as high as 25% to 30% vacancy rate) may have invested in regional areas, where there is not the expected return inter alia of population and therefore traffic volumes.

Indeed the national trend of a 0.8 correlation between capital investment in roads and households by county, would clearly indicate that road investment followed the national housing bubble

5.7.4. Political Influence

The Government developed the National Spatial Strategy (NSS) in 2002 and subsequent National Development Plans (NDP). These documents gave considerable focus to increasing the population in the BMW counties, consequently leading to considerable productive infrastructure investment. While it was necessary to a certain extent, the tracking of the developments to ascertain when there was sufficient was not done. There are now counties

where there was sufficient housing stock in the 2006 census to accommodate the population recorded in the 2011 census, with surplus.

5.8. CONCLUSIONS

The review of Ireland's investment in its road network has identified a number of interesting observations:

- The roads investment was generally in line with motorway construction and road improvement. Road investment was in line with the hectares of the counties with a correlation of 0.9
- There is evidence of a correlation between the roads investment and the housing bubble, a 0.8 correlation
- Ireland's international rating of quality of roads has improved over the study period; however we are at the same ranking as EU countries with less innovative and far lower GDP economies, eg Turkey, Lithuania, Slovenia and Iceland.
- The IMF in a recent paper clearly identified Ireland's infrastructure as being a 'high level' structural reform gap.
- This situation has to be improved with more targeted road investment, outside of political influence and government policies.
- There has been a lack of record keeping over the period, eg of tax relief data, housing stock figures in the 2002 census and distribution of investment in local authorities
- Development contributions had a large positive impact on local authority budgets over the study period (as high as 20%). This aided the development of productive infrastructure. This finance is not available at present to the local authorities.

- It is strongly recommended that a complete review of national development and planning strategies be undertaken, and a more balanced and sustainable policy be developed. Ireland, at this very difficult economic time needs to ensure that where there is investment, it will lead to economic growth and improve Ireland's international rating.

6.0 STAKEHOLDER ENGAGEMENT AS A MEANS OF ASSESSING THE STATE OF IRELAND'S INFRASTRUCTURE ⁴

6.1. ABSTRACT

Infrastructure of sufficient capacity, in the correct location, is crucial to an economy's growth and well-being. In undertaking research to identify the issues and gaps in relation to Ireland's infrastructure (with particular focus on physical networks such as roads, water etc.), open interviews with high level stakeholders was determined as the optimum mechanism for the data gathering. Engineering research is largely focused on quantitative analysis, which is generally not the most appropriate in exploring policy questions. This chapter outlines the methodology of the research, illustrating the virtues of engaging with high level stakeholders through the use of open interviews, in answering policy questions. A mixed method of analysis was used: with NVivo, a computer assisted qualitative data software package (CAQDAS), used to code and qualitatively analyse the interviews; followed by a quantitative analysis of the output undertaken using chi-squared (χ^2) testing.

6.2. INTRODUCTION

State investment in productive infrastructure is extensively cited as critical to a country's economic growth and development among economists and the World Economic Forum (WEF) (Morgenroth, 2011, OECD, 2006a). As Ireland exits the deep recession it has experienced in the period 2006-2014, the level of investment in productive infrastructure has begun to improve. While the literature covers the broader question of Ireland's shortcomings in relation to industry locating in a region, knowledge of the infrastructure enablers to

⁴ Submitted to International Journal of Project Management – currently under review

industries locating within a district is not well addressed. As industry is the backbone of any country's economy, key industrial stakeholders were identified as the best source of data. This chapter explores the use of mixed method research (qualitative and quantitative) in identifying what are the determinants to Industries locating within a region of Ireland, which is a gap in the current literature.

Many have called on Engineers and Project Managers to take a leadership role, with enhancing communication with disparate stakeholders and thus to develop new ways of thinking and approaching decision making for infrastructure (Hart *et al.*, 2014). There is a growing interest in how engineering research relates to practice, policy and industry (Jesiek *et al.*, 2010). The findings of Jesiek *et al.*, calls for a close '*relation to industry*' as an important research area, and certainly the work of this chapter addresses this issue. Indeed the recent call from the International Journal of Project Management '*to bring the public administration and project organising research communities together in mutually beneficial dialogue*' is a very welcome one (Winch and Sanderson, 2015). This author would question should this dialog not be extended to include key industries. Too often each group is working in a '*silo*' type of dialog. The research methodology presented in this chapter brings together the policy makers, and industrial corporate decision makers and includes personnel from the construction sector, the project managers, in discussing the importance of infrastructure to industries locating within a region. Many have written of the importance of stakeholders in the success of project outcomes, and this body of research and knowledge has grown significantly in recent years (Garrod *et al.*, 2013, Mok *et al.*, 2014, Yang *et al.*, 2011).

This research is based on grounded theory (Bringer *et al.*, 2004), with the initial qualitative analysis of the data collected in the interview process, followed by quantitative analysis using χ^2 testing. Grounded theory is the construction or development of theory through the analysis of data. The paper outlines the methodology for using the open interview process for data

gathering; the use and benefits of a computer assisted qualitative data software package (CAQDAS) for the coding and qualitative analysis; while demonstrating how this output can be used in a quantitative exploration of the interviewees opinions; thus resulting in the identification of key infrastructure drivers and infrastructure policy questions.

6.3. RESEARCH METHODOLOGIES IN ENGINEERING RESEARCH AND THE CHALLENGES

There are a number of options to address the research question of:

- *What are Ireland's Infrastructure gaps, from an industry perspective?*
- *How infrastructure influences industries locating in a region?*

They vary from a review of recent reports; assessment of datasets, i.e. water quality etc.; or to interview a learned and well-informed group of stakeholders. The latter was chosen as the preferred data generation process. The use of interviews as a research technique in the humanities has been well-documented and utilized, while the use of qualitative methodologies is unfamiliar territory for engineering researchers. This is recognised by Baillie and Douglas, when they suggest that the use of qualitative research emerging in engineering can sometimes fall

*'betwixt and between - with reviewers from neither social science nor
engineering domains recognizing what they see as quality and hence rejecting
the work'*

(Baillie and Douglas, 2014).

The use of interviews as a research methodology poses many challenges: firstly the identification and engagement of stakeholders of sufficient high-level and impartiality from diverse groupings; and secondly how to analyse the interviews thus resulting in meaningful findings. It was clear at the outset that these findings and the analysis process would need to be structured and transparent, and thus the need to use a CAQDAS package.

6.4. USE OF CAQDAS - COMPUTER ASSISTED QUALITATIVE DATA SOFTWARE AND NVIVO

Historically, the use of interviews as a means of perusing a ground theory methodology would have been extremely laborious, with the data trail difficult to follow and analyse. An advance in computer technology during the 1990's led to the development of a number of software packages for the analysis of qualitative data, and thus the emergence of *Computer Assisted Qualitative Data Software* (CAQDAS). There have been a number of concerns voiced with regard to using a CAQDAS, that centre around the loss of data from interviews, the translation of words into numbers, and even possible data loss from the interviews (Crowley *et al.*, 2002). It is argued that the use of such software aids transparency of the research thus enhancing the analysis of the interviews. Historically qualitative data, in the form of transcribed interviews, were analysed using highlighters, post-its and scribbles. The use of CAQDAS allows interview text to be imported, coded and analysed in a structured manner.

A review of alternative CAQDAS programs available was undertaken with NVivo (NVivo, 1999-2013) identified as the most suitable for this research. There is much literature written on the use of NVIVO in the management and analysis of qualitative data (Auld *et al.*, 2007, Bazeley and Jackson, 2013, Bringer *et al.*, 2004, Crowley *et al.*, 2002). NVivo supports the importing of a number of alternative forms of data and allows for this to be analysed in a number of different formats. Richards (Richards, 1999) maintains that prior

to the advent of NVivo, rich data from qualitative research had been poorly supported by computer programs.

The experience of using NVivo for this research, demonstrates that the software is an organizational tool which leads to the structured storage, analysis and development of a node structure from the interviews (Bringer *et al.*, 2004). The application of NVivo was limited to the analysis of the interviews, but could have been extended to include e.g. the literature review.

The use of CAQDAS, NVivo in this instance, does not drive the research or the ultimate output, but rather the way the researcher interprets the nodes and findings. Indeed the 800 minutes of interviews (each interview was approximately an hour), recorded as part of this research, would be an enormous task to code and analyse without the aid of such a software tool. NVivo led to a very structured development of the research topic and enabled relatively easy access to different interview topics and analysis of each source during this research. This will be evidenced in section 6.5 below.

All research and in particular the interview process seeks to collect the richest possible data (Richards, 1999). The interview process for this chapter comprises three key components: the industries selected; the person interviewed; and the questions used during the interview. The following a synopsis of the process used.

6.5. THE RESEARCH METHODOLOGY FOR THIS WORK

The stages in the research process are as illustrated in Figure 6-1 below: identify suitable interviewees; undertake the interviews; analyse interviews for patterns, themes, priorities; identify infrastructural gaps and perform quantitative analysis.

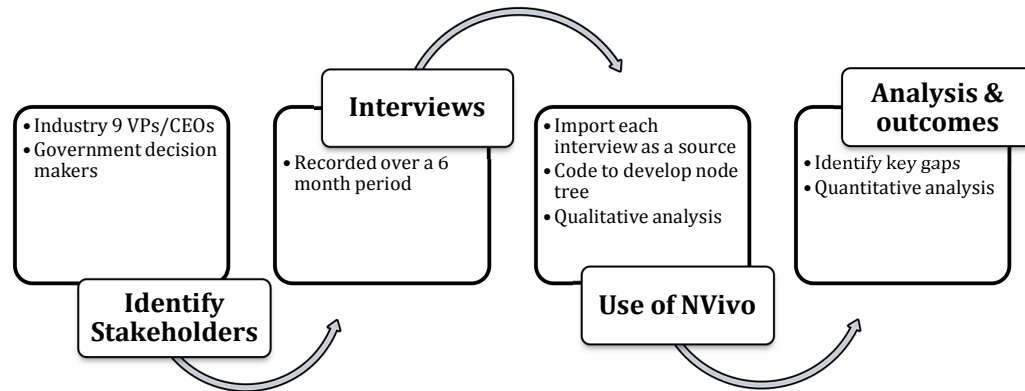


Figure 6-1: The stages in this research

Section 6.4 of this thesis outlines the use of computer assisted qualitative data software, with NVivo the selected software for this research. This type of software aims to codify and analyse non-quantitative data, to enable structured and meaningful analysis to be carried out on otherwise ‘random’ information. The objective is to distil fresh insights from the data, insights that might remain obscured by the volume of original material being analysed. Therefore, the use of NVivo allowed for the structured codification, analysis and presentation of the findings, from the interviews carried out with high-level stakeholders as part of this research.

The NVivo software was originally developed in 1999 to assist in the analysis of interviews in the social sciences. While transcribed interviews in ‘word’ document format were analysed in this research, the software can also import other data formats such as audio, videos, digital photos, PDF files, web and social media data.

When undertaking the interviews that will subsequently be imported into NVivo, it is important that a profile of the interviewee is recorded, as this may form a key part of the later comparative analysis. These are termed as attributes or values, and thus allow for the analysis of the data by either, ie. the opinion of all males, of particular origin, aged 40-50 etc. on a particular topic (node).

Richards (the developer of NVivo) describes this as the '*obvious device of sets where one can freely create sets of documents or nodes, the sets can overlap as good sets should*' (Richards, 2002). This could include comparing opinions of: males with females; interviewees of a certain age category with those from another; interviewees of different business type, country of origin; etc.

Different methodologies of research require different types of data and thus different ways of working with it. Selecting the sources of the data to be analysed is the most important building block and is obviously crucial. The rationale for selecting the interviewees in this research is outlined in section 6.6. The researcher initially develops the structure of their project in NVivo, which is based on having two different databases. These consist of: a document system, ie. the text from the interviews in this case; and a node system, which is developed by the researcher in the 'coding' process.

Nvivo supports the importing of non-processed data, which can later analyse the text as a series of sections, focussed on particular topics (Durian, 2002). Within NVivo the imported 'sources' are studied to develop theme 'nodes' and derivate 'child nodes', each of which are tagged with attributes. These give a very clear visual image of the structure of the interviews. The node search process is based on Boolean logic, whereby the intersection of coding at a number of nodes corresponds to number of text sections that answer the research query.

The imported data can be analysed for trends, e.g. word count, or words by interviewee or theme/node, giving the researcher an overview of the interviews for analysis. The data that is coded to nodes is using SGML

schemata (The Standard Generalized Markup Language ISO 8879:1986), and is thus compatible with other qualitative and quantitative software packages.

NVivo's powerful query tools then allows the researcher to have an overview of the data and drill down/query in a number of ways. This can be done by: each interview; each 'classification' or 'attribute' of interviewee e.g. all the male interviewees, interviewees of a certain age, a particular country of origin; or query by theme nodes and child nodes. The query software allows the immediate access to many strands of inquiry, and results can be presented in word format; or visually in the form of node maps and word maps.

6.6. IDENTIFYING THE INTERVIEWEES

In order to develop '*robust priorities for infrastructure*' Thekdi and Lambert suggest that stakeholders in the research process should be from a diverse perspective, expertise, and interest (Thekdi and Lambert, 2014). Thus the initial challenge was to identify which industries should be selected and who to interview. There are a number of distinct industrial sectors within Ireland; Central Statistics Office data on industrial output was used to identify the key industrial sectors that should be interviewed (CSO, 2013b). These are the ICT; Pharmaceutical; construction; consultancy. Details of the companies are included in Table 6-1.

Once the preferred sectors had been identified, a range of senior-level executives at CEO/VP or equivalent, were selected and contacts made to organize interviews, as illustrated in Figure 6-2 below.

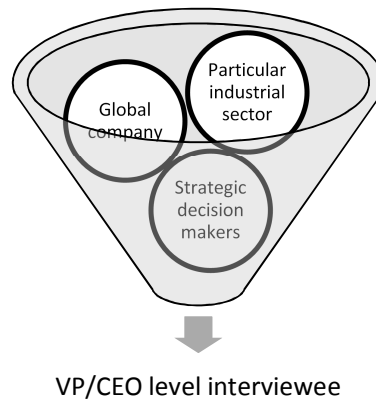


Figure 6-2: Criteria for selecting interviewees - Corporate Decision Makers (CDs)

Participants (Corporate decision makers–CDs) at the most senior level were deliberately targeted to ensure they had strategy/decision-making positions and power within their organizations; influence in deciding on office/company locations; that they would be impartial to their current location due to being at such a high organizational level; and they would be interested in their business growth and thus furnish unbiased answers during the interview process.

To ensure a balance to the research, Policy Makers (*PM*) were also interviewed. The PMs were identified from within a high level of government or semi-state bodies. Again the criteria for selecting these interviewees were based on having a high level of authority/input to decision-making and to have a geographical distribution. Of course the interviewees do not operate in silos, there is a degree of cross-sectoral involvement by participants as detailed in Table 6-1 below. A number of the interviewees currently, holding corporate positions, were also members of government semi-state boards, either presently or in the past. For example interviewee CD4 has held a number of positions, formerly being CEO of a semi-state utility company, is presently chairman of a semi-state board, president of a Chamber of Commerce, and has established and manages a private equity firm.

*Stakeholder Engagement as a means of assessing the state of Ireland's
Infrastructure*

Interviewee CD8 holds a VP position in a global pharmaceutical company, while currently heading up the Irish and Asian operations of this company and also previously served as a board member of a state agency.

Stakeholder Engagement as a means of assessing the state of Ireland's Infrastructure

<i>Participant</i>	<i>FDI - SME - Gouvernement</i>	<i>Industry</i>	<i>Occupation/Position within organisation</i>	<i>Additional roles to main occupation</i>	<i>Strategic Development decision maker</i>	<i>No of Employees total</i>
PM1	Public Service	Government	Former Departmental Government Secretary	Government agency Board Member	Medium level	
PM2	Public Service	Semi-state	Former CEO and Present Chairman of semi-state organisations	Government agency Board Member	High level	
PM3	Public Service	Education	VP of Academic Institution and Former member of National Competitiveness Council	Government agency Board Member	Medium level	
PM4	Public Service	Government	Senior Civil Servant/ Ministerial Adviser		Medium level	
PM5	Public Service	Government	Director of Services, in a Local Authority		Low level	
PM6	Politician - Former Minister	Government	Former Government Minister		Medium level	
CD1	Large Irish multi- national	Food and Beverages	Retired CEO and founder of large SME, many other business interests in Ireland	Business Founder; Government agency Board Member	High level	24182
CD2	SME	ICT	Business founder		Medium level	10
CD3	Large Irish multi- national	ICT	Senior Department Manager in organisation/company		Medium level	2000
CD4	SME	Utility company	Former CEO of semi-state and currently Chairman of Boards	Chamber of Commerce; Government agency Board Member	Medium level	1000
CD5	Large Irish multi- national	Consultancy	Department Manager in organisation/company	Departmental manager	High level	2000
CD6	US FDI	ICT	VP/CEO Level		High level	13,800+
CD7	US FDI	ICT	Chief Technical Officer - CTO		High level	75049
CD8	US FDI	Pharmaceutical	VP/CEO Level	Board Member	High level	91500
CD9	European FDI	ICT consultancy	VP/CEO Level		High level	434,246

Table 6-1: Profile of the 6 Policy Makers (PMs) and the 9 Corporate Decision Makers (CDs) interviewed for this research

Table 6-1 above provides a profile of the interviewees and their positions within their organizations, with other positions/roles that they have fulfilled. The interviewees are of high managerial level as evidenced in the table, with the CDs representing companies with in excess of 630,000 employees globally. The quality of the interviewees is crucial in such a research activity, and Table 6-1 demonstrates the high level and calibre of interviewees that participated in this process.

