NEW ANALYTICAL METHODOLOGIES FOR EVIDENCE-BASED INFRASTRUCTURE PLANNING IN THE PUBLIC SECTOR


Mr. Martin M. Spollen & Dr. Johann Gallagher

This paper describes a new research-led approach to strategic infrastructure planning that is being developed by the Strategic Investment Board (SIB) in Northern Ireland and piloted in government departments and agencies. The Strategic Infrastructure Planning Model (SIPM) helps policy-makers to explore the complex relationships between delivery costs and operational performance for different configurations of capacity and location so that future capital investments in operational facilities (e.g. schools, hospitals, libraries) are better informed by evidence of optimality.

The approach brings together findings of primary research into consumer choice and microeconomic scale costs modelling for selected services and facilitates 'what if' scenario evaluation to inform policy development in areas such as service accessibility, consolidation and network development. The SIPM approach is being developed in the context of the Executive's Investment Strategy for Northern Ireland, but the same approach could be applied in other regions.

Background

A vital asset of any region is its infrastructure in the key areas of transport, communications, energy, water treatment and the facilities that support delivery of public services such as healthcare and education. The availability, quality and resilience of this infrastructure has a significant influence on potential economic growth and competitiveness and, equally important, on the quality of life and equality of opportunity for a region's residents.

Investments that lead to stronger growth are particularly critical for Northern Ireland given that per capita income, as measured by Gross Value Added (GVA), lags the UK average by more than 20 percent[1]. The 2011-2012 Global Competitiveness Index[2] published by the World Economic Forum recognises infrastructure as a factor of competitiveness and also asserts the importance of qualitative features such as inclusiveness and environmental sustainability for quality growth. Given the importance of infrastructure in many aspects of people's lives and a region's economy and environment, the planning and delivery of infrastructure assets should be undertaken in ways that reflect its significance.

While Northern Ireland's infrastructure is generally in fair condition, like most developed regions more needs to be done to modernise service delivery and address demand-side and regulatory pressures in key areas of the economy. A recent Institution of Civil Engineer's (ICE) inquiry states that Northern Ireland's stock requires attention *'to enable effective functioning and avoid infrastructure failure'* in the coming years[3]. The Northern Ireland Executive (the Executive) inherited a legacy of underinvestment in civil infrastructure from the period of the 'Troubles'. With the advent of the Good Friday / Belfast Agreement in 1998 and the devolution of authority to the Northern Ireland Assembly and the Executive, plans emerged to redress the infrastructure deficit with unprecedented levels of investment.

In May 2002, the Reinvestment and Reform Initiative (RRI) announced the first major response to the need for infrastructure renewal. The initiative proposed a new model for delivering infrastructure investments to accelerate key capital projects for

the social and economic regeneration of Northern Ireland. To carry out this work, the Strategic Investment Board Limited (SIB) was established by statute in 2003 to undertake *'strategic investment functions'* for the Executive and public bodies carrying out major investment works[4]. The SIB's remit is to: advise the Executive in relation to the formulation and implementation of its programme of major infrastructure projects; advise and assist public bodies carrying out major projects; and, by agreement, to assist in the delivery of such projects.

Since 2003, the approach to strategic infrastructure coordination, planning and delivery in Northern Ireland has steadily evolved through two cycles of infrastructure programmes. This paper outlines progress in recent years, discusses the work streams ahead and the describes the use of the Strategic Infrastructure Planning Model (SIPM), a model being developed by the SIB to help policy-makers explore the complex relationships between delivery costs and operational performance future capital investments.

