An Chomhairle Náisiúnta Eacnamaíoch agus Shóisialta
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Urban Structure, Spatial Planning and Climate Emissions

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National Economic & Social Council

Urban Structure, Spatial Planning and Climate Emissions

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1.1 Introduction

Ireland is at a critical phase of national policy on climate change and transition to a low-carbon economy and society. There is now a growing recognition that a new and more ambitious policy framework is required in order to meet both our EU Emission Targets (2020 & 2030) and our longer-term national policy objective of achieving a transition to a competitive, low-carbon, climate-resilient and environmentally sustainable economy by 2050. The National Planning Framework (NPF) represents an attempt to establish a new strategic role for statutory planning linked to clear economic, social and environmental objectives. In relation to climate change, the NPF includes, as a national policy action, a commitment to reduce our carbon footprint by integrating climate action into the planning system in support of national targets for climate policy mitigation and adaptation objectives, as well as targets for greenhouse-gas emissions reductions.

This research note begins by summarising some of the literature that has sought to explore the relationship between urban structure, spatial planning and climate emissions, in particular transport-related emissions. Section 3 then considers some of the key methodological issues and challenges associated with this issue, drawing in part on earlier NESC work on the governance of infrastructure policy-making (2018). The note concludes with an overview of the enabling role of urban structure in supporting sustainable development and mobility. A more detailed research paper is provided in Chapter 2.

1.2 Examining the Relationship between Urban Structure, Spatial Planning and Climate Emissions

There is quite a rich literature that has sought to identify, and indeed quantify, the relationship between spatial planning, urban form and climate emissions. At times this literature has produced contradictory results (Hickman & Banister, 2007). However, increasingly there is an acceptance that urban structure and mobility appear to be inextricably linked (Hickman & Banister, 2014; RTPI, 2018). In this context, the research has increasingly focused on the nature and strength of this relationship and how urban planning can play a more enhanced role in achieving sustainable mobility. At the same time, it is accepted that the inter-relationships between urban structure and travel are complex. In response, the analysis has become more sophisticated, with an increasing consideration of multivariate relationships and both attitudinal and cultural contexts (Hickman & Banister, 2014, 2007).

The work of Hickman and Banister has been very influential in highlighting both the strategic potential of spatial planning in reducing transport-related emissions and the necessity of integrating transport and urban planning. Using a Visioning and Backcasting for Transport (VIBAT) analytical approach, these authors have undertaken a series of case studies and policy reviews that have sought to demonstrate the potential role of urban planning and urban form in supporting a transition to sustainable mobility and reducing carbon-related emissions.

Introduced in 2015, the OECD Spatial Planning Instruments and the Environment (SPINE) project analyses the environmental and economic effectiveness of spatial and land-use planning instruments, as well as the potential gains from policy reforms. One strand of this work relates to the use of the Multi-Objective Local Environmental Simulator model (MOLES). MOLES is an integrated environmental economic model focusing on the quantification of costs and benefits arising from various urban policies targeted at land-use and urban mobility patterns. The MOLES model is an amalgam of an urban general equilibrium model (U-GCE) and an urban microsimulation model designed to represent the long-run evolution of urban areas (Tikoudis & Oueslati, 2017). Currently the MOLES model is being applied to two empirical research projects:

- Mitigating greenhouse-gas emissions in sprawled urban areas: the case of Auckland, NZ; and

- Tackling air pollution in dense urban areas; the case of Santiago, Chile.

The OECD contends that this model will assist policy-makers in distinguishing between potential 'best' practices—interventions that increase economic efficiency and environmental quality—and regressive actions.

A literature review undertaken by the RTPI (2018**)** highlighted that settlement patterns and urban forms that promote sustainable mobility can play a critical role in reducing transport emissions, with larger settlements characterised by higher densities and mixed land-uses reducing the need to travel by car.

Modelling work, using travel-to-work data for the Greater Dublin Area (GDA), concluded that the model's results reveal a link between the location of workplace destination and carbon emissions generated per person to travel to that location (Byrne & Carty, 2012). The modelling results indicated that destinations that are close to public transport options in city-centre locations demonstrate lower CO_2 emissions readings than those in more out-of-town locations that do not have access to the same range of public transport options. The CO_2 per employee in city-centre locations is up to four times lower than that associated with travel to or outside the M50.