6.7. THE INTERVIEWS & DEVELOPMENT OF SURVEY QUESTIONS

The interview questions were developed from an extensive literature review, and highlighted in other works by Moloney et al (Gunnigle and McGuire, 2001, Moloney and McKeogh, 2013, Moloney and McKeogh, 2014). The interview style and questions were open, thus encouraging the interviewee to develop each question and allow the possibility of adding or developing other themes around the importance of infrastructure. The following is an overview of the questions raised:

- Importance of infrastructure networks as a determinant to industries locating in Ireland/ in a particular location
- The organisation's primary and secondary infrastructure requirements, in both capacity and location
- Opinion on how Irish Government et al manages infrastructure delivery, should there be a single entity with responsibility
- List and rank main infrastructural gaps (the results of this are presented in other work by Moloney et al (Moloney and McKeogh, 2014)
- Importance of Ireland's international ranking vis a vie infrastructure quality

The sequence of undertaking the interviews is crucial in such research and interviewee CD4 was identified as a suitable first interviewee. This interview

proved extremely rich in topics and in fact contributed to 72 nodes, once the node tree was developed through NVivo. This first interview led to additional questions being added to subsequent interviews. Table 6-2 below identifies the sequence of the interviews, with the number of nodes and references of each source.

Stakeholder Engagement as a means of assessing the state of Ireland's Infrastructure

<i>Participant (Source)</i>	<i>Interviewed on</i>	<i>Source created on</i>	<i>Occupation/Position within organisation</i>	<i>No of Nodes</i>	<i>No of References</i>
CD4	19-Mar-13	16-Oct-13	Former CEO of semi-state and currently Chairman of Boards	73	487
PM3	08-Apr-13	31-Jan-14	VP of Academic Institution and Former member of National Competitiveness Council	60	163
CD7	08-Apr-13	21-Oct-13	Chief Technical Officer - CTO	32	116
CD6	10-Apr-13	27-Oct-13	VP/CEO Level	27	73
CD8	11-Apr-13	21-Oct-13	VP/CEO Level	38	133
PM5	15-Apr-13	01-Nov-13	Director of Services, in a Local Authority	46	147
PM1	19-Apr-13	03-Nov-13	Former Departmental Government Secretary	47	146
CD9	07-Jun-13	01-Nov-13	VP/CEO Level	25	73
PM4	18-Jun-13	02-Feb-14	Senior Civil Servant/ Ministerial Adviser	47	162
CD3	08-Nov-13	31-Jan-14	Senior Department Manager in organisation/company	24	52
CD2	17-Nov-13	31-Jan-14	Business founder	17	45
CD5	18-Nov-13	30-Jan-14	Department Manager in organisation/company	36	72
PM6	23-Nov-13	31-Jan-14	Former Government Minister	33	68
PM2	01-Dec-13	30-Jan-14	Former CEO and Present Chairman of semi-state organisations	52	148
CD1	11-Dec-13	31-Jan-14	Retired CEO and founder of large SME, many other business interests in Ireland	34	117

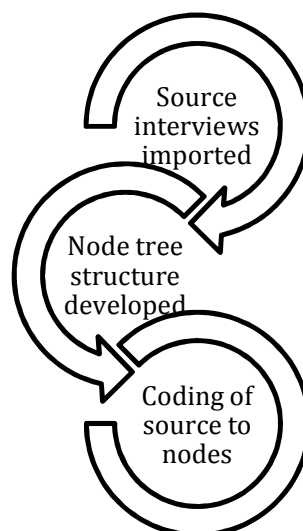
Table 6-2: Sequence of interviews, coding and number of nodes and references per interviewee

6.8. IMPORTING THE INTERVIEWS AND THE PROCESS OF CODING AND DEVELOPING THE NODES

It was considered to be crucial that interviews be personally typed by the researcher, and this was done on an on-going basis, through and post the interview period. This added additional clarity to the flow of the interview text, and contributed to additional questions being added to subsequent interviews.

As can be seen in Table 6-2 coding commenced in October 2013, with 60% of the interviews completed. Interview CD4 was the first to be coded and very much led to the overall structure of the node tree. Table 6-2 identifies the number of nodes from each of the interviewees and thus the relative richness of the interviews with the different stakeholders.

The NVivo process is illustrated in Figure 6-3 below. Once the interviews were typewritten (using MS word), they were then imported into NVivo. Each imported transcript became a 'source' in NVivo. Each source was analysed for different topics/thoughts and thus produced a 'node'. As additional interviews are coded, the number of sources referring to each node develops. The particular extract of the interview is assigned to the 'node', thus facilitating easy exploration of each node after coding is completed.

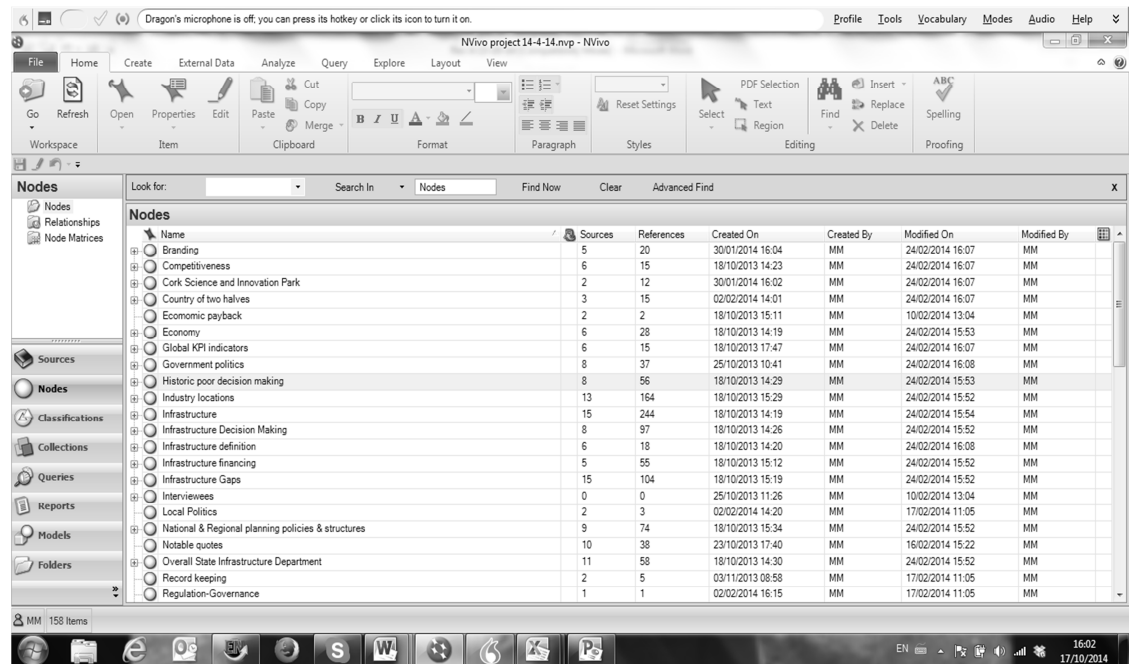


Stakeholder Engagement as a means of assessing the state of Ireland's Infrastructure

Figure 6-3: The NVivo process of data input and coding

As the coding continued a 'node tree' evolved, which illustrated the different discussion topics of the interviews.

Once all of the interviews had been coded, each node was then explored to identify 'child' nodes of the adult node. Not all adult nodes had child nodes. There are a number of different viewing options; Figure 6-4 (the node view) below illustrates the adult node tree following the NVivo coding. This allows a view identifying the number of sources and references that discussed each node.



Name	Sources	References	Created On	Created By	Modified On	Modified By
Branding	5	20	30/01/2014 16:04	MM	24/02/2014 16:07	MM
Competitiveness	6	15	18/10/2013 14:23	MM	24/02/2014 16:07	MM
Cork Science and Innovation Park	2	12	30/01/2014 16:02	MM	24/02/2014 16:07	MM
Country of two halves	3	15	02/02/2014 14:01	MM	24/02/2014 16:07	MM
Economic payback	2	2	18/10/2013 15:11	MM	10/02/2014 13:04	MM
Economy	6	28	18/10/2013 14:19	MM	24/02/2014 15:53	MM
Global KPI indicators	6	15	18/10/2013 17:47	MM	24/02/2014 16:07	MM
Government politics	8	37	25/10/2013 10:41	MM	24/02/2014 16:08	MM
Historic poor decision making	8	56	18/10/2013 14:29	MM	24/02/2014 15:53	MM
Industry locations	13	164	18/10/2013 15:29	MM	24/02/2014 15:52	MM
Infrastructure	15	244	18/10/2013 14:19	MM	24/02/2014 15:54	MM
Infrastructure Decision Making	8	97	18/10/2013 14:26	MM	24/02/2014 15:52	MM
Infrastructure definition	6	18	18/10/2013 14:20	MM	24/02/2014 16:08	MM
Infrastructure financing	5	55	18/10/2013 15:12	MM	24/02/2014 15:52	MM
Infrastructure Gaps	15	104	18/10/2013 15:19	MM	24/02/2014 15:52	MM
Interviewees	0	0	25/10/2013 11:26	MM	10/02/2014 13:04	MM
Local Politics	2	3	02/02/2014 14:20	MM	17/02/2014 11:05	MM
National & Regional planning policies & structures	9	74	18/10/2013 15:34	MM	24/02/2014 15:52	MM
Notable quotes	10	38	23/10/2013 17:40	MM	16/02/2014 15:22	MM
Overall State Infrastructure Department	11	58	18/10/2013 14:30	MM	24/02/2014 15:52	MM
Record keeping	2	5	03/11/2013 08:58	MM	17/02/2014 11:05	MM
Regulation-Governance	1	1	02/02/2014 16:15	MM	17/02/2014 11:05	MM

Figure 6-4: The Node tree in NVivo

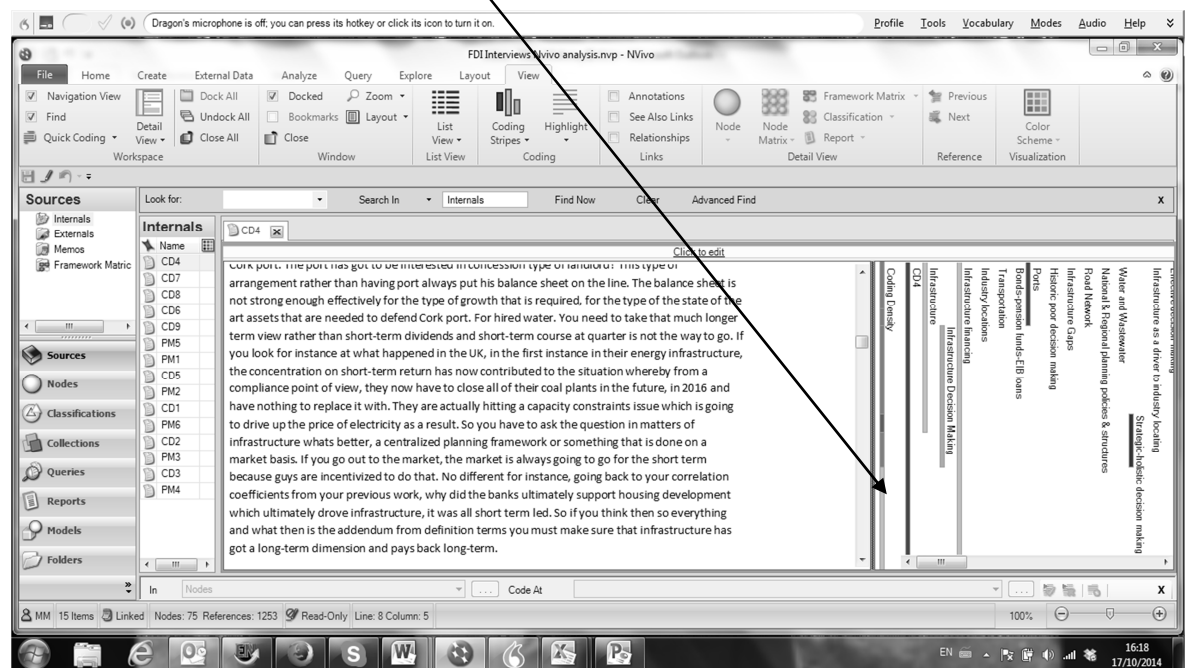
Stakeholder Engagement as a means of assessing the state of Ireland's Infrastructure

A number of the nodes were discussed by all of the interviewees. The benefit of NVivo is that each node can then be explored to develop a full picture of the interviewee's thoughts on the particular topic.

Likewise each source was scrutinised for the discussion topics that were illustrated with coding strips, as in

Figure 6-5 below. This demonstrated the coding density of different passages in the source transcript.

Figure 6-5: Screen illustration of the coding strips and coding density in a section of a source interview



When all 15 interviews were coded to develop the node tree with child nodes, an exploration of the topics was undertaken, identifying the number of references made to each topic and by whom. It was evident that there were differing opinions between the corporate decision-makers and the

policymakers. These were explored extensively both qualitatively, with quantitative assessment also undertaken. A chi-squared (χ^2) analysis was undertaken (in section 6.9.1), to understand the level of independence or not, of members of the two groups i.e. CDs and PMs, on different research topics.

6.9. THE ANALYSIS AND RESULTS

Using open interviews, with a suggested list of questions, will obviously result in the majority of the topics centred on the main research topic. However, in this data gathering a number of other nodes arose during the interview process, i.e. National planning and policy making; local government; the emergence of 2 Irelands – Dublin and the rest of the country at two different speeds of recovery and development. This is the benefit of using open interviews with high level stakeholders as a research mechanism for strategic policy issues. If a number of fixed questions, with e.g. a scoring system were used, there would have been no mention of these other topics, many of which will form future research topics that need to be explored.

The key infrastructural gaps identified by the Stakeholders were the lack of regional communications connectivity of sufficient speed, bandwidth at an appropriate cost; followed closely by poor water quality and capacity. The full analysis of the gaps is presented in other work by Moloney et al. (Moloney and McKeogh, 2014).

The value of using software such as NVivo, is that the data once imputed and coded can be analysed in a number of ways. An exploration of the number of sources, under the two main classifications of the industrial corporate decision makers CDs and policy makers (PMs), that discussed each topic and how many individual references they made to it during the interviews, either individually or under their classifications, can be extracted. These are presented in

Figure 6-6 below.