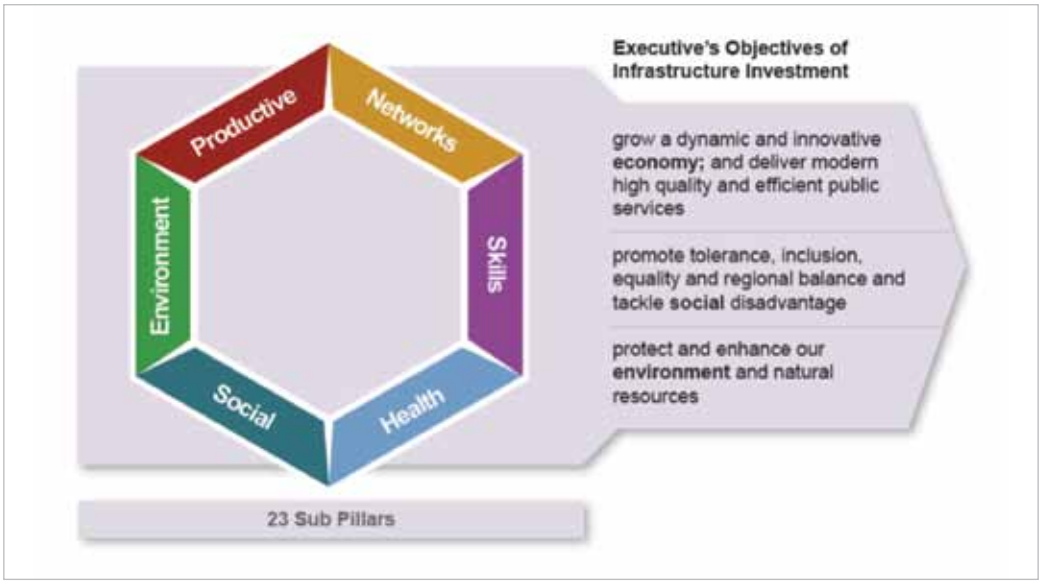
Whilst the paper focuses on Northern Ireland, there is scope to apply these techniques in the Border region of Ireland and across other jurisdictions, as appropriate. In more recent years, a similar focus has emerged in many other developed regions; for example strategically-focussed infrastructure investment initiatives have been introduced in the Republic of Ireland (1999 & 2007)[5,6], Australia (2008)[7], New Zealand (2010)[8] and at Westminster (2010)[9]. Canada's equivalent to SIB, Infrastructure Canada, was established in 2002 and its infrastructure plan has been in place since 2007[10].

Infrastructure Investment Strategy for Northern Ireland

The first Investment Strategy for Northern Ireland (ISNI 2005-2015) was published under Direct Rule in December 2005. It set out a rolling programme of infrastructure investment for a ten-year period that focused on the stimulation of the economy and social renewal. This coordinated approach sought to accelerate the delivery of overdue upgrades to roads, schools, hospitals, housing and other infrastructure. The second strategy, ISNI 2008-2018, was the first strategy published by the Executive in December 2008 and coincided with the new UK budget period. Whilst ISNI 2005-2015 made good headway in focusing attention on longer-term planning, ISNI 2008-2018 represented a step change in thinking on infrastructure coordination, incorporating spatial functions and planning techniques – and informed by the priorities of locally-elected Ministers and Assembly. The second strategy also highlighted the benefits of North-South Cooperation in infrastructure investments and in particular for the border region in Ireland. The National Development Plan for the Republic of Ireland 2007-2013 also featured cross-border cooperation in its capital investment strategy.

A subtle but important change in ISNI 2008-2018 is the introduction of the Investment Framework shown in Figure 1. This new framework encourages coordination among those responsible for delivery of infrastructure and, importantly, is linked to administrative and financial accountability structures. Adopting the investment framework represented a move away from the silo-oriented approach where investments were proposed by individual government departments to an approach focused on coherent areas of investment. This is achieved by organising investment plans into six investment pillars and 23 sub-pillars, each supported by detailed Investment Delivery Plans. This represents a shift in emphasis from who is delivering to what is being delivered. From a citizen's perspective, this provides more clarity on what public money is being spent on. From a strategic policy perspective, the new structure helps to join up the plans of government departments and agencies to identify synergies and help maximise efficiencies. In ISNI 2008-2018, there is also a strong focus on transparency and visibility of delivery. All departments and agencies responsible for project delivery are required to provide up-to-date status on projects that is made available to the public through an innovative on-line information portal (www.isni.gov.uk).

Figure 1: Investment Framework



Source: Investment Strategy for Northern Ireland 2008-2018. Northern Ireland Executive

The publication of the successive investment strategies did bring an important strategic focus, enabling rational coordination and phasing of investments into deliverable and affordable programmes of work. Investment levels rose sharply from circa £800m in 2002 to £1.7bn in 2008-2009. Over the coming years, anticipated capital spending will be somewhat lower reflecting the difficult global economic climate and funding cuts to the Northern Ireland Block Grant. In this context, the investment strategy and delivery framework are more important than ever to focus attentions on the must do investments that will help to support economic recovery and service reform.

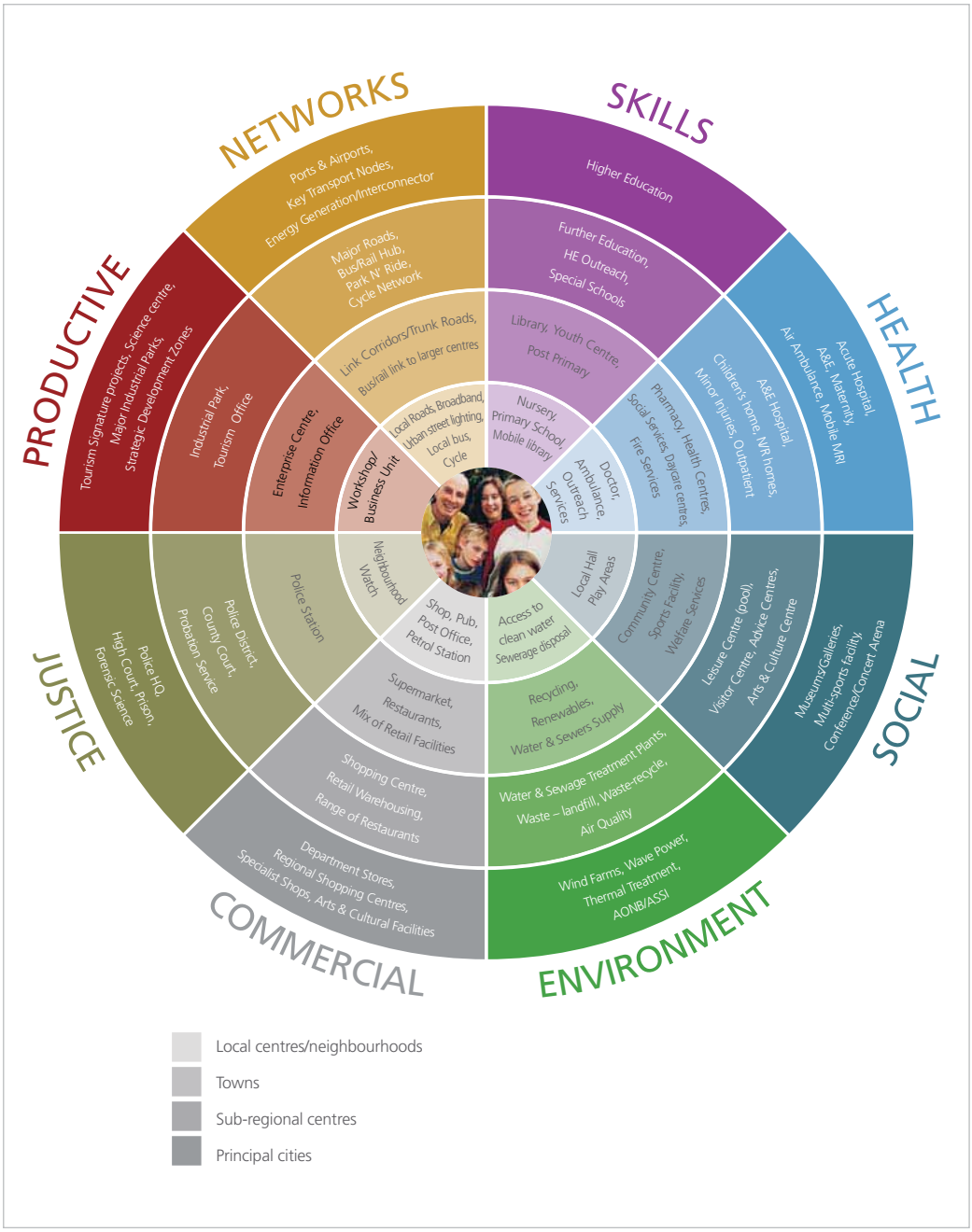
People and Places: Spatially Appropriate Services

Another benefit of the approach developed in successive investment strategies is the inherent focus on place and how investments support and sustain communities that are spatially organised in a hierarchy of settlements across the region. Interjecting a better understanding of 'people and place' and the interaction between the two is important to effective capital investment programmes. Before investing, the costs and benefits of enhanced services should be considered in terms of the impact on citizens and the contribution to place building. ISNI 2008-2018 included tools to assist departments and spending bodies in this regard. The Hierarchy of Settlements and Services Wheel, shown in Figure 2, is one such tool.