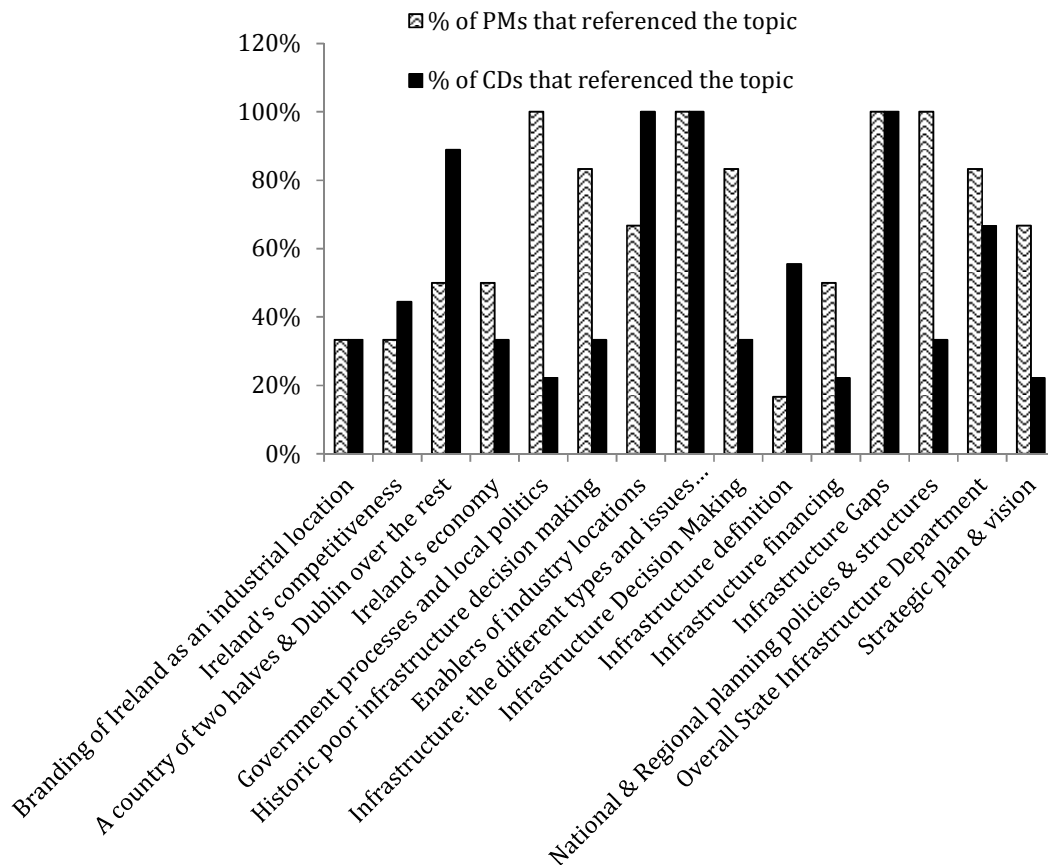


Figure 6-6: Overall survey structure illustrating main discussion topics, with % of policy makers (PMs) and corporate decision makers (CDs) that discussed the topic.

The main research topics were discussed by both groups: with the PMs appearing to be more interested in the historic investment patterns and the greater need for national policy, with the need for a strategic plan and vision; while the CDs were more focussed on the developing country of two halves – ie. Dublin over the rest of the country, and the enablers to industries locating within a region.

6.9.1. Statistical analysis of NVivo results

The NVivo output statistics were analysed using a Chi-squared test (χ^2) for statistical association, also known as the null hypothesis (Devore, 1999). The test statistic is a measure of the discrepancy between the observed values as measured using the NVivo number of references and an expected set of values. If the p-value is ≤ 0.05 , then there is a $\leq 5\%$ chance of incorrectly stating that there is lack of independence on the dataset as observed.

In this study, the two categories of data tested are subsets of the full population as coded in the NVivo analysis. If the calculated p-value is less than or equal to 0.05, this means that the counts/references in NVivo are not independent of whether the references came from the PMs or the CDs and thus the number of references is due to their categorisation of being either a CD or a PM. Conversely a large p-value (>0.05) would suggest that the observed dataset is independent of which group they are a member of; and thus it could be suggested that both groups have a similar level of interest in the topic. This χ^2 test was carried out for a number of parent and child nodes, and the p-values calculated for the data set. The test takes into account the fact that there are different sample sizes, with 6 PMs and 9 CDs.

An analysis of what determines or inhibits industries locating within a region, as presented in

Table 6-3 below, results in a p-value of <0.001 , thus indicating that the number of references, and thus the level of interest in the topic are dependent on whether the interviewees are either PMs or CDs.

*Stakeholder Engagement as a means of assessing the state of Ireland's
Infrastructure*

<i>The relative number of references to nodes discussing what determines/inhibits industries locating in a region</i>	<i>PM references</i>		<i>CD references</i>	
Industry Locations	38	(23%)	126	(77%)
Change in current thinking is necessary	5	(56%)	4	(44%)
Critical Mass of industries in specific regions	5	(36%)	9	(64%)
Infrastructure as a driver or inhibitor to industry locating in a region	7	(21%)	26	(79%)
Why industries locate in a particular region & and Dublin over the rest of the country	7	(18%)	33	(83%)

Table 6-3: Nodes discussing what determines/inhibits industries locating in a region

Further χ^2 tests were carried out on the observed data sets from NVivo and the p-values are presented in Table 6-4 below.

Stakeholder Engagement as a means of assessing the state of Ireland's Infrastructure

Interview discussion topics	Data set tested	p value from χ^2 analysis	Observation
Infrastructure: Benefits & stability of infrastructure; Capacity of infrastructure networks; broadband connectivity; infrastructure planning; ports; power distribution network; transportation networks; water and wastewater	the sum of the PM references and CD references	0.006	Dependent on whether they were CDs or PMs
Infrastructure: Benefits & stability of infrastructure; Capacity of infrastructure networks; broadband connectivity; infrastructure planning; ports; power distribution network; transportation networks; water and wastewater	the sum of the CD references, analysed to compare the references of the FDIs and the SMEs	0.003	Dependent on whether they are from an FDI or SME company
Transportation: airports; rail & road network	the sum of the PM references and CD references	0.397	independence on whether they were CDs or PMs
Broadband connectivity: benefits of broadband; broadband cost & broadband quality	the sum of the PM references and CD references	0.175	independence on whether they were CDs or PMs
Water and Wastewater: basic requirements; capacity & Capital investment plans, funding and paying for water	the sum of the PM references and CD references	0.852	independence on whether they were CDs or PMs
Industry locations; change in current thinking is necessary; critical mass of industries in specific regions; Infrastructure as a driver or inhibitor to industries locating; why Dublin over the rest of the country & why industries locate in particular regions	the sum of the PM references and CD references	<0.001	Dependent on whether they were CDs or PMs
National & Regional planning policies & structures: Local councils & authorities & regional authorities; Planning and politics; Planning system; Rural and urban Ireland; Unstructured planning	the sum of the PM references and CD references	0.030	Dependent on whether they were CDs or PMs

Table 6-4: Calculated p-values for specific discussion topics

It is observed that the p-values for specific items of infrastructure e.g. water, broadband and transportation networks were high in value i.e., greater than 0.05, thus illustrating an independence on whether they were CDs or PMs; while the more general discussions on planning policy, industry locations and benefits of infrastructure were very low p-values thus illustrating that there was a lack of independence in the observed data sets on which classification the interviewee belonged to (PMs or CDs). The benefit of these findings shows the relative variance in opinion, between different categories of interviewees, and further highlights the importance of the initial identification and sampling of the interviewees for such a study.

6.10. DISCUSSION AND CONCLUSIONS

Project Managers are pivotal to the decision making and project managing of the infrastructure development process. Prior to construction of infrastructural assets, it is crucial that stakeholders are involved in the identification and prioritisation activity. The use of open ended interviews with key stakeholders for data collection, during the project identification, prioritisation and initiation stages, is fundamental to the overall success of projects. Project Managers and Engineers generally opt/prefer to use numbers and quantitative data and analysis. However, in exploring policy questions, and engaging with high level stakeholders, interviews can provide a rich and deep set of data, as illustrated in this research.

This chapter clearly illustrates the value of qualitative research methods along with the use of CAQDAS packages, such as NVivo in the exploration of policy issues affecting project development and execution, in a structured and transparent manner. Using the χ^2 analysis allows for the exploration of the independence of which group they are a member of, and thus can be used for alternative categories of interviewees.

The use of this form of grounded theory and exploration proved very insightful for the research topic being explored, with some major findings. The need for

change in infrastructure investment and how decisions are made was a dominant topic, along with identifying the key gaps in Ireland's infrastructure: water quality and capacity; and access and capacity of broadband.

7.0 INFRASTRUCTURE GAP ANALYSIS FOR IRELAND⁵

7.1. ABSTRACT

Ireland has gone through a radical transformation from the Celtic Tiger years to the IMF-EU bailout of 2010. This chapter presents evidence of the priority infrastructural gaps that will inhibit economic growth, based upon interviews with a broad spectrum of key stake-holders.

The paper explores the factors for industry locating within a region and highlights the issues associated with national, regional and local planning and how these can potentially inhibit or aid industrial development within a region and thus the region's growth.

This chapter demonstrates serious short-comings in the broadband connectivity to all areas outside of Dublin and the need for the basic requirement of water quality and capacity to be urgently addressed. It reinforces the need for investment in Ireland's physical infrastructure to be aligned with a long-term strategy and vision, with infrastructural investment decisions based on a holistic, numbers-based evaluation methodology.

7.2. INTRODUCTION

Ireland appears to be emerging from its severe recession of 2008-2013. A key strength in this regard is the high number of multinational companies that have chosen Ireland as a location. To attract and maintain these companies, it is crucial that the drivers to their choice of location are fully appreciated. There has been much written about the contribution of labour issues, ie. productivity, Ireland's preferential tax rates and the skilled workforce in attracting industries to the country (Gunnigle and McGuire, 2001, Hannigan, 1999). The literature

⁵ Accepted for Publication in ICE Proceedings: Municipal Engineer (2014)

also identifies physical infrastructure as being instrumental in a company locating and expanding within the country. However, little work has been carried out on the specific requirements and the current gaps in Ireland's infrastructure, which this chapter addresses. The methodology chosen for the research was to undertake interviews with key stakeholders, those that have influence in decision-making and policy-making. The interviewees were drawn from foreign direct investment (FDI) companies; Irish originating multi-national companies (MNCs), some of which are now large global brands; a politician and former Government Minister; and 5 senior public servants. The primary purpose of the interviews was to identify infrastructural gaps; distinguish those that inhibit industries locating and growing within a region; and make recommendations on how infrastructural decision-making should be modified, so that the process is holistic, focused on a national plan and monitored to ensure its effective delivery. This chapter presents qualitative evidence supporting the need for more strategic investment in Ireland's key infrastructural networks.

7.3. IRELANDS INDUSTRIAL MAKEUP

Exports are a key element of Ireland's economy, accounting for 56% of the GDP in 2012 (CSO, 2013a, CSO, 2013b). Ireland's key export markets are the UK market accounting for 15%, the United States 21% and the rest of the EU accounting for 60% (CSO, 2013b).

Ireland and the US have a particularly strong industrial partnership. US firms invested approximately \$23 billion in Ireland in 2011, this amount exceeding US investment in all of developing Asia combined. Indeed Ireland's share of US FDI in Europe rose by 14.7% over the years 2010 and 2011 (Enright and Dalton, 2013, Quinlan, 2012). Literature supports the hypothesis that good quality infrastructure plays a part in attracting FDI (Rodríguez *et al.*, 2009).

Quinlan in his report on the Irish-US economic relationship clearly identified the strength of the relationship. However, he also made it very clear that for Ireland to be a leader in 21st century technologies, the country's infrastructure must be

able 'to provide the scale and diffusion across all sectors'; furthermore that an updated first world infrastructure was also key; and highlighted the need for continuous improvement of Ireland's road, rail, airport, broadband capabilities and a bigger smarter electrical grid (Quinlan, 2012). This and many other reports (IDA, 2010, UNCTAD, 2008), clearly show the need for clarity on what and how Ireland needs to invest to satisfy its existing multi-national companies, to encourage further expansion and aid the growth of indigenous industries within the country.

7.4. INFRASTRUCTURE AND INDUSTRIES LOCATING IN A REGION

There have been a number of studies which explored the overall factors influencing industries to locate within a region (Erdal and Tatoglu, 2002). Gunnigle (Gunnigle and McGuire, 2001) and Hannigan (Hannigan, 1999) have both identified infrastructure as being a key issue impacting on the level of inward investment and growth. Hannigan's study of 87 companies places infrastructure as the foremost important factor influencing competitiveness in the Irish economy; while Gunnigle interviewed 10 companies, of which one identified infrastructure as the key driver and another as the fourth issue to them choosing Ireland. Gunnigle further emphasizes that the quality of the country's overall infrastructure was used as an initial criterion in selecting Ireland, and the quality of the local infrastructure influenced the specific choice of location within Ireland. Gunnigle's study was undertaken in 2000, at a point when Ireland was increasing the rate of infrastructural development. More recently, the need for infrastructural investment is further confirmed by Forfas and others (Irish Government, 2014, National Competitiveness Council, 2011)

'The availability of a competitively priced world class infrastructure (energy, broadband, transport, waste and water) and related services is critical to support enterprise development, competitiveness and job creation. While Ireland has made significant investment in infrastructure in recent years, further investment and

reform is required to ensure that our critical infrastructure can support economic recovery and enterprise growth’ (Forfas, 2012)

However, these reports fail to identify the specific gaps, the priority locations for further investment or the type of reform required to deliver the necessary quality and capacity of infrastructure

Moloney and McKeogh (Moloney and McKeogh, 2013) demonstrated that while there was significant Irish state infrastructural investment in water, wastewater and the road network over the period 2003 to 2009, it may have been misspent, with a large proportion of this investment influenced by and misdirected due to the Celtic Tiger and the housing boom. There is a clear correlation between the number of housing units, many of which lie vacant or incomplete, that have been constructed across Ireland and the level of Irish state infrastructural investment. Now more than ever, it's critical that limited Irish state infrastructural investment occurs in line with where it's needed most, with the optimum return on the investment (Bradley and Untiedt, 2012). It is projected that Ireland's GDP will grow by 5% in both 2014 and 2015, and thus it is crucial that the capital investment announcements being made by the Government are of the correct type, capacity and in the correct location (Duffy *et al.*, 2014b). The survey undertaken as part of this research aims to prioritise the greatest infrastructural gaps.

7.5. METHODOLOGY

7.5.1. *The Survey Format*

Much has been written about the need for better decision making in the role out of infrastructure projects (Alçada-Almeida *et al.*, 2013, HM Treasury, 2013, Morgenroth, 2011, OECD, 2009, Rogers *et al.*, 2012, Ziara *et al.*, 2002), and their prioritisation; however there is a lack of literature on key gaps and priorities from the perspective of industry locating within a region. Furthermore, in light

of the unstructured rollout of infrastructure over the past decade (Moloney and McKeogh, 2013), it was decided to undertake a series of interviews with high-level stakeholders to understand the gaps and priorities for future infrastructural investment in Ireland and its impact on industrial growth. A total of 15 interviews were undertaken in 2013, with a structured list of questions for each interview. The interviews resulted in over 800 minutes of recordings, which were typewritten and imported to NVivo (NVivo, 1999-2013), a qualitative analysis software program. The group of interviewees were selected from two broad groupings: senior policy makers (PMs) within the public service (6 interviewees); and decision makers (CDs) within foreign direct investment (FDI) companies and Irish multi-nationals and small and medium enterprises (SMEs) (9 interviewees).

In selecting the interviewees it was recognised that they needed to be in a senior position within their organisations and preferably with responsibility for more than one location, thus ensuring their impartiality to identifying gaps within particular regions. The high-profile interviewees were thus selected on the basis of a number of criteria: an interviewee from each of the major industrial sectors; those holding Vice-President/CEO level positions and therefore part of the decision making process in their organisations. The industrial sectors were identified from CSO statistics of employment and output and included: Bio-Pharma; food and beverages; telecommunications; IT service sector; software development, support and vendors; Engineering and construction consultancy. The Policy makers are key personnel, holding strategic central and local government positions.

In order to maintain the anonymity of the participants, they will be referred to as participant PM1-6 (policy makers within central government and local authorities) and CD1-9 (corporate decision makers at a high level within their organisations). Their positions and the size of their organisations are outlined in Table 7-1 below.

Participant	Organisation	Occupation/Position within organisation and current location	No of global employees
PM1	Public Service	Former Departmental Government Secretary, Leinster and Munster	
PM2	Public Service	Former CEO and Present Chairman of semi-state organisations; Leinster	
PM3	Public Service	VP of Academic Institution and Former member of National Competitiveness Council; Munster	
PM4	Public Service	Senior Civil Servant/ Ministerial Adviser; Dublin	
PM5	Public Service	Director of Services, in a Local Authority; South of Ireland	
PM6	Politician - Former Minister	Former Government Minister; Dublin	
CD1	Large Irish MNC - Food ingredients, additives and products & Beverages	Retired CEO and founder of large Irish enterprise, many other business interests in Ireland	24182
CD2	SME - ICT: Telecommunications and broadband provider for regional Ireland	Business founder	10
CD3	Large Irish MNC - ICT: financial and support services	Senior Department Manager in organisation/company	2000
CD4	Large Irish utility company	Former CEO of semi-state and currently Chairman of Boards	1000
CD5	Large Irish MNC - Engineering and Construction Consultancy	Department Manager in organisation/company	2000
CD6	US FDI - ICT software development and support	VP/CEO Level	13,800+
CD7	US FDI - ICT: telecommunications hardware and software development	Chief Technical Officer - CTO	75049
CD8	US FDI - Bio-Pharma	VP/CEO Level	91500
CD9	European FDI - ICT: software development and support; outsourcing and hosting; consultancy	VP/CEO Level	434,246

Table 7-1: Profile of Interviewees, illustrating their positions within their organisations and geographical locations (Munster- southern counties; Leinster – counties around Dublin; Connacht –western counties).