The wheel clarifies the spatial context of different levels of public services by relating the type and scale of service provision to types of communities, for example, a neighbourhood, a small town, district town or a city. This approach recognises the different but complementary roles of different sized settlements as locations for modern quality public services. It also emphases the needs of residents and businesses in planning and supports the objective of promoting equality of opportunity. The approach was subsequently adopted and further endorsed in the draft revision to the *Regional Development Strategy* for Northern Ireland[11] and in a seminal horizon-scanning report by the Irish Academy of Engineering and Engineers Ireland for

Figure 2: Hierarchy of Settlements and Services

The wheel seeks to move debate away from settlements competing against each other within the region to a planning paradigm where centres collaborate and 'play to their strengths'.



Source: Strategic Investment Board

Inter*Trade*Ireland[12]. The relationship between cities, towns and rural areas must remain one of mutual and positive interdependency.

It is important to note that the wheel does not seek to over-simplify the complex relationship between settlements and service provision. It can be applied as a guide to anticipated service levels rather than either a reflection of the current stock, or indeed a commitment to provide a minimum service standard. As shown by research conducted by the Department for Social Development (2006)[13], in practice settlements will not always conform to the spatial attributes and related activities as illustrated in the wheel; centres can provide either a greater or lesser range of services than the population may support in absolute terms, and accessibility to some services, such as health, may be more sensitive than to others. Local and central government in the Republic of Ireland have applied similar approaches to the wheel. South Tipperary County Development Board developed the Local Agenda 21 wheel to help improve co-ordination and delivery of local and sub-regional level services[14] and the Irish Government included a similar tool in the *National Spatial Strategy*[15].

As with the investment framework, the wheel encourages vertical and horizontal integration by providing a platform for collaboration among central government, local authorities and the voluntary, community and private sectors. In principle, it could be applied across jurisdictions, for example in settlements along the Border, to identify opportunities to share services and improve accessibility where appropriate. Developing an understanding of different catchment areas and the corresponding levels of services encourages those responsible for delivering the services to focus on key issues regarding the accessibility of public services and ensuring that the resulting services are affordable, economically operated and effectively managed to sustain high quality. Accessibility is a fundamental consideration in the modelling being piloted by Northern Ireland's departments and agencies as described later in this paper.

Data as a Foundation for Strategic Infrastructure Planning

Planning for public services faces complex tradeoffs when attempts to reshape the provision of infrastructure and services to meet future demands must also take into account current issues and opinions that may constrain policy options. The ISNI approach, with its longer-term focus, encourages departments and agencies to look critically at their infrastructure stock and how the current service network performs in setting a course for future reform and investment.

Under the ISNI approach, service providers are encouraged to examine system-wide networks before drilling down to individual projects. In the past, decisions on capital projects may have been taken in isolation and without sufficient consideration of the impact on the wider network or service catchment area. On occasions, this led to sub-optimal outcomes with facilities becoming operationally or financially unsustainable. To avoid such instances, departments and agencies, supported by the SIB, are developing new analytical techniques for strategic infrastructure planning underpinned by detailed statistical models. The UK Council for Science and Technology has endorsed the use of such techniques[16].

This type of infrastructure modelling is predicated on the availability of comprehensive, spatially-referenced data on demand and service supply. Northern Ireland, in this respect, is data rich. There are spatially-referenced datasets on demography, socio-economic characteristics and public services infrastructure. The postcode system, in particular, helps departments and agencies to collect detailed geo-coded administrative data on service uptake. Analysis can then be undertaken at Census Output Area level[17] – the smallest geographic unit for which robust statistics can be produced – or at higher geographical units. With the introduction of the new small area outputs in the Republic of Ireland for the 2011 census, there may be opportunities to undertake this work within the border region or on island of Ireland basis in the future. The International Centre for Local and Regional Development and the

All-Island Research Observatory have begun some of this spatially referenced modelling to measure accessibility of services. For now, there remain challenges to reliable geo-coding of equivalent administrative data in the Republic of Ireland in the absence of a postcode system. There are plans afoot, however, to introduce a national system for geo-referenced data in the Republic of Ireland, which will enable this type of analysis on an all-island basis. This has important implications for future infrastructure planning in the border region.

The following sections describe in more detail a Strategic Infrastructure Planning Model concept being developed by SIB and outlines its application and future potential in reforming public infrastructure planning.

Strategic Infrastructure Planning Models (SIPM)

The SIPMs are predictive computer models that can be used to improve the way public services are organised and delivered. The models help policy-makers to simulate the impact of policy alternatives on the cost and operational performance of new infrastructure investments. These simulations can be used as an evidence base to support policy development through real-time evaluation of alternatives, stakeholder engagement and public consultation. Ultimately, the SIPM approach can help to identify which option best promotes the desired policy outcomes consistent with the available resources.

SIPMs are distinguished from traditional business planning approaches in that specific recognition is given to network effects that are relevant to real world infrastructure planning problems. They do this by accounting for displacement and additionality of service use when the system under study is 'disturbed' from its current configuration – for example, when modelling the introduction of a new service in a community or rationalising a number of facilities. By capturing elasticity of demand with respect to significant factors, for example, travel distance as an impedance factor, and assessing the implications for demand at remaining facilities in the network, these models outperform traditional business planning models in predictive accuracy. For this reason, such models are widely used in competitive environments such as the major retail sector. They can also handle demand-side change, such as the likely impact arising from population growth, ageing and changing settlement patterns over time.

At its most fundamental, SIPMs are simply a mathematical representation of the complex interactions between two surfaces. The demand surface represents the pattern of public service demand as it arises across space and time. These demands can usually be observed in retrospect from data held on relevant public service administrative systems; for example, patient administration systems in hospitals, student enrolment systems in schools and colleges, loan management system in public libraries and incident recording systems in the emergency services. The demand surface can be expressed at the level of the individual user or as small-area aggregate statistics; which one is used will influence the analytical approach to SIPM development as is explained later. Data used to characterise demands usually seek to capture location, age, gender, socio-economic indicators and community background because these data are often significant in explaining citizens' behaviour. Time of demand is important to capture in some areas, such as emergency services, because demand can vary significantly by hour of the day and day of the week.

The second surface – the supply surface – represents the existing configuration of service delivery points across a region that exists to satisfy the demand discussed above. Each point – be it a school, a library or a police station – can normally be described by a number of measurable attributes specific to the service. These attributes may include; location, component services offered, opening hours, floor area, building condition and, in some cases, attributes that are closely identified with demand from particular communities or sub-groups in the general population of users.

In addition to demand and supply datasets, the spatial separation between demand and supply points must be captured as an additional explanatory variable since the interactions take place across space. The traditional means of taking this measurement has been to calculate arithmetically the Euclidian (as the crow flies) distance between origin-destination pairs, utilising the Irish grid co-ordinates of each. In highly urbanised areas, a modification to the arithmetic yields rectilinear distances that may better reflect transport geography. Where anonymous data on individual transactions are being used, the availability of home postcode allows for a very fine measurement in both cases. Alternatively, approximations can be made using population-weighted centroids of Census Output Area as origins.

In its work, SIB now routinely uses road-routed (or 'network') distances based on length of the fastest route between origin-destination pairs. This overcomes the limitations with arithmetic estimates discussed above by using the actual road network. Many GIS packages, such as ArcGIS and MapInfo, have a facility to calculate road-routed distances if a regional road network layer is made available. Microsoft MapPoint Europe comes bundled with the UK and Ireland road network, which can be tightly coupled with Microsoft Excel using Visual Basic to perform the necessary plotting, routing and distance calculations and provides a usable mapping interface.

Yet, experience in Northern Ireland has shown that significant efforts and resources are required to assemble and prepare administrative datasets to support SIPM development. In recent projects staff time has been devoted to data integration, especially when data is supplied by different agencies; staff resources are also required to validate the different data and undertake queries to reconcile any inconsistencies among the information provided. Future studies can streamline this process through proactive liaisons with information personnel in the services concerned.