7.5.2. Qualitative analysis process

The analysis of the interviews in NVivo seeks to identify and code common topics and patterns in the responses to the interview questions. Once the 15 interviews were coded, an exploration of the topics, with the number of references made to each and by whom, was undertaken. Obviously the majority of the topics are infrastructure related; however a number of other topics arose in the interviews e.g. national planning and policy making; local government; the emergence of 2 Irelands – Dublin and the rest of the country, at two different speeds of recovery and development. Figure 7-1 below illustrates the themes of the interviews, identifying the number of sources that discussed each topic and how many individual references were made to topics during the interviews of both the PMs and the CDs. In addition to the identification of the infrastructural gaps, this chapter explores the priorities for industries locating within a region and the political element to infrastructural planning.

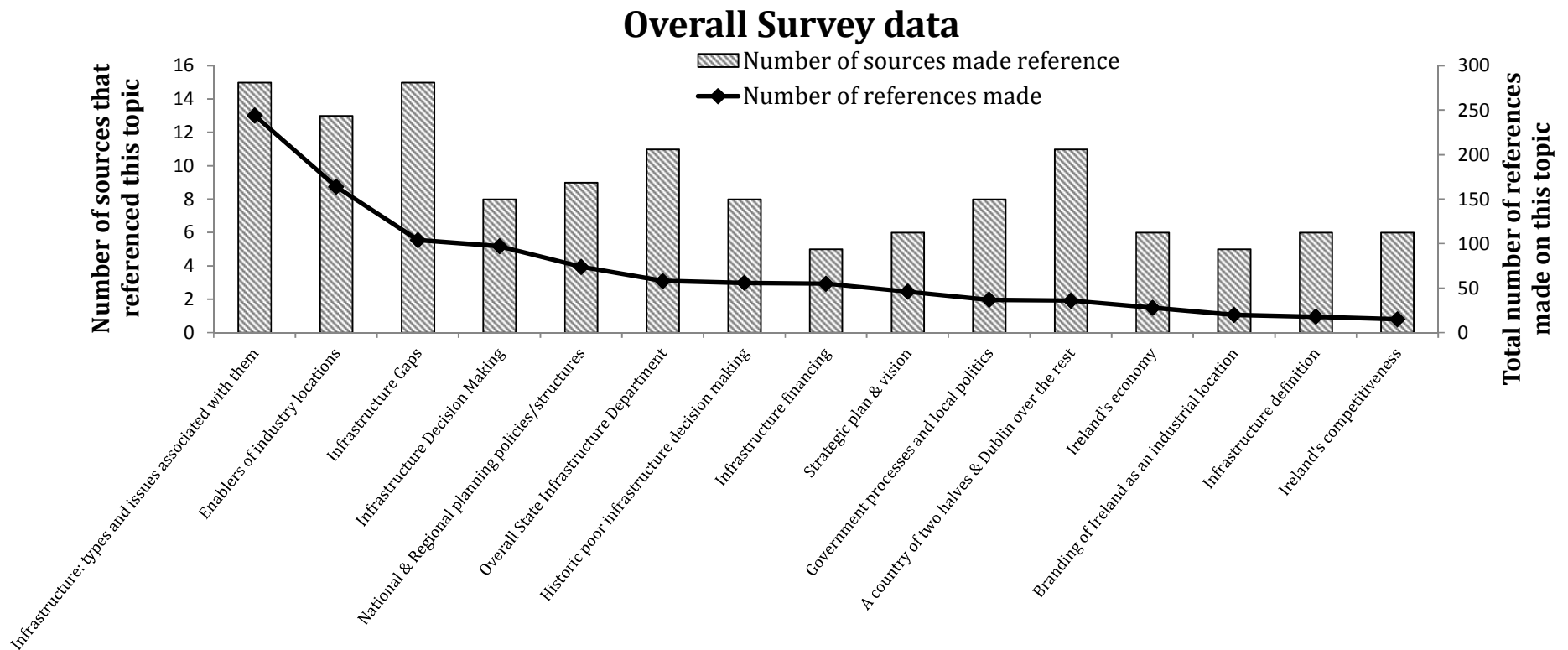


Figure 7-1: Overall survey structure illustrating main discussion topics, with the total number of sources and references for each topic

7.6. OBSERVATIONS FROM THE DATA

7.6.1. *Industries locating within a region*

There was considerable discussion on infrastructure as a driver to industry locating within a region: however there is a clear picture emerging of “two Ireland's” i.e. Dublin versus the rest of the country. Even though Ireland has a number of other smaller cities, it was suggested that they do not appear to have the critical mass to aid their development, in the way that Dublin has clearly done. In October 2012, the Irish Government announced the Local Government Bill, which was published in 2013 (Irish Government, 2012, 2013a). It abolished town councils (which numbered 80, and would have a much lower level of budget and policy making relative to the local authorities) and reduced the number of City and County Councils (Local Authorities) from 34 to 31. However, many interviewees suggested that the policy of maintaining 31 were still too many local authorities and should be revisited by Government, with a view to providing centres/nodes of sufficient mass to offer a counter balance to Dublin. The number of ‘nodes’ and their location should be carefully identified, with many feeling that there were too many ‘gateways’ and ‘hubs’ identified in the 2002 NSS (Government, 2002). These ‘nodes’ would need to be serviced by adequate and appropriately sized infrastructure; with airport connectivity identified by many as being critical.

The Dublin region has attracted a large percentage of new jobs over the past two years. While 25% of the population live within the greater Dublin region a number of interviewees also perceived and remarked on the large number of new jobs that have been created within that region over the past decade. Dublin has attracted many companies within the information and communications technology sectors (ICT) in particular, out of proportion to even its large population. Thus it is suggested that a ‘cluster effect’ is very much in evidence in Dublin. This is discussed later, in Section 7.7. The ICT sector, in line with EU NACE codes, includes information and communication; Publishing activities; Motion picture, video and television programme production, sound recording and music publishing activities; Programming and broadcasting activities;

Telecommunications; Computer programming, consultancy and related activities; and Information service activities (CSO, 2008).

There is also the importance of what might be termed supporting or social infrastructure for companies locating within an area i.e. hotels, restaurants, a vibrant town/city in which to socialize, schools and the availability of affordable and high standard housing. The industries come for their core business but the quality of life available to their executives and visitors helps them to stay and expand in the country. To ensure that there is infrastructure of sufficient capacity and quality in the region to enable industrial development is very much 'a chicken and egg' situation, where the infrastructure providers are waiting for industries to locate there, and the industries are waiting for or expecting infrastructure to be readily available. This is evidenced in the increasing use of empty factories/brownfield developments which have site entrances onto main roads, and connections to all of the main utilities. These brownfield facilities have the initial connections available, albeit of insufficient capacity to meet the industry/business needs. However, the long lead-in and potential uncertainty of permits and planning permissions is significantly reduced.

Many organizations are seeking to be part of a campus type development, where they are part of a larger clustering of their own sector and aligned partners, located alongside a third or fourth level institution. And once again these campus or industrial type parks offer plots within the park, with ready-made connections to utilities. Indeed, some executives suggested that corporate decisions are based on whether the proposed location of a facility will reflect well on the organisation, and therefore they are looking for quality locations to be 'flagship' facilities. Ireland does not have many of these offerings presently. Historically the Industrial Development Authority (IDA) developed industrial sites to target specific types of industries; however the location and quality of these and the services on offer, are not now in line with the present and future needs of industries.

7.6.2. Political Element

Ireland's political system has a local and national dimension, which facilitates strong local lobby groups (O'Malley and MacCarthaigh, 2011); this was referred to by a number of the interviewees. There have been instances where a small number of independent TDs (members of the Irish parliament) have held the balance of power in governments and have thus forced infrastructural investment decisions in favour of their constituency. Therefore it is impossible to ignore the political element in 'encouraging/facilitating' industries to locate within a politician's jurisdiction. There is a clear and urgent need for a national strategic plan, free of political interference; and the type of political patronage system, where each Government Minister fights for his own constituency. The need for a review and restructuring of Ireland's spatial planning process and governance will be addressed in further research; however many of the interviewees cited a clear and urgent need for a national strategic plan, free of political interference; and the type of political patronage system, *'where there is one for everyone in the audience needs to stop - it's killing Ireland'* (PM3, 2013). It was suggested that Ireland needs a single entity responsible for the development of a holistic, numbers based, integrated approach to infrastructure. This could be a 'systems-of-systems' approach like that currently being investigated in the UK (Hall *et al.*, 2014, Hall *et al.*, 2013) and suggested by the OECD and ESRI (Lunn and Ruane, 2013b, OECD, 2006a). The author highlighted the need for improved record keeping by Local Authorities and central Government Departments in previous work (Moloney and McKeogh, 2012). The need for accurate and up-to-date records is further reiterated by Aikman (Aikman, 2014) who suggests that *'the maintenance of accurate asset records is a cornerstone of asset management'*. One retired Senior Civil Servant suggested that a lack of standardisation of records suits some people, since decisions on infrastructural spending tend to be highly political.

7.7. INFRASTRUCTURAL GAPS

Each of the participants was asked to identify what they considered as the most important gaps in Ireland's infrastructure, for an industry and business to locate and prosper within a region. The results of this are illustrated in Table 7-2 below, identifying the top priority for each participant.

Participant	Largest perceived Infrastructural gaps to be addressed			
	1st Priority	2nd Priority	3rd Priority	4th Priority
PM1	Planning policy for developments	priority of gateways		
PM2	airport and road connections	Dublin centric thinking	a country overly structured - lacking in national strategy	good 1st impressions on the initial visit
PM3	enabling networks for industry to locate	water ²	roads and public transport	broadband ¹
PM4	water ²	planning process to focus on strategic sites	broadband ¹	power
PM5	broadband ¹	Airport connectivity	water ²	
PM6	power	broadband ¹	water ²	Dublin public transport system
CD1	emerging island of 2 Irelands	Airport connectivity	broadband ¹	water ²
CD2	broadband ¹	power		
CD3	water ²	broadband ¹	power	Skilled work force
CD4	broadband ¹	water ²	the power grid to take renewables	public transport and airport connectivity
CD5	wastewater capacity in industrial zoned areas	broadband ¹	power	water ²
CD6	broadband ¹	power - cheap reliable	airport connectivity	
CD7	water ²	broadband ¹	roads and public transport	
CD8	access via road network to airport/port	broadband ¹	parish type mentality – more national delivery	
CD9	road network	broadband ¹	power	

Table 7-2: Key infrastructural gaps identified in survey (Note: Broadband ¹, speed, availability & cost; water ², capacity and quality)

These infrastructural priorities were categorised under 5 main headings:
Broadband/communications connectivity; water quality and capacity;

transportation networks- roads, rail, airports and ports; the power grid; and spatial planning/governance. Points were then assigned on the basis of 4 points for priority 1; 3 points for priority 2 and so on. The aggregated scores for each category are represented as a percentage in Figure 7-2 below. This clearly demonstrates that broadband/connectivity is identified as the greatest need. Water, spatial planning and transport networks had similar scores. This chapter will consider broadband in the 1st instance and then water, individually in Section 7.7. The transportation networks include many individual systems, and the findings outlined in Table 7.2 above include airport connectivity and road links in particular. These networks and the issue of spatial planning and governance will be explored in future work by the author.

Key Infrastructure Gaps

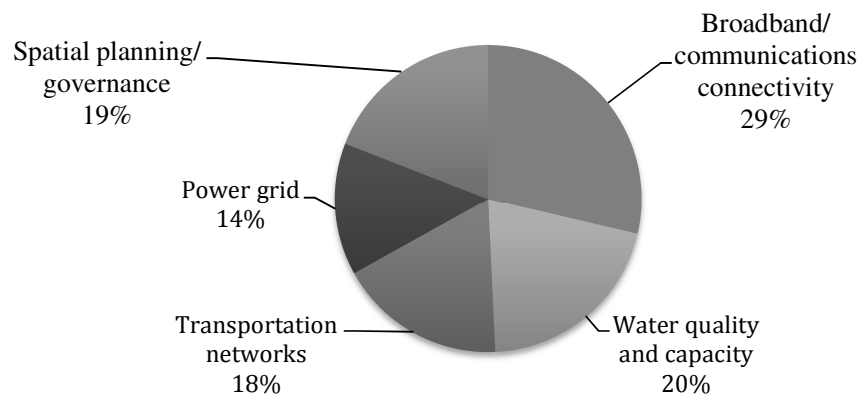


Figure 7-2: Key infrastructural gaps, weighted from interviews

7.8. KEY FINDINGS FROM THE INTERVIEWS AND QUANTITATIVE EVIDENCE OF IDENTIFIED INFRASTRUCTURE GAPS

7.8.1. *Communications Connectivity*

'We're in the new technological era and if you don't have high-speed connectivity, to which businesses and other countries are accustomed to, you are starting with one hand tied behind your back'

Broadband connectivity has been identified as the largest infrastructural gap in the study, and highlighted as the greatest need as per Figure 7-2 above. There is little doubt that high-speed and large bandwidth is a great economic advantage to a region, with studies showing that the internet can account for up to 6% of GDP in advanced economies (Department of Communications, 2012). In discussing connectivity, the key issues are: the broadband speed in the region; the latency; the bandwidth available for downloading and uploading; the resilience with backhaul from alternative lines and suppliers; and the availability of Tier 1 connectivity.

A Tier 1 connection is described as one in which the user can reach every other network on the Internet without purchasing IP transit or paying settlements to another owner. All external connectivity feeds to Ireland are terminated in Dublin, except one cable into Northern Ireland. Large organisations, and in particular ICT FDI companies, want to locate near a Tier 1 termination, for low cost and high resilience. So Dublin is in a key position to attract ICT companies, at the expense of the rest of the country. This is clearly evidenced in the distribution of ICT companies, the majority of which are located in Dublin, with 63% (CSO, 2013b) of all the country's ICT employees. Figure 7-3 below illustrates this for a selected number of the more populated counties.

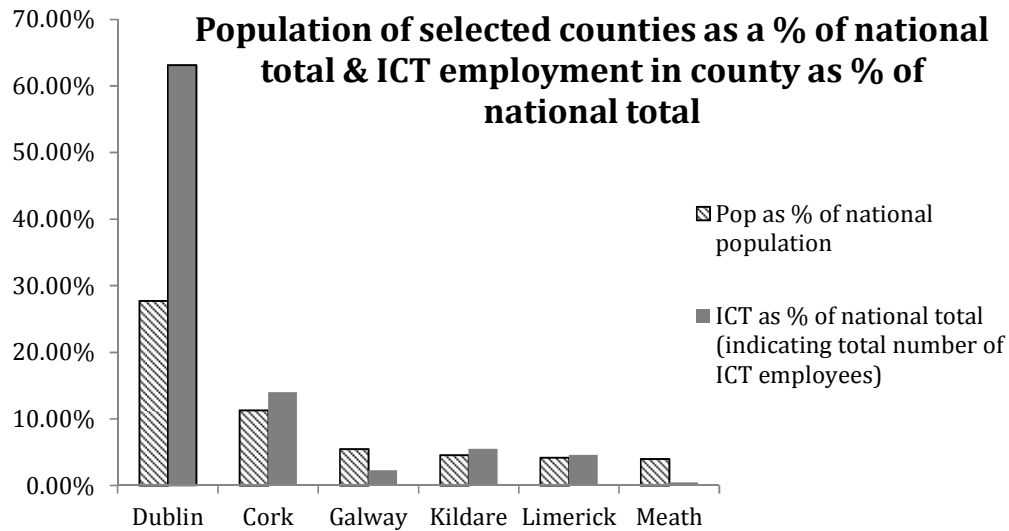


Figure 7-3: National population distribution and employment in the ICT sector in selected counties, as recorded in 2011

Source: CSO Industrial Statistics, the 2011 census (CSO, 2011, CSO, 2013b) and author's calculations

A recent report (CorkBIC, 2012) has identified that growth levels for Irish bandwidth have been approximately 50% year-on-year, with future growth forecast to be approximately 35 to 40%. It is estimated that the regions outside of Dublin, i.e. Cork, Limerick, Galway and Waterford, will account for 30% of national demand. However, while international connections to regions outside of Dublin have been mooted, to date none of these have materialized. The National Competitiveness Council called for Ireland to have a world class telecommunications infrastructure. It felt that Ireland ranked poorly in terms of local broadband of sufficient speed and that it is vital to the country's '*ability to do business*' (National Competitiveness Council, 2011)

The Irish government commissioned the installation of high speed fibre broadband, Metropolitan Area Networks (MANs) in 94 urban areas over the past decade (ENet). The overwhelming feedback in the interviews was that these need to be connected with additional fibre-cable, and that it is now time

for the Irish government to intervene and provide the backbone and operations in the same way as it constructed the MANs in the 2000's.

There are a number of broadband carriers between Dublin and regional Ireland eg. Cork, Galway and Limerick. But regional 1Gbps internet connectivity costs are upwards of 300% more expensive in regional Ireland relative to Dublin (CorkBIC, 2012). This is extremely uncompetitive, and was highlighted in a number of the interviews. Increasing connectivity requires access to underground ducting, which reportedly exists and is in the control of the semi-state bodies of Bord Gais, the National Roads Authority and Irish Rail. As these are state owned, surely these can be 'opened up' to new/additional fibre installation. The MANs are resilient and ringed, however, what now appears to be missing is this level of speed, bandwidth and commercial competition connecting the major centres. It has been suggested that the Irish government should undertake the provision themselves to open the telecommunications networks to regional Ireland. Similarly, with Tier 1 connectivity to the regions, it could be argued that the market has failed to provide such connectivity; which could be the basis for direct provision by the Government, without contravening EU state aid rules.

7.8.2. *Water capacity and Quality*

'water is like no other commodity, excepting food, in that it is essential for human life' (OECD, 2006a)

Overall, the need for a reliable supply of clean potable water of sufficient capacity was identified as one of the most important infrastructural gaps to be addressed. There have been a number of instances where water has been unavailable, infected with *Cryptosporidium* or had boil water (BWN)/ water restriction (WR) notices in place for a variety of reasons, with consequent reputational damage to Ireland Inc. In 2012 there were 50 BWN/WR notices in place affecting in excess of 50,000 users. While some notices were new in that year, many have been in place since 2008, when the EPA took over the reporting of water quality (EPA, 2013c).

The impact on Ireland's corporate image, while difficult to measure, is no doubt real. One particular contributor in the West of Ireland discussed the issues associated with the lack of potable water in its facility. They cited situations where they were forced to cancel senior corporate visits from the US and those of potential customers, due to the lack of potable water in both their facility and surrounding 4 star hotels. While Ireland prides its self on its developed economy, the reputational damage of boil water notices, is affecting the external perception and branding of Ireland.

Dublin has 1.5 to 2% available spare capacity (headroom) in its water treatment generation relative to consumption, which is extraordinary for a capital city. Indeed the entire Dublin supply region, with an estimated population of 1.5 million (Dublin City Council, 2014), had severe water restrictions for 8 days in late 2013. A senior Civil Servant suggested that the amount of money required for the level of investment needed in water and wastewater in the next 10 years outstrips most other areas.

Some of Ireland's water mains date back to 1890. Little investment has been done to upgrade the existing network which at this stage is an archaic, antiquated and leaking system, with 42% loss of water through leakage (Department of the Environment Community and Local Government, 2012). As far back as 2006, the ESRI called for investment in the rehabilitation of the existing network (ESRI, 2006). However, the water network and water treatment plants still require extensive work; in Q3 2013, 25% of the Irish population (944,447 people) water supply was on the Environmental Protection Agency Remedial Action List (RAL) (EPA, 2013b). Many of the non-compliance issues are blamed on weather events like prolonged rain, severe storms resulting in power outages etc. However, to have 25% of the population being provided with water from a treatment plant that is on an RAL is not acceptable in a developed economy (EPA, 2013b).

Moloney and McKeogh undertook a study (Moloney and McKeogh, 2013) which mapped the capital investment in the water and wastewater networks of each local authority. Their study revealed that a large number of counties spent well

in excess of the aggregated average investment per capita. Figure 7-3 compares the counties on the RAL listing (EPA, 2013a) and the investment that has been undertaken in each of the counties during the period 2003-2009. It reveals that there are water quality supply issues in 67% of the local authorities, with many local authorities investing in excess of 150% of the national average, as illustrated in Figure 7-4 below.

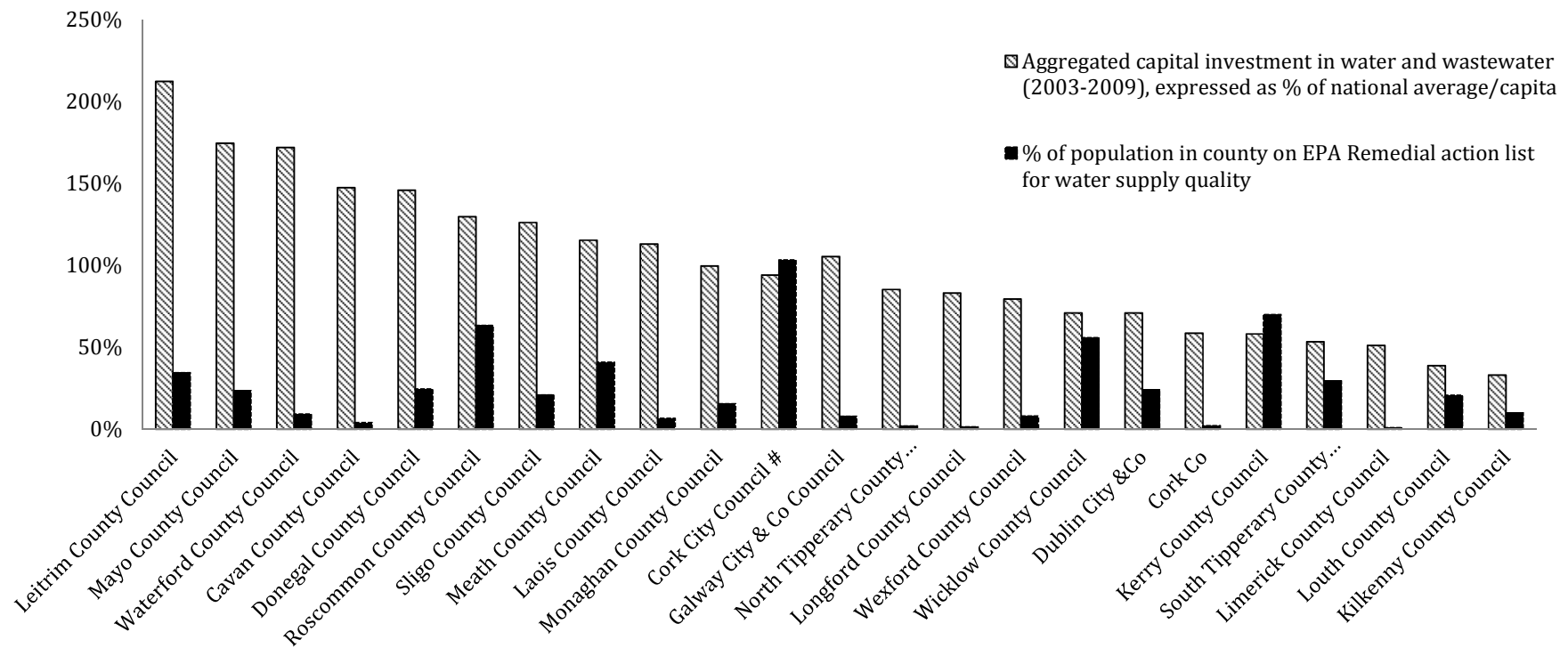


Figure 7-4: Counties on the RAL listing and the investment that has been undertaken in each of the counties during the period 2003-2009, in water and wastewater

Source: (EPA, 2013a, Moloney and McKeogh, 2013)

These findings would suggest that the monies have not been appropriately invested or the investment was insufficient to improve the water quality in the county. The new semi-state responsible for water and wastewater, Irish Water, was established in 2013. They are projecting a €1.77 Billion capital investment (Irish Water, 2014) (of which they currently have approved funds of €1.2b) over 3 to 4 years, which is on average 20 to 40% below the investment during the period 2003-2009 (Moloney and McKeogh, 2013). With the current shortage of capital funds, it clearly demonstrates the need for a more holistic review of water infrastructure investment, to ensure it's of the appropriate type, and in the right location.

7.9. CONCLUSIONS & RECOMMENDATIONS

The thesis of this chapter is that infrastructure investment in Ireland has not been linked to a clear long-term national development strategy; and as a result has allowed major infrastructural gaps to appear. This hypothesis was tested by conducting interviews with key stakeholders in industry and national policy makers. The interviews not only confirmed this thesis; but also gave insights to some of the underlying issues which need to be addressed in terms of Ireland's infrastructure. The issue of broadband connectivity and more specifically the issues around poor broadband access, speed and competitive pricing were identified in the areas outside of Dublin, with the need for Tier 1 connectivity. The water network requires urgent and very significant investment, with possible reputational damage being done to Ireland Inc. if not addressed in a speedy and coherent manner. The Irish Government in its review of infrastructure and capital investment 2012-2016 listed the key productive infrastructure priorities as public transport, roads and environmental services (which would include water services).

While this is in line with the findings of the research in this chapter for water and transportation, the key gap of broadband connectivity receives little economic support other than

'Developing the policy and regulatory environments to support the commercial sector in delivering next generation broadband technology, and committing Exchequer resources should specific instances of market failure arise'
(Department of Public Expenditure and Reform, 2011).

The research in this chapter clearly indicates the failure of the market to deliver, and thus it is time for the Irish Government to intervene with economic investment.

There was considerable discussion in the interviews on the emerging pattern of a country under 2 speeds – Dublin and the rest. It was felt that this is leading to a very imbalanced development of the country and that the increasing speed of Dublin's expansion could lead to the strangulation of its transport, water and power networks. Dublin's transport network is already nearing capacity, and as the city has started to recover economically, this will put immense pressure on the road and rail systems. The Dublin region has grown by 16% over the period 2002-2011 years (CSO, 2002, CSO, 2011); with the ICT sector having in excess of 60% of all its employees in Dublin.

There needs to be a new national spatial strategy and an entity responsible for its delivery, with strategic locations identified for increasing the economic growth of the country. Each of the infrastructural providers needs to then follow a priority which has been set by this entity, a national infrastructure agency. There is no point in zoning lands within a particular area if this is not a priority for the infrastructural providers. This entity should have responsibility for developing a 10 to 20 year plan because infrastructure development needs a long-term strategy; focusing on the type, capacity and quality of networks necessary in particular regions to support economic growth. It cannot be developed based on annual budgets, personal priority of government ministers in relation to future elections etc.

This chapter identifies the key infrastructural gaps and priorities for industrial development in a particular region. The data gathering for this chapter, i.e. the interview process, provided a great insight to the strengths and shortcomings of Ireland's infrastructural networks. The need for a high standard of broadband-

communications network was an overwhelming gap identified, closely following by a water supply of sufficient capacity and quality, along with upgrading the transportation networks. As positive signals emerge that Ireland is exiting the deep recession of the late 2000s (Duffy *et al.*, 2014b), the data presented in this chapter clearly identifies that for the economy to grow and develop, there must be a more focused investment on upgrading infrastructural networks. The evidence is conclusive that this has heretofore not been the case, and that a more holistic and inclusive methodology needs to be developed and implemented to ensure that the scarce funds available for infrastructure investment are of the correct type, capacity and in the necessary location to aid economic expansion.

8.0 SYSTEMS-OF SYSTEMS ARCHITECTURE FOR IRELAND'S INFRASTRUCTURE⁶

8.1. ABSTRACT

Infrastructure development is a long term process, which cannot easily adapt to sudden change; and infrastructure assets can have long lifetimes. Poor investment choices risk locking in poor policy choices for substantial periods of time. The 'need' for a new infrastructure asset arises due to demographic, economic or policy changes. But historically Ireland's infrastructure investment has also been driven, in part, by the pursuit of political / economic policies which have themselves 'created' infrastructure needs; and often decided on an isolated project-by-project basis. In contrast, a systems-of-systems approach is a fusion of network modelling, consideration of various policy options, and appraisal of the impact of alternative demographic and economic scenarios on multiple systems. In this way, the demand for new infrastructure can itself be tested under various policy scenarios, providing evidence for investment decisions. This chapter assesses Ireland's readiness to adopt a system of systems approach to infrastructure decision-making, and proposes a methodology for its development and implementation

8.2. INFRASTRUCTURE – A CRITICAL NATIONAL ASSET

'The basic physical and organizational structures and facilities (e.g. buildings, roads, power supplies) needed for the operation of a society or enterprise' (Press 2008)

There is little doubt that reliable infrastructure, of sufficient capacity, is critical to a country's economic growth and prosperity, as extensively covered in the literature (Helm *et al.*, 2009, Lunn and Ruane, 2013b, Martins *et al.*, 2013, Munnell, 1990a, Munnell, 1990b, Ouyang, 2014, Rinaldi *et al.*, 2001). It is more

⁶ Submitted to ASCE Journal of Infrastructure Systems on 10th of December 2014 and currently under review.

difficult to understand which type of infrastructure and of what capacity can contribute to growth and prosperity. Many alternative methodologies are currently in use that aid in formulating decision-making for infrastructure investment; however most generally look at the specific project in question (with the focus of this chapter being productive networks). It is clear that for any one element of an infrastructure network to operate, it requires supply or assistance from another network. For example, a water supply treatment plant needing a power supply network. A Systems of Systems (SoS) approach looks at constituent systems e.g. a water network, a power network; identifies their interdependencies with other systems; and examines the impact of one network on another. In adopting such a spatial and dynamic approach, alternative drivers to development within an area or region, and alternative growth and demand scenarios can be tested. This is currently difficult to do using static methodologies. DeNeufville and Scholtes describe *'current methods as inadequate and passive'*, thus pointing to a need to adopt a systems approach to decision making (Neufville and Scholtes, 2011).

Internationally, an SoS approach is being advocated for infrastructure investment decision making. For example, the Institution of Civil Engineers in the UK called on policymakers to utilize interdependency analysis and infrastructure timelines to plot current and future policies and sought greater coordination and communication between government departments (ICE, 2013). Similarly, many agencies and reports have called for a more coordinated plan for Irish state infrastructural investment (Forfas, 2012, ICE, 2013, Irish Academy of Engineers, 2011).

This chapter proposes the use of the Systems-of-Systems (SoS) methodology in Ireland, to optimize which infrastructure networks require to be upgraded, where, and by how much. In previous work undertaken by Moloney et al, evidence would suggest that state infrastructural investment has been mis-spent or overinvested in particular areas such as water and wastewater, which now serve ghost estates and underdeveloped towns and villages (Moloney and McKeogh, 2013). This chapter will test how the use of an SoS approach could

have aided in a more holistic and sustainable development in Ireland; a case study will be used for illustration.

Ireland has recently exited its EU and IMF bailout programme, and is projected to have a 5% GDP growth in both 2014 and 2015 (Duffy *et al.*, 2014a). It is now crucially important that precious funds earmarked for capital infrastructure investment be spent wisely to deliver the optimum return, which heretofore may not have been the case.

8.3. HISTORIC INVESTMENT PATTERNS

Ireland invested considerably in its infrastructure over the period 2000 to 2010. However it is clear that Ireland has quite some distance to go. The World Economic Forum (WEF) Reports identify infrastructure as a '*basic requirement pillar*' for competitiveness (Schwab, 2014). Ireland ranks 25 overall in competitiveness (of 144 countries); the overall quality of its infrastructure at 36th.

Morgenroth has illustrated that Ireland's investment of general government gross fixed capital formation (GFCF) has been in line, as a percentage of its GDP, with its European counterparts (Morgenroth, 2014b). So while the investment was considerable, one has to question why it did not improve the country's WEF infrastructure rating and ranking as it should have. It is suggested that this is due to a combination of: inflated construction costs; monies invested to support vacant houses; oversizing of infrastructure; and investment in incorrect locations (Irish Academy of Engineers, 2011, Moloney and McKeogh, 2013, Morgenroth, 2014b). Indeed Gramlich (Gramlich, 1994) argues that the most important question in looking at infrastructural investment is not on whether there has been a shortage of investment but rather whether government policy has been appropriate.