Once the empirical datasets are assembled, the next step is to develop the algorithms that will form the engine of the SIPM. Where individual-level single choice responses are being used, logistic regression techniques using maximum likelihood are most appropriate. This approach combines and weights the independent variables with an objective to maximise the predicted probability attributed in the model to the alternative selected in practice. See Ben-Akiva and Lerman (1985)[18] and Train (2009)[19] for a thorough review of appropriate methods. In contrast, where area-based aggregate statistics form the dependent variable (e.g. small area demand rates), then spatial interaction models fitted using least squares regression techniques will be appropriate. Such models are extensively described by Fortheringham and O'Kelly[20]. Algorithm development using these classical methods requires specialist software to perform the optimisations, including R or Biogeme (both freeware) or commercial packages such as SAS or Matlab. Bayesian methods that do not rely on optimising an objective function in the same manner may also be appropriate. In either case, skill and experience is needed to undertake the fitting process and associated testing in order to comply with professional standards, especially if the resultant model is intended to inform major capital investment decisions.

Models developed are normally validated in a number of ways. Where information on observed before and after impacts of facility closures are available, then the comparisons of the observed impact to that predicted by the SIPM provides an ideal litmus test. It is also important to consult with operational staff in the services under study who can provide valuable feedback on model performance at a sub-regional level.

The final stage is to wrap the algorithms and accompanying base datasets in a user-friendly front-end to allow the non-technical user to create and evaluate policy scenarios with relative ease. Functionality will be informed by user requirements,

but normally a wide range of policy parameters can be included as user-defined variables.

When used to simulate the effect of service rationalisation or reconfiguration, a SIPM model will typically provide policy-relevant information such as:

- The impact on total miles travelled by service users (inc. cost & emissions impact);
- Change in overall demand levels for the service (+/- additionality);
- Change in demand levels at specific service supply points (+/- displacement);
- Change in first-preference denial rates, where supply-side capacity ceilings are in place and invoked at a facility level;
- Change in facility utilisation rates;
- Change in response times performance (for 'travelling out' responder services);
- Additional internal costs (e.g. cost of additional pupils eligible for free travel);
- Other cost implications of the above (e.g. economy of scale effects).

The next section describes how this innovative approach is being implemented under ISNI.

Investment Strategy and SIPMs

SIPMs have an important contribution to make in future strategic infrastructure planning and related service reform in Northern Ireland and elsewhere. This is all the more relevant in the present economic climate, where recurrent budgets to support frontline service delivery are under unprecedented pressure and Ministers and their respective Departments are focussed on driving up efficiency to offset the impact of budget cuts imposed on the Executive. The ability to simulate the anticipated impact of different policy alternatives rapidly, using pre-assembled datasets and tried-and-tested algorithms, can promote policy choices that are informed by objective evidence of what works best. This is particularly true where questions about the spatial configuration of service delivery – and the consequent impact on accessibility, performance and cost – are being scrutinised to identify opportunities for reform that improves productivity.

Similar models are used by major retailers and logistics operators; in an efficient and competitive market environment with constant returns to capital, these optimised networks help to lower prices for consumers and increase service quality by avoiding unnecessary costs.

Early examples of prototype spatial planning models for public services build on a series of commissioned research studies and applications by Hindle and Spollen reported between 1999 and 2009 for clients in Northern Ireland and Great Britain[21, 22, 23, 24]. One example is the development of a spatial planning model for acute hospital services in Northern Ireland that includes functionality to assess projected population catchments and demand volumes for a wide range of specialties at sites across the region[25]. Similar approaches are used by Hindle (2007) in his development of a response time simulator to inform optimal deployment strategies and investment for acute ambulance services in Northern Ireland[26]. Learning from this simulation tool, together with appropriate investment and service reconfiguration, has contributed to a substantial improvement in emergency ambulance response times to Category A (life-threatening) incidents across the region.