8.3.1. *The National Spatial Strategy and Political Influence*

Ireland recognized the need to think strategically about spatial development, and developed its first National Spatial Strategy (NSS), in 2002 (Irish

Government, 2002). This study was far-reaching in its vision. It identified key regional gateways and hubs which aimed to attract industrial development and housing construction and encourage more balanced regional development. However it has proved to be very much a static document, i.e. it was written in 2002 and has not yet been replaced or revised. Such a strategy cannot remain valid indefinitely, as demographics and economic circumstances change over the projected 18 years. A significant example, as shown in previous work by Moloney et al. was how housing construction quickly out-reached projected numbers, but construction still continuing in specific towns and regions (Moloney and McKeogh, 2013). This led to in excess of 2,800 ghost estates (Department of the Environment Community & Local Government, 2011) during the economic downturn. Unfortunately many of these houses were constructed in rural locations which are unlikely to see commensurate economic growth, and thus will remain largely vacant. Despite the aspirations in the National Spatial Strategy, or in regional development plans, at local level considerable influence was exercised by landowners and developers in all parts of the country, to persuade Local Authority Councillors to exercise their reserved functions, and so force the rezoning of land for housing. The consequential impact of such rezonings, in terms of infrastructure provision, was to drive water services investment to serve the resulting housing developments (Moloney and McKeogh, 2013). Now, as economic recovery begins in Ireland, this large stock of vacant houses in rural areas will not address the current housing shortage in the large urban centres e.g. Dublin and Cork, further confirming the negative consequences of not following a more holistic evidence-based approach.

In overall terms, investment decisions, such as housing projects with their attendant infrastructure needs, have generally been made in isolation. The project might make financial sense in itself, and may give a good internal rate of return or cost to benefit ratio; but this approach fails to address the project's impact, positive or negative, on other systems with which it is interdependent.

It should also be noted that state capital investment decisions are subjected to the political cycle. Similar to many western democracies, Ireland's maximum

term of office for its Parliament (the Dáil) is 5 years (Irish Government); with new Governments and Ministers often reprioritising investment plans in their particular departments. But the infrastructure investment cycle can be considerably longer, particularly at the pre-construction stages of technical feasibility, decision-making, securing statutory permissions, ensuring public support and committing funding. This mismatch of timeframes exposes infrastructure investment decisions to the risk of short-term or purely political appraisal, either for or against a proposal, that may have little basis in evidence. It is the thesis of this chapter that a SoS approach would provide a greater degree of evidence-based support for or against a potential policy or investment decision, so as to help insulate superior decisions from countermanding political influence.

8.4. THE NEED FOR CHANGE

To evaluate the need for change of the current form and performance of infrastructure decision making, a series of interviews were undertaken with key stakeholders, within two main groupings. The first group were nine corporate decision-makers that hold vice president/chief executive officer level positions within their organizations. The second cohort were six policymakers drawn from local and central government departments, academic research institutions and members of Parliament as per Table 8-1 below.

	<i>Occupation/Position within organisation</i>	<i>Organisation</i>
<i>Policy Makers</i>	Former Departmental Government Secretary	Public Service
	Former CEO and Present Chairman of semi-state organisations	Public Service
	VP of Academic Institution and Former member of National Competitiveness Council	Public Service
	Senior Civil Servant/ Ministerial Adviser	Public Service
	Director of Services, in a Local Authority	Public Service
	Former Government Minister	Politician - Former Minister
<i>Corporate Decision Makers</i>	Retired CEO and founder of large irish enterprise, many other business interests in Ireland	Large Irish MNC - Food & Beverages
	Business founder	SME - ICT
	Senior Department Manager in organisation/company	Large Irish MNC - ICT/service industry
	Former CEO of semi-state and currently Chairman of Boards	Large Irish utility company
	Department Manager in organisation/company	Large Irish MNC - consultancy
	VP/CEO Level	US FDI - ICT
	Chief Technical Officer - CTO	US FDI - ICT
	VP/CEO Level	US FDI - Pharma
	VP/CEO Level	European FDI - ICT

Table 8-1: Profile of interviewees

The purpose of these interviews was twofold: to identify infrastructural gaps; and to gather feedback on the effectiveness or not of current government policy in relation to infrastructure decision-making.

In undertaking the interviews, which were recorded, typewritten and analyzed using computer assisted qualitative data software package (CAQDAS) NVivo (NVivo, 1999-2013), the key areas which arose in relation to decision-making are summarised to the following key points:

- an excess of local political input to decision-making
- recent construction boom in Ireland clearly facilitated by zoning and planning
- Ireland should be more interested in strategy rather than structure
- Ireland's current planning system is dysfunctional
- strategic planning is stifled by political influence and intervention
- Ireland's infrastructure is stressed because of the recent economic growth, followed by a lack of capital investment
- the prioritisation (when funds are deemed to be available) of '*shovel ready*' projects by government ministers rather than projects based on greatest need and/or return
- regional corridors of good ICT connectivity and infrastructure service makes eminent sense but would not sit well with Ireland's local/parish politics
- different agencies making investment decisions on discrete assets with no one central body formulating decisions based on the wider economic benefit

Overall the feedback from the interviewees shows a need for change in infrastructure provision, with joined-up thinking at a national, regional and local level. As Ireland currently does not have one government department or agency in charge of infrastructure, the opinion of the interviewees was sought on this topic. All interviewees agreed that one central agency or department would be a positive step in delivering cohesive and consistent thinking; however the fear was voiced that this Department could be '*Dublin centric*'. It was interesting that the retired government department General Secretary suggested that '*if there were no politics involved you would start with a plan for the country and where Ireland is going*'. And this in essence is what a Systems of

Systems approach would deliver. It would allow for a national assessment to be undertaken, and provide evidence to policymakers and decision-makers alike.

The focus of this chapter is to identify and discuss both the merits and challenges of developing a dynamic simulation method for Ireland's productive infrastructure networks (eg. water, waste-water, transportation, power and ICT connectivity). Heretofore individual infrastructure networks have been modelled/analysed in isolation. This is recognized by Thissen and Herder who discuss historical infrastructure systems that were both physically and logically separated (Thissen and Herder, 2009). But now due to technological advances, in particular with information technology, infrastructure systems have become interlinked and interdependent. Rinaldi et al discusses the need for a greater and deeper appreciation of the interdependencies of individual infrastructure networks, and recognizes the difficulty in developing a comprehensive architecture for the modelling and simulation of interdependent systems (Rinaldi *et al*, 2001). Of course the first step in this process is to develop models of the constituent systems. When the current individual systems have been modelled, then interdependencies with the other systems can be identified and modelled.

8.5. A SYSTEMS-OF-SYSTEMS APPROACH TO IRISH STATE INFRASTRUCTURE INVESTMENT – IS IT POSSIBLE?

8.5.1. What is SoS?

A review of the literature gives many (often complex) definitions for ‘Systems of Systems’; however Jamshidi’s definition (Jamshidi, 2009) is the one preferred by this author.

‘Systems of systems are large-scale integrated systems that are heterogeneous and independently operable on their own, but are networked together for a common good’

While the use of such an approach in large-scale projects outside of computer science and electrical engineering has been somewhat limited, there is growing interest in the SoS approach to national infrastructure planning, and indeed in further using the models and simulations to access critical national infrastructure (Alderson, 2012, Barr, 2012, Hall *et al.*, 2013, ICE, 2013, OECD, 2006a, Young and Hall, 2014) systems. The primary focus of the work in this chapter is to explore the development and use of SoS initially to prepare a roadmap for future infrastructure investment. However, a SoS approach would also provide the starting point for undertaking a critical infrastructure analysis.

As outlined in section 8.2, the SoS methodology is based on understanding the impact of each independent or constituent system and how it interacts or is interdependent with other systems. Rinaldi *et al* identified 6 key dimensions for describing infrastructural interdependencies, based on: infrastructure characteristics; how the system is operating; interdependency types; environmental dimensions; the response behaviour of the systems; and the types of failure (Rinaldi *et al.*, 2001).

The approach models each constituent network; and identifies the interdependent nodes. This allows the impact that a change in one system has on another system to be identified, quantified and evaluated. One such example would be a water system: the water is abstracted from a source e.g. reservoir ;

this reservoir could also be a power source; the water abstraction is dependent on power for pumping; the water treatment plant is dependent on power and ICT communications for operation; and a road is needed to the water treatment plant for its operation. So while each of these power, water, ICT and road systems operate independent of each other, there is interdependence for the resilience of their operation.

8.6. SYSTEMS OF SYSTEMS AS AN EVIDENCE BASE FOR DECISION MAKERS

Historically, capital investment decision making has been made by each utility/system operating within their own silo. The output from a SoS analysis allows policy and decision makers to make evidence based decisions, as illustrated in Figure 8-1 below.

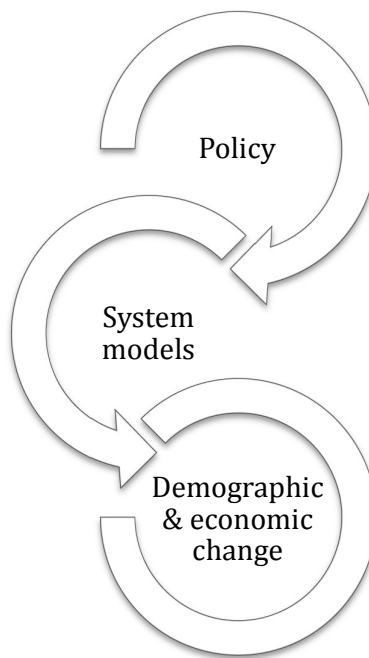


Figure 8-1: The integration of policy, constituent models and change scenarios

Indeed Lunn and Ruane suggest that a systems approach allows the key stakeholders to be '*embedded in a dynamic system*' (Lunn and Ruane, 2013b).

The methodology allows for communication between the different parties, allows scenarios to be tested and optimised, with feedback loops. Best and Holmes suggest that it could be transformative to decision making (Best and Holmes, 2010). The OECD in its review of infrastructure to 2030 *'highlights the importance of considering infrastructure not just as distinct sectors but also as a series of interdependent systems'* (OECD, 2006a). They further identify that as independent systems interact ever more closely, *'it allows for increased synergies while also heightening vulnerability to disruption and failure'*, in many cases potentially cascading failures.

8.6.1. *International developments in Systems-of-Systems*

The use of SoS is increasingly seen as a methodology for quantifying system vulnerabilities as part of a country's critical infrastructure network (Labi *et al.*, Marrone *et al.*, 2013). A recent EU report has identified that *'A part of our new approach is looking at the interdependencies between critical infrastructures, industry, and state actors'* (EU Commission, 2013). The development of a SoS approach would assist Ireland in preparing its critical infrastructure response plan, in line with the EU directive on European Critical Infrastructures (European Union, 2008)

The European Union has recently launched a state-of-the-art report on systems of systems. It recognizes that the increasingly *'connected nature of modern society requires a more complex study of individual networks and thus the need for and a SoS approach to decision-making'* (T-Area-SoS, 2011). The EU has funded this and a number of other research groups under FP7, the 7th Framework Programme funded for European Research

The U.S. Department of Homeland security undertakes infrastructure analysis modelling and simulation through the national infrastructure simulation and analysis Centre (NISAC) (Parrott, 2013). Other research groups include the Next Generations Infrastructures group in TU Delft and the DANSE consortium (DANSE Consortium, 2014).

In the UK, the Infrastructure Transitions Research Consortium (ITRC) have issued numerous studies and journal papers (Hall *et al.*, 2014, Hall *et al.*, 2013, ITRC, 2013, Young and Hall, 2014), which clearly demonstrate the use of a SoS approach as a

'dynamic, flexible system which has the capability to be a holistic tool to model infrastructure networks; and to test them for a range of drivers such as demographic change, varying economic options, and change of fuel composition'

eg, cost of carbon, transition to green energy; all by reference to high, medium and low growth scenarios. ITRC have developed preliminary models, which can be used to test for various system constraints, growth, and vulnerabilities.

The difficulties in undertaking modelling and simulations of national infrastructure systems has been clearly recognised (Abbott, 2006, Alçada-Almeida *et al.*, 2013, Barr, 2012, Best and Holmes, 2010, Hall *et al.*, 2013, Rinaldi, 2004, Rinaldi *et al.*, 2001) and pose many challenges, inter alia:

- availability and accuracy of asset data to develop constituent models
- privacy/copyright issues as some assets are in private ownership
- security issues – the storage of large scale infrastructure information in one location
- availability of real-time data to calibrate and validate models
- maintenance of database information, to ensure it is in real-time and dynamic

Rinaldi *et al* suggests that a comprehensive SoS architecture must leverage new and existing software applications; access as wide a variety of data as is possible bearing in mind the difficulties outlined above; accommodate a broad range of analysis scenarios (Rinaldi *et al.*, 2001).

8.6.2. An Irish SoS Framework for infrastructural investment

Figure 8-2 below illustrates a proposed methodology which would enable Ireland to develop and adopt a SoS approach to infrastructural development. Such a methodology, by its very nature would be holistic and integrated; would be inclusive of the various stakeholders – academics, policymakers, financiers, developers, and planners, with outputs providing an evidenced-based approach to planning the future spatial development of Ireland.

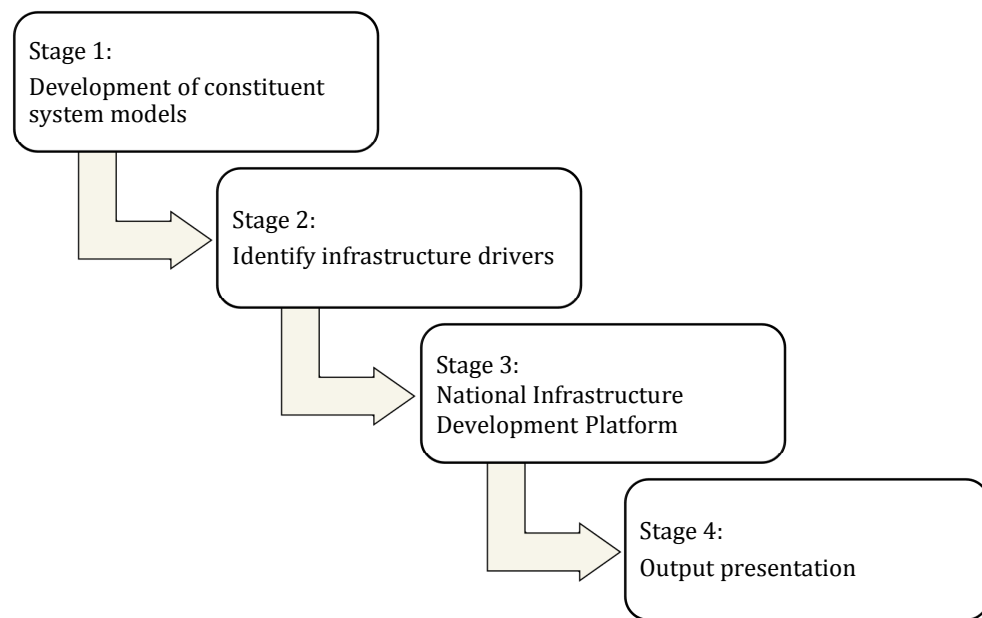


Figure 8-2: Proposed framework for Ireland

- Stage 1. The development of constituent system models for: water, wastewater, transportation, energy and ICT networks
- Stage 2. The identification and quantification of alternative infrastructure drivers of change and the development of scenarios for: high, medium and low growth; and capacity or demand constraints
- Stage 3. The development of a National Infrastructure Development Platform (NIDP)
- Stage 4. The output from the NIDP – results of testing alternative scenarios

Figure 8.3 below illustrates an overall preliminary system architecture for the proposed methodology

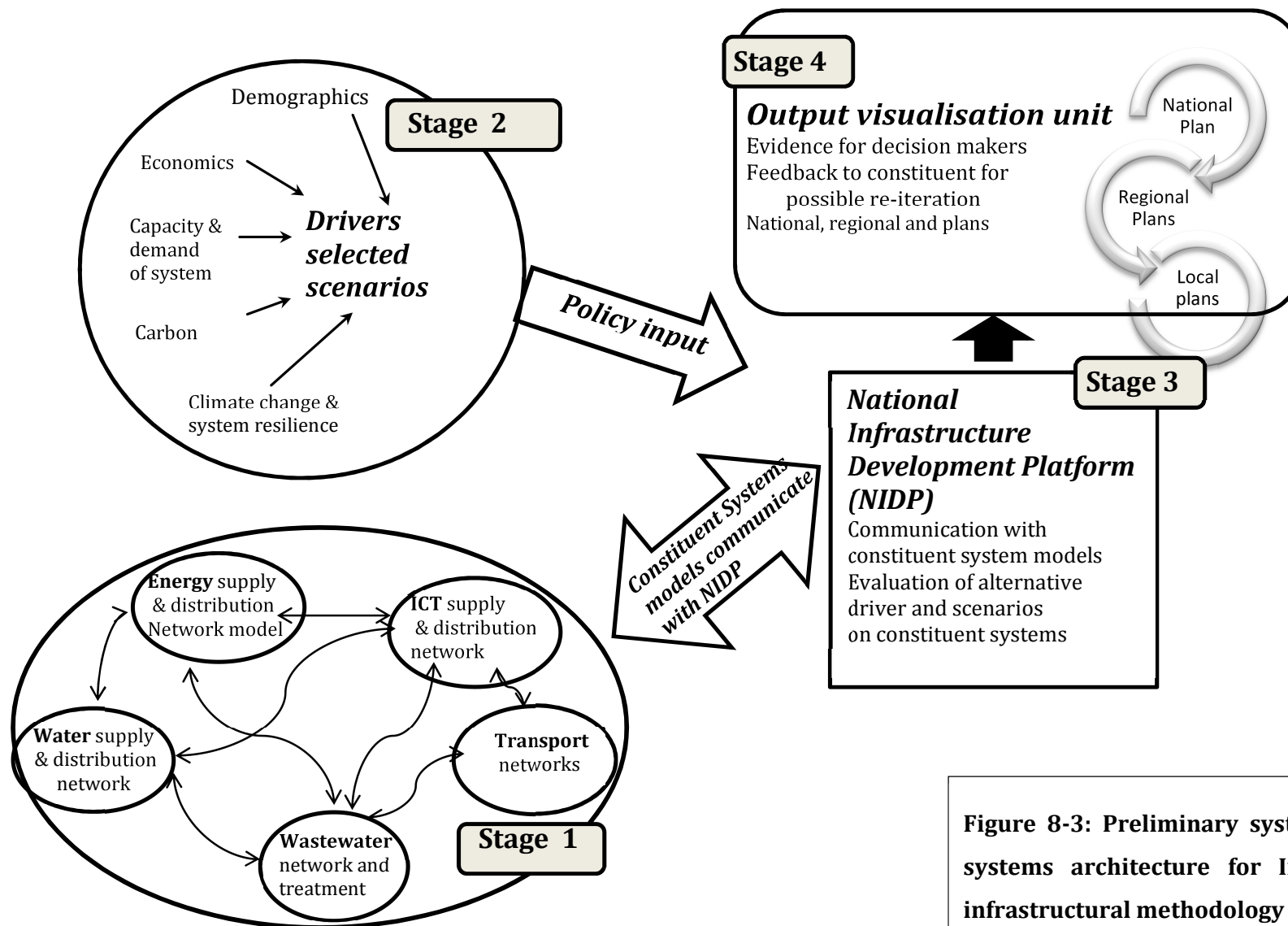


Figure 8-3: Preliminary systems-of-systems architecture for Ireland's infrastructural methodology

8.6.3. *Stage one: Development of constituent systems models*

The first step in the development of this methodology would be the collation of data and the development of constituent system models. It is suggested that the five constituent systems that would initially form part of this work would be the energy, water, wastewater, transport and ICT communication networks. Ownership of the various systems differ, from semi-state to private ownership. The structure of the individual networks poses differing complexities. An example would be that power is generated to match demand. On the other hand a wastewater treatment plant, will generally only receive waste from the network of pipes connected to it.

The INSPIRE Directive

The European Union under the INSPIRE directive (European Union, 2007), and subsequent regulations, requires member countries to record specific geospatial data and make it freely available. It requires member states to report the existence of the datasets and their compliance with the data they record.

Annex III requires that datasets of '*Utility and governmental services, includes utility facilities such as sewage, waste management, energy supply and water supply...*' be recorded in line with the directive (European Union, 2007).

Each country reports every two years and Figure 8-4 below shows Ireland's position relative to some of its EU counterparts. Ireland has less than 60% of the datasets recorded and of those less than 40% are compliant with the requirements of the EU. So therefore the initial data gathering and preparation of the system models will present a significant challenge, however one that the EU requires Ireland to undertake in any case.

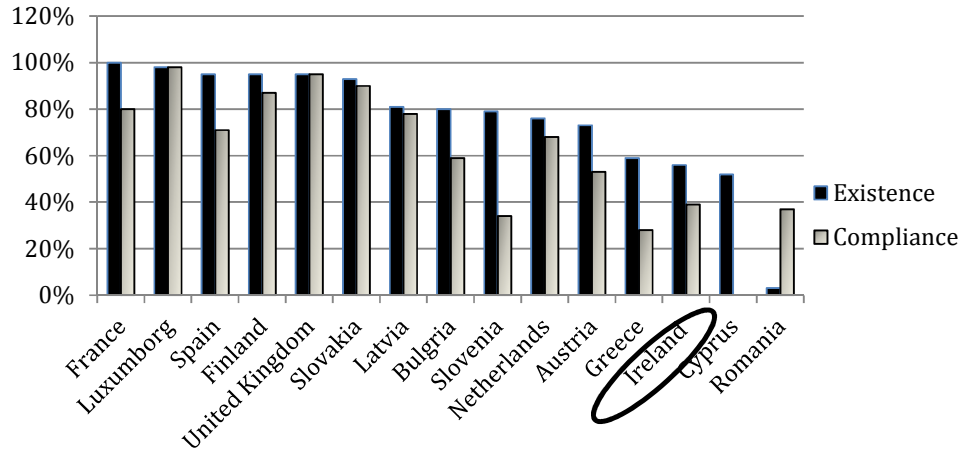


Figure 8-4: Metadata compliance with INSPIRE (EU Directive) for spatial data (European Union, 2007, INSPIRE, 2014)

Source: European Union INSPIRE (INSPIRE, 2014) and authors own calculations

Evaluation of accessible data

To develop a model of a network requires data which is accurate both spatially and with all elements/nodes included. This in itself would be the initial challenge, as Ireland has varying degrees of information available on its different systems. To assess the viability of preparing constituent system models, a proposed list of 116 different data sets/layers was prepared after a literature review of current international practice; and information was sought on the level of data that is currently available and accessible (Barr, 2012, European Union, 2007, INSPIRE, 2014). Table 8-2 below identifies the main systems, with the system and information owners identified, and an initial estimate of the availability of data in each set. It does not address issues of data protection and privacy, which will of course be important, but fall outside the scope of the present paper. Likewise, data sharing across various stakeholders will be vital to the success of a SoS approach; addressing this issue will form a major component of implementing such a methodology.

	<i>Number of datasets suggested</i>	<i>Primary source of Data</i>	<i>Existence/availability of data sets</i>	<i>System owners</i>
<i>Demographics</i>	9	Central Statistics Office (CSO) census and website	Excellent, due to recent 2011 census. Data mostly open-source	CSO data
<i>Transportation</i>	34	Interview with Department of Transport	The National Roads Authority, Irish rail and the bus routes of the state-owned lines are reasonably complete. Limited access to realtime data. Private bus route not available. Port and Airport data held by individual semi-state companies	Semi-state agencies and individual transport company owners
<i>Water & wastewater</i>	35	Interview with Irish Water, who took over ownership and management of utilities in January 2014 from 34 Local Authorities	Overall poor - Very limited data, and lack of confidence in datasets available. Currently compiling data from 34 local authorities, with varying data. Modelling of networks will commence once data gathering complete. Very little realtime data.	Currently transferring all assets to a new semi-state utility company
<i>Energy Data</i>	30	Utility companies	National usage available, reasonable level of data on energy use by type of fuel for both domestic and industrial. Consumption and geodata held by utility providers and should be possible to access.	Gas and power distribution grids in semi-state ownership. Generation public & private ownership
<i>ICT</i>	8	Information gathering from various sources	No overall data set available, as the telecoms network was privatised in 1999. A large number of ICT providers, and thus no overall map. Some semi-states have underground ducts which could be used for running data/fibres, but again data not freely available.	Majority of lines and fibre in disparate ownership. Some Fibre networks in towns and cities owned by State but operated privately

Table 8-2: Availability of datasets for constituent systems

The dataset list included the following:

Demographics: geospatial information on the population, age profile, land use, income, ethnicity, household size, commuting patterns and lifestyle

Water and wastewater: water treatment plant location, capacity; wastewater treatment plant capacity by plant and demand by user; network size, location and capacity; geospatial data on consumption by user type; power usage

Energy: geospatial data on household and industry demand and usage by fuel type; energy infrastructure capacity and demand for generation and distribution by fuel type

ICT: geospatial data on households and industry by usage type and capacity; tier 1 connectivity location and capacity; fibre location and capacity; vacant underground ducts (thus possible future routes for fibre); capacity and demand of communication network for both fixed and wireless

It is very clear the initial challenge will be gathering the asset data, and developing a constituent system model. However, the development of the dataset list indicated in Table 8-2 should provide a reasonable start to the process.

8.6.4. *Stage two: Development of infrastructure drivers and scenarios*

In order to develop a holistic and integrated methodology for Ireland, the drivers or initiators of development or change to infrastructure development must next be identified. There are some obvious ones like aging assets (which would be included in an asset management system); demographic change; and economic change, either growth or reduction. However, there are drivers which may not initially appear obvious: technological change or development; climatic change thus challenging the resilience of existing networks or assets; and the possible variability in the accounting of carbon footprint.

Infrastructure is considered a long-range investment and in looking at possible drivers to assess the need for an asset, one would need to consider short, medium and long-term scenarios.

Thus it is suggested that the following at a minimum would form the 'drivers' section of the evaluation methodology:

- Demographics and their spatial variability – policy in relation to growth projections for Cities and the rural areas
- Economic change and its variation across different regions within the country
- Possible climatic changes, testing the resilience of infrastructure assets such as road surfaces, harbours, power lines. The Intergovernmental Panel on Climate Change in its 2014 climate change report identifies that governments at various levels are starting to develop plans and policies so as to integrate the climate change agenda into broader development plans (IPCC, 2014).
- The impacts of carbon costing and fuel change mixes, e.g. a 'green' fuel
- Impact of policy (Global and European) in relation to CO₂, and its impact on national targets and taxes
- Policy strategies in relation to the operation of the assets, eg. capacity and demand assessment. For example the recent introduction of metered water charges in Ireland will most likely reduce usage. Thus policy can increase available capacity without constructing additional assets.

8.6.5. *Stage 3: National Infrastructure Development Platform*

This would require the establishment of national infrastructure development platform (NIDP), with the ability to communicate with constituent systems, develop scenarios and test each of the drivers as identified in stage 2 of the process. Key components / requirements:

- Communicate with the constituent system models and the different

infrastructure driver sets

- Integration and Iteration layer – which would develop and store the results of different test case simulations and provide the pathway to feedback loops to the constituent system models. This would allow the evaluation of a change in one system, and the resulting impact on its interdependent systems.
- The NIDP would be maintained as a ‘live’ system with re-runs at suitable timeframes, to understand change and its impact as it occurs, i.e. demographic increase in a particular region and its possible impacts on the constituent systems.
- Undertake the simulations in line with the varying time scales of the different constituent systems. These can have substantial impact of the system models and simulation outputs. (Rinaldi *et al.*, 2001)

8.6.6. *Stage 4: The Output*

Heretofore Ireland’s spatial planning in the form of the NSS, has been a static process of reports etc, and it is suggested that the development of a dynamic SoS plan be developed. It is imperative that it would remain dynamic, with responsibility been given to a single body to ensure it would be maintained as a ‘live’ system, enabling future scenarios to be tested, e.g. new government policy etc. Key components / requirements:

- Deliver the answers to the ‘what-where-when’ question for infrastructure development
- Evaluate based on a multi-attribute performance of cost, reliability, adaptability, environmental impact

The tool could be further developed to optimise the constituent systems, thus further aiding policy and decision makers on the possible outcomes of a scenario.

8.6.7. *How could it contribute to Irish infrastructure investment decisions?*

Adopting such a methodology would present many initial challenges, the first of these being the data gathering exercise as discussed above (Stage one of the process). However, developing an overall model of each constituent system would be a necessary precondition to the success of the SoS approach, and the usefulness of any output. However, once it had been developed, the SoS approach would offer significant benefits relative to the current 'traditional' approach to infrastructure decision-making, as summarised in Table 8-3 below. Both approaches are compared under the headings of spatial dimension; long term planning; holistic sustainable decision making; and decisions being subjected to political influence, with an SoS approach clearly offering substantial benefits over the traditional approach.

Systems of Systems Architecture for Ireland's Infrastructure

	Parameter	Traditional Approach	Systems of systems
Spatial	Interaction with other systems during DM	Individual system project evaluated in isolation	interaction/interdependencies of adjoining systems taken into account
	Network changes considered in evaluation	Static type process- once inputs decided for evaluation, seldom revisited	Dynamic - once models and iteration developed, relatively easy to rerun with new scenario, i.e. sudden change in demographics & economics
	Change in desired outcomes	Static type process- very difficult to change	least cost/ optimised cost to achieve desired outcomes
Long term planning	Long term planning	Silo operation & future planning for DM of individual systems	holistic evaluation of system with its interdependent systems
		Asset constructed according to timeframe of asset owner	Optimal time to construct an infrastructure asset identified
	Zoning of land for development	Each Local Authority develops its own plan	National vision for nodes of development and thus feedback to local authorities on 'suitable' quantity of zoned land, based on demographic patterns.
			SoS would have feedback on demographic change, thus highlighting need and allowing policy makers to 'decide' on future plan for county
			Allow for identifying nodes for industrial development and thus highlighting constituent systems needs
	Long term planning of infrastructure	Very time consuming and cumbersome	once models developed relatively easy to rerun alternative scenarios & provide evidence for decision making
Holistic sustainable decision making	The island of Ireland very small - size of small to medium city. Need a national plan	NSS developed 12 years ago & not revisited	once models developed relatively easy to rerun alternative scenarios
	Apply holistic decision making in line with sustainable development	Very difficult with a static approach	once models developed relatively easy to rerun alternative scenarios to evaluate sustainability
	Optimum time to build an asset	Is disconnected from real time data	SoS can have feedback loops to constituent system that can trigger the need/optimum time to construct the asset for an asset
	Resilience of assets	Cannot run scenarios	Run scenarios to understand what the loss or damage of an asset would have on the overall network
Political influence	Government cycles	Projects prone to individual ministerial input/manipulation	More long term strategic planning - thus more difficult for 'immediate' political change
	Policy dictated constraints	Take a single approach	SoS facilitates input of alternative scenarios to policy constraints & evaluate optimum for chosen constraint
		Disconnected from policy alternatives	
	Political influence	vulnerable to political influence	Very difficult to argue with evidence and politically more risky to propose option contra to evidence.

Table 8-3: A traditional form of decision making versus a SoS approach

8.7. CASE STUDY: VILLAGE X IN COUNTY CORK WOULD HAVE BEEN DIFFERENT IF SOS HAD BEEN USED.

To further substantiate the need for Ireland to adopt such an approach, the case study of a small village in north County Cork, Ireland, is discussed below. Consideration of this example illustrates how a SoS approach would have identified how the decisions to develop this village in the way it has been, would have been unwise.

Village X is a small village in north County Cork. The village has experienced extraordinary growth and change over the past 10 years, with the 2011 national census indicating a growth of 580% in the number of houses constructed in the village, post 2006, relative to those built between 1991 and 2000, as illustrated in Figure 8-5 below. The 2011 census, which used small area plans to record data, shows a housing stock (the number of dwellings available for habitation, as opposed to the number of occupied units) of 320 units, with 16% vacant (CSO, 2011).

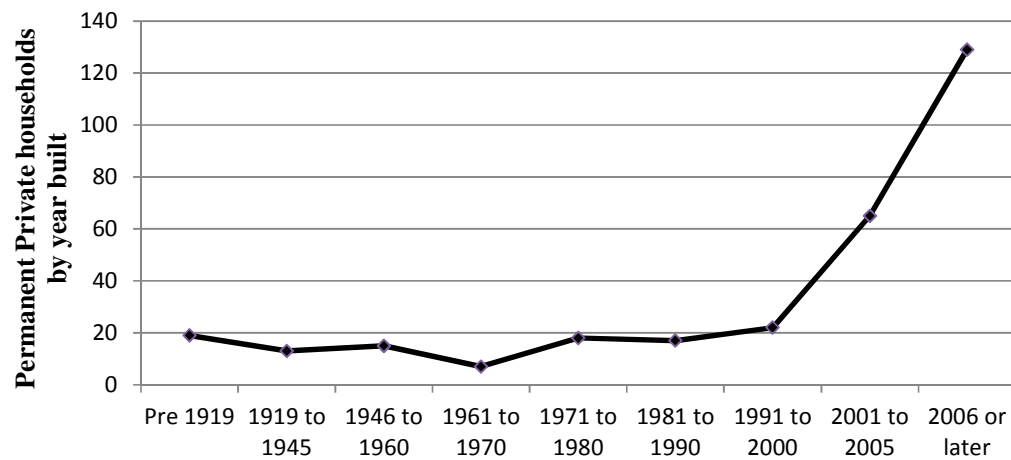


Figure 8-5: Permanent private households by year built, in Village X

Source: 2011 Census of Ireland and Authors' own calculations (CSO, 2011)

The legislation governing the zoning and planning of areas is the Planning and Development Act 2000 (Department of Environment, 2000). This requires a county to prepare a development plan for its administrative area every 6 years. Once these have been adopted, Local Area Plans (LAPs) are then prepared for the major areas within the county. Village X is located within the electoral district of Mallow, and thus was included in the Mallow LAP for 1996, 2005 and 2011. In terms of process, a draft LAP is prepared and issued by the relevant Local Authority's Executive for consultation; once a draft LAP is issued for consultation, members of the public are given time to make submissions, seeking changes.