Building on this success, SIB launched a pilot SIPM study to support LibrariesNI in its strategic review of public library services across Northern Ireland. In the first stage, a model of population accessibility was developed. The model allows LibrariesNI to simulate the effect of changing public library configuration (opening or closing facilities) on levels of public accessibility[27]. Up to eight future library network scenarios can be pre-defined and then compared to the current library configuration acting as a baseline. The results reveal in detail how local communities across the region will be affected by changes. The model also illustrates the change in population-based catchments for each library remaining open under each scenario to help gauge the impact on demand levels and resources at these branches.

The accessibility model contains an innovative module to permit library management to design

mobile library routes as mitigating action in instances where a fixed branch is to be closed; or, more generally, to improve accessibility for rural and more remote communities.

In the second stage of the work, further and more detailed statistical analysis of the determinants of library demand and customer flows was undertaken to enhance understanding of borrower behaviour. Design of the study was informed by recent research on determinants of public library demand in Norway.[28] Using the maximum likelihood method, the most powerful algorithm developed is capable of explaining over 93 percent of the variance in the observed number of transactions at over 100 libraries across the LibrariesNI network. This remarkable level of precision means that the impact of any proposed investment and reorganisation on future demand levels can be estimated more accurately using a customised Decision Support System (DSS) to combine algorithms, relevant datasets and a user interface for scenario set-up and presentation of results. Once fully completed, the DSS will provide new and insightful management information to inform and help facilitate appraisal of issues ranging from strategic network development opportunities to efficient operational resource planning.

Looking forward

SIB is offering assistance to develop similar SIPM approaches to other areas of the public sector, particularly those services that rely on a large and spatially distributed network of frontline facilities. Given the ability of these models to illustrate better the microeconomics of service provision and, from that, to help identify productivity-maximising service reform opportunities – it follows that future investment strategies could be developed using SIPM approaches. An additional benefit in the context of capital prioritisation will be the ability to compare more readily the anticipated return to capital for individual projects, both within sectors (where departments face competing internal priorities) and across sectors that vary considerably in nature and scale. In this way, future investment strategies could be built 'from the ground up' on the basis of delivering, over time, a service configuration and estate that is optimised to deliver contemporary needs in an affordable manner. Proposals for investment projects can then be prioritised on a descending returns basis – with the overall speed of transition determined by the funding available in each budget period.

These new techniques allow policy-makers to evaluate service provision in terms of its availability, accessibility, and financial and operational viability – issues that are profoundly affected by spatial and demographic considerations as well as technological and cultural changes. With the introduction of small area outputs in the Republic of Ireland, in the future these modelling techniques could be applied to evaluate the provision of services in catchment areas within the border region.

Such innovation in citizen-focussed spatial planning and evidence-based service improvement is an example of the Executive's determination to improve the quality of public services for communities across Northern Ireland and, in doing so, help to mitigate the effects of funding cuts imposed on its budget. The approaches outlined in this article can also help to provide evidence and measures to evaluate the trade-offs in choosing must do investments that contribute to economic recovery. Much work has been done and future investment strategies will build on this.

Martin M. Spollen joined the Strategic Investment Board (SIB) in 2006 to lead the development and implementation of the Executive's multi-billion pound Investment Strategy for Northern Ireland. He is a Fulbright scholar with a published track record in mathematical modelling and operational research applied to the public sector. He is also an Advisory Board member at the Centre for Economic Empowerment in Northern Ireland. Prior to joining SIB, he was a Director of Consulting with a London-based PLC, specialising in public sector practice.

Dr. Johann Gallagher is a policy adviser for the Strategic Investment Board (SIB) in Northern Ireland. Since 2005, she has been part of the team providing strategic advice to Ministers on the development and delivery of the long-term investment strategy for the region. Prior to joining SIB, she worked as an economic consultant in Belfast and Dublin. She specialises in strategic and spatial planning, public policy analysis and project evaluation.

Endnotes

[1] In 2009 Northern Ireland's GVA per capita was £15,795 compared to the UK average of £20,357. Equivalent rates in other UK regions were £20,442 in England, £14,842 in Wales and £19,744 in Scotland (NISRA, ONS, December 2010). GVA per capital for the Border, Midlands and West (BMW) region of the Republic of Ireland in 2008 was 25,337, considerably lower than the State average of 36,228 (Central Statistics Office, February 2011).

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