The 1996 Mallow LAP (Planning Policy Unit, 1996) indicates no specific areas zoned for planning, but a very large development boundary designated 'zoning subject to adequate sanitary services'. In 2005, an additional area of approximately 34 hectares in Village X was zoned for development between the draft LAP and the final adopted LAP, as a result of amendments voted through

by the elected members of the Local Authority, using their reserved functions. (Planning Policy Unit, 2005b) (Planning Policy Unit, 2005a). This is a an extraordinary level of revision, in a village with 38 houses registered in 2005 (Planning Policy Unit, 2011).

Other infrastructural developments occurred in the Village to support its growth. These are summarised in Table 8-4 below.

Infrastructure Network	Upgrade in past 10 years	Source of information
Road network	€3million was invested upgrading the approach alignments to the village	2005 LAP (Planning Policy Unit, 2005b)
Wastewater network	Wastewater treatment was built by a private developer, commissioned in 2007. Designed population equivalent of 990PE Current load in 2013 is 500PE, but census data would suggest that the actual PE is in the region of 300PE	A review of the planning files (Cork County Council, 2005) EPA waste water discharge licences for Village X treatment works, (EPA, 2014)
Water Network	Water supply funded by a private developer.	Interviews
Gas, power, communications networks	Level of investment difficult to establish due to lack of open data, but must have occurred due to growth of village	
Excessive housing construction	16% vacancy rate of houses	2011 census (CSO, 2011)
National School (part of a social network)	3 new classrooms between 2007 and 2012, with 480% growth in Student numbers	Department of Education Student roll books (Department of Education, various)

Table 8-4: Infrastructure upgrades to support growth of Village X

Source: various, as outlined in the table above

As in Village X, the practice of private developers building water supply and wastewater facilities as part of a planning permission appears to have been 'standard' practice in a number of Local Authority administrative areas. This

poses many questions, *inter alia*: how were these facilities sized; who prepared and oversaw the specifications; were the designs and specifications in line with the Department of Environment guidelines, considering that these were being developed by private developers, with a view to selling houses; and as such were obviously not appraised in line with the Department of Finance (at the time) public spending code (Irish Government Economic and Evaluation Unit, 2014). In the design and development of any infrastructure asset good engineering practice requires the identification of the optimum engineering solution, including the optimum life cycle operation and maintenance (O&M) costs. However, again as in Village X, County Councils have 'inherited' these plants, by a process of taking-in-charge, which evidence would suggest are over-sized (due to the incompleteness of many of the planned houses), and are thus incurring wasted additional costs in their O&M.

If a SoS approach had been adopted, a demographic study would have looked at alternative scenarios of how Village X should grow. It would identify the supporting infrastructure necessary, and allow each of the constituent system owners to understand and quantify the impact of such growth on their systems. And ultimately the SoS approach would have empowered policy and decision makers with the evidence to 'decide' on how to develop Village X, if in fact at all.

8.8. CONCLUSIONS AND RECOMMENDATIONS

The IMF in a recent publication (Abiad *et al.*, 2014) has suggested that the time is right for an infrastructure push, and that the impact of such investment is stronger when there is an economic slack. Their study shows that where there is an infrastructure need, now would be a suitable time to invest. Based on Ireland's current position in the WEF competitiveness scale, the research undertaken to identify Ireland's infrastructural gaps, and Ireland's exit from its bailout program would all suggest that now is an opportune time for Ireland to invest strategically in key pieces of infrastructure. The work presented in this chapter identifies a Systems of Systems approach as being the optimum

methodology to identify where and how Ireland should invest; a conclusion that is consistent with emerging international best practice. To enable such a methodology to be undertaken requires the development of a National Infrastructure Development Platform which would house and communicate across the different constituent system networks. This research would suggest that Ireland needs to standardize its record-keeping and develop models of its constituent systems in the first instance. There is a need for a National Infrastructure office to overview and manage this process, as much of the data might be commercially sensitive and would need to remain within state ownership.

Thus the Authors would suggest that, rather than ask 'should' Ireland adopt a SoS methodology for infrastructure investment, the question should be '*why not*' and '*can Ireland afford not to?*'

9.0 CONCLUSIONS AND RECOMMENDATIONS OF THIS RESEARCH

There has been a significant lack of published work exploring how Ireland has invested in its physical infrastructure networks in the recent past, and how it should into the future. The research presented in this thesis addresses this gap.

9.1. IRELAND'S UNSUSTAINABLE INVESTMENT IN IT'S PHYSICAL INFRASTRUCTURE

The overwhelming findings of this research demonstrate the lack of coherent and sustainable historic investment in Ireland's physical infrastructure networks, during and post Ireland's '*celtic tiger*' period.

An in-depth analysis of: the national infrastructure spend; a study of the 34 local authorities (including 80 town and urban councils) annual financial statements; and records from the DoECLG and the NRA for the period 2003-2009, revealed some extraordinary patterns. The correlation analysis in Chapter 4.0 provides clear evidence of the link between housing construction and the level of investment in the physical infrastructure networks of water and wastewater in particular, and roads to a lesser extent. With housing vacancy rates of 15-30% in many of these counties of Ireland, it can be concluded that infrastructure investment in these counties was oversized or in many cases may be redundant. Evidence presented in Chapter 1.0 of developers providing the water and wastewater facilities in numerous towns and villages during the study period raises many questions: who provided and validated the basis of design loadings; or whether economic scenario testing was carried out to understand the potential issues if the projected population did not move into the town or village. Ireland now has the situation where capital infrastructure assets of e.g. water and wastewater facilities have been substantially oversized in many such locations. These assets will incur operation and maintenance (O&M) costs, which are considerably inflated relative to the actual populations served. In the

absence of further measures to mitigate such overcapacity, O&M costs will continue to be incurred at inflated levels, for the life time of the assets, which is generally 20 years or more.

Planning contributions by developers to Local Authorities during the Celtic Tiger period resulted in a significant impact on the Authorities finances, contributing upwards of 20 to 30% in some instances. This input to the Local Authority Finances contributed to their 'financial independence' over the study period. While expenditure needed to be in line with the public spending code, there are many instances of where Local Authorities managed to invest in assets which may not have been in line with overall Government Department plans.

One would have expected that the quality of the infrastructure in the individual Local Authorities would have improved substantially over the period due to the very large levels of investment, but Ireland's international rankings in the quality of infrastructure do not demonstrate this. Furthermore, the gap analysis in Chapter 7.0 undertaken with key stakeholders and the supporting evidence, identifies serious shortfalls in critical infrastructure systems. The analysis identifies Ireland's primary infrastructure gap as regional communication capacity and quality. This is followed closely by water quality and capacity. The investigation illustrates that 25% of Ireland's water supplies are on a remedial action list (RAL). Water quality and capacity is identified as one of the key gaps in Irish infrastructure for both industries and policy makers, while the country's wastewater treatment plants have recorded a 23% non-compliance with effluent standards.

9.2. THE IMPACT OF GOVERNMENT POLICY ON INFRASTRUCTURE DELIVERY

This thesis presents a series of situations where government and political intervention has interfered with the strategic planning process. The significant impact of tax incentives cannot be ignored. The Government's introduction in the 1980s of what are now called 'section 23' tax incentives led to a somewhat uncontrolled, undocumented and unmanaged development, of housing in particular (as evidenced in Chapter 3.0). The fact that in excess of 70,000 housing units were constructed under such schemes with no visible public record of where they were located is quite extraordinary. The Department of Finance, in preparing its submission on the removal of such tax incentive schemes, failed to identify the location of the properties, and linked them only to the county of tax registration of the owner. However, through continued questioning and dialogue, the records of the units' physical locations were discovered to be held solely in a particular computer in a DoECLG office in the west of Ireland. This level of record keeping is indicative of the many issues encountered in this research.

It would appear that there was no set target of section 23 tax incentive units for each local authority; and no national vision of how many should be constructed. Tax incentives in themselves are clearly of great benefit to the targeted area, e.g. for urban regeneration. However, there was no clear plan of where these should be located and how they should be accounted for.

The difficulty in gaining access to water services investment values, in part due to the lack of standardisation of records across local authorities and government departments, was significant. With the high level of capital spend by the Irish State over the study period, the standard of record keeping was poor. The inadequacies varied from a complete lack of records; to poor transparency of records; the use of aggregated numbers for a number of categories of investment; or no electronic records at all.

An example of this is the recording of water and wastewater capital investment monies. The country invested approximately €6 billion in its water and waste water networks over the period 2003 to 2009. This figure has been compiled, as part of this study, from DoECLG records and Local Authority annual financial records. The central government grant aid figures through the Department of the Environment, Community and Local Government were available under the four headings of: water; wastewater; economic support; and management & rehabilitation. It was thus not possible to distinguish the DoECLG investment in water from wastewater due to the aggregated values for economic support and management and rehabilitation, for both the water and wastewater networks. Most local authorities reported their spend as an aggregated figure for water services, ie. water and wastewater. This thesis infers that if the data analysed in this work had been explored on an on-going basis by a central government body – eg. an National Infrastructure Agency, warning lights would have come on.

Such an agency would need to be independent of the political cycle, and the evidence from the recent Irish Water debate would suggest that political influence is more focused on vote getting, than considering the national interest. Whether Irish Water introduces a metered or flat charge, the fact remains that Ireland needs considerable investment in its water and wastewater networks.

The level of communications connectivity across regional Ireland is a very urgent need, and does not appear to be getting the level of government engagement that it needs and warrants. It was highlighted as the main infrastructural gap by both policy makers and corporate decision makers. Irelands prides itself on a 'smart' economy; however if this is to stretch beyond Dublin, then urgent and immediate action is needed to facilitate providers to land a Tier 1 communications connection in regional Ireland, with a route to connect to Dublin, and thus providing a ring system which ensures resilience in the network.

The starting point in any analysis is data gathering and model development. Chapter 1.0 provides substantiation of the lack of data in many sectors, water and wastewater in particular.

9.3. SYSTEMS OF SYSTEMS: INTEGRATED SPATIAL PLANNING AND INFRASTRUCTURAL DELIVERY

A case study is presented in section 8.7. This is a small village in north County Cork, which experienced very high zoning of land relative to the number of houses that were in the village in 2000. The village has grown from 20 dwellings in 2000 to over 200 in the 2011 census. This particular village had an additional 35 hectares of land zoned for residential development in the 2005 local area plan (LAP) relative to the draft. These additional lands would have been included in the zoning after submissions/lobbying from interested persons and possibly political influence. The disproportionate extent of land zoning for development in the villages and towns of Ireland has resulted in items of infrastructure having been oversized, in many cases redundant including in the case study village X.

Ireland has exited from its financial bailout and as the economy recovers it is suggested by stakeholders, interviewed as part of this research, that the infrastructure is strangled, particularly around Dublin, and this will inhibit Ireland's recovery. The planning of infrastructure is a long term process, which needs to be tested using various policies, climate change impacts, and demographic variability which itself is dependent on various scenarios. And how can an infrastructure network be analysed coherently without data on the present capacity and locations? This is currently the situation in Ireland, with a lack of models for the water networks in particular. The level of information on the wastewater treatment plants and networks is scant and somewhat unreliable as evidenced in section 8.6.3.

Since Ireland privatised the communications market in 1999, there is no overall map of network cables and capacity. There is a need for the Government to intervene and deliver Tier 1 connectivity and its connection to locations outside of Dublin. Through the interview process in this research many identified the locations of ducts, e.g. along roads, rail lines and gas lines. These could be used

to deliver the necessary communications connectivity coverage across the country; but to date this has not happened.

It is the conclusion and recommendation of the thesis that Ireland needs to develop a dynamic type of analysis and scenario testing for its spatial planning and infrastructure delivery. It is proposed that a systems-of-systems be adopted which would aid in policy making and resultant decision making. There has been too much 'silo' style decision making, as evidenced in this research. This thesis concludes that the impact of asset development cannot be correctly evaluated without considering the impact on its interdependent systems, and evaluating against various drivers and scenarios. A SoS methodology encompasses these elements, and is gaining traction in infrastructure evaluation in a number of countries and is a future area of research, as scoped in section 8.6. The first phase will require the scoping and data gathering to develop the constituent system models.

While it was not the objective of this research to consider social and societal impacts of infrastructural investments; Ireland's future sustainability would be best served by adopting a SoS methodology to planning and development, as described in this thesis, in combination with consideration of key factors aimed at providing optimum societal benefit.

9.4. LIMITATIONS OF THIS RESEARCH

The focus of this thesis was to analyse past patterns of infrastructural investment across the Republic of Ireland, to undertake gap analysis with key stakeholders, and to propose a change in how the country undertakes its infrastructure decision-making.

The data collection aspect of the historic investment proved extremely difficult due to the inconsistency of record-keeping across government departments and local authorities. The research presented on the historic investment has a number of limitations. The water and wastewater investment during the study

period could not be separated, since the aggregate of these investments were categorized as 'water service'. In addition, the historic analysis of infrastructure investment was limited to the sectors which are fully funded by government as access to records by private utility providers and semi-state organizations was not possible.

The case study presented in Chapter 8 of a small village in North County Cork is very much indicative of what happened in many villages across the 26 counties during the 'celtic tiger'. This village was used to indicate the extraordinary levels of land rezoning, development and lack of centralized government decision-making, all of which are characteristic of that time period in Ireland's development.

In undertaking interviews with key stakeholders to identify Ireland's infrastructural gaps, the focus was to ensure that the interviewees within the corporate decision makers grouping were of high level within their organizations and where possible have global impact. The calibre and level of the interviewees is evidenced in Chapter 6. The literature would suggest that the basic elements of metathemes are present within six interviews, with saturation within the first 12 (Guest *et al.*, 2006). So while this study limited the policymakers to six interviewees and the corporate decision makers to nine, this sample size should more than illustrate the key infrastructural gaps.

This thesis identifies the need for change in current decision-making methodologies, with the need to adopt a systems approach. To do this, modelling of infrastructure networks would be necessary. But this thesis illustrates the lack of available data on Ireland's infrastructure networks, which represents the first obstacle in developing system models.

9.5. FUTURE RESEARCH

This thesis proposes a systems of systems methodology, which should form part of the decision-making process in national physical infrastructure network development. The development and implementation of such a methodology

presents a number of opportunities for further research. These would include the following, *inter alia*:

- A list of datasets has been proposed in Chapter 8 of this thesis, within which many areas currently lack information. In partnership with one or more local authorities and the relevant infrastructure providers within the geographical locality, undertake a detailed and extensive data gathering exercise of the existing level of infrastructure data.
- Investigation of current construction contracts for infrastructure development, critiquing them for information gaps and propose what and how network information should be gathered and stored so as to feed into a systems of systems analysis.
- Critique current systems analysis methodologies to identify the most suitable mechanism to undertake a systems of systems analysis of Ireland's infrastructure networks
- A systems of systems approach recognizes and analyses the interdependence of one system with another. The development of such a methodology requires the system boundaries to be defined and understood. What are the optimum system boundaries for each of the system networks in Ireland's infrastructure?

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11.0 APPENDIX A –PUBLISHED PAPERS NOT INCLUDED IN THIS E-THESIS

‘Analysis of investment decisions in Irish state infrastructure’

Authors: Mary Moloney and Eamon McKeogh

ICE Proceedings: Urban Design and Planning in 2013 (E-Pub date 17th December 2013)

DOI reference code is 10.1680/UDP.13.00009.

‘Infrastructure gap analysis for Ireland’

Authors: Mary Moloney and Eamon McKeogh

ICE Proceedings: Municipal Engineer

DOI reference code is 10.1680/muen.14.00033.

‘Quantifying Ireland's infrastructural deficit’

(BCRI) conference , September 2010.

Authors were Mary Moloney, Karsten Menzel, and Eamon McKeogh

ISBN number is 978-0-9542973-3-6

‘The distribution of capital investment in Ireland's road network 2003 - 2009’

Authors: Mary Moloney and Eamon McKeogh

BCRI conference 2012

ISBN 978-0-9573957-0-1