A number of studies have highlighted the potential role of transit-oriented development (TOD) in supporting the transition to sustainable mobility. In particular, scenario building has been used to demonstrate how transport-orientated development strategies can reduce the scale of transport-related greenhouse gas (GHG) emissions compared to business-as-usual approaches.

- Tirwari *et al.* (2011) estimate that adopting a transit-orientated approach to the proposed development of the Bentley Technology Precinct (Perth, Australia) would generate 47 per cent less carbon emissions by all users in 2031 compared to a business-as-usual approach.

- A similar case-study approach is used by Seo *et al.* (2013) in their work on measuring and estimating the potential environmental and economic impacts of introducing transit-orientated corridors (TOCs) in the city of Anyang (S. Korea). Using regression analysis, this study concludes that, by increasing the ridership ratio of public transport, the decreased road traffic would reduce CO_2 emissions by between 40.2 and 73.1 million tons yearly.

- Finally, Cervero and Sullivan (2011) consider the potential synergies that can be created by combining TOD with green urbanism. Drawing on a number of case studies and relevant *ex post* evaluations, they argue that the inherent synergies offered by a Green TOD approach can reduce the environmental footprint relative to conventional developments by upwards of 30 per cent.

1.3 Evaluating the Environmental Impact of Urban and Transport Planning: the Need for a New Approach

The studies reviewed adopted a variety of methodological approaches, often in combination, in seeking to both identify and quantify the relationships between the built environment, mobility and emissions, including:

- regression analysis;
- *ex post* evaluations;
- VIBAT;
- multi-criteria analysis;
- GIS modelling;
- scenario building and modelling; and
- the Multi-Objective Local Environmental Simulator model (MOLES).

At one level, it is important to continue to develop the quality and sophistication of quantitative models as such approaches clearly have a role to play in making the environmental case for better spatial planning. At the same time it would be a mistake to assume that quantitative models are the answer to the complex challenge of transitioning to a more sustainable form of urban development. Hickman *et al.* (2013) state, for example, that the lack of evidence is not the main barrier to transitioning to a model of sustainable mobility.

Hickman and Banister (2014) suggest that making the case for the role of transport planning in contributing to the achievement of longer-term developmental goals, including reducing GHG emissions, requires a number of elements. First, there is a need to reframe transport planning, moving from the conventional transport planning and engineering focus towards an emphasis on sustainable mobility (see Research Paper: Table 4). Second, there is a need to embrace and work with uncertainty, rather than assuming that this can be modelled away. Third, transport planning has to be deeply integrated with land-use/urban planning. These two areas moreover need support from complementary economic and social policies. Fourth, there is a need for major changes in the theory and practice of transport planning. To date the focus has been mainly on how to move people around efficiently while the issue of why people move has been somewhat neglected. Finally, there is a need to develop and adopt alternative methodologies.

In part, addressing the challenges of evaluating and appraising infrastructure projects—including those related to major transport investment—requires the use of a wider set of quantitative and qualitative research tools and methodologies (Brown & Robertson, 2014; OECD, 2017). There is, as noted, a strong tradition of scenario building and modelling in transport analysis and, indeed, such techniques have been used in the literature reviewed. In undertaking their national infrastructure assessment exercise, the UK Government's National Infrastructure Commission (NIC) adopted a range of quantitative and qualitative research methodologies (NIC, 2016). This included detailed quantitative modelling of the baseline outcomes identified by four scenarios and particular packages of policy measures. Interestingly, although such modelling was seen as providing insights, it was accepted that it also simplifies reality. The NIC thus contends that its role is essentially to provide some context for the commission's judgements on future infrastructure needs.

Roelich (2015) argues that traditional cost-benefit analysis is limited by its failure to capture the value of investment in infrastructure resilience. It highlights the need to adopt methodologies that can quantify and/or monetise environmental and social outcomes. These social and environmental benefits, moreover, need to be viewed as being on an equal footing with economic outcomes.

Although it is important to encourage change in the actual analysis undertaken, there is an equally important need to change the role or place of technical analysis in the overall decision-making process (Rosewell, 2010). In particular, the output from such analysis should be an input into intensive policy dialogue and deliberation that is designed to build shared understanding as to the types of actions that should be taken, including investments to support sustainable urban development and sustainable mobility.

> Between political negotiation and technocratic decision making there is a big gap. If models were only seen as exploratory and partial, it would be easier to use them as tools to play with rather than tools for answers and this would give much more potential for the processes to create consensus rather than creating divisions which can only be resolved by direct intervention (Rosewell, 2010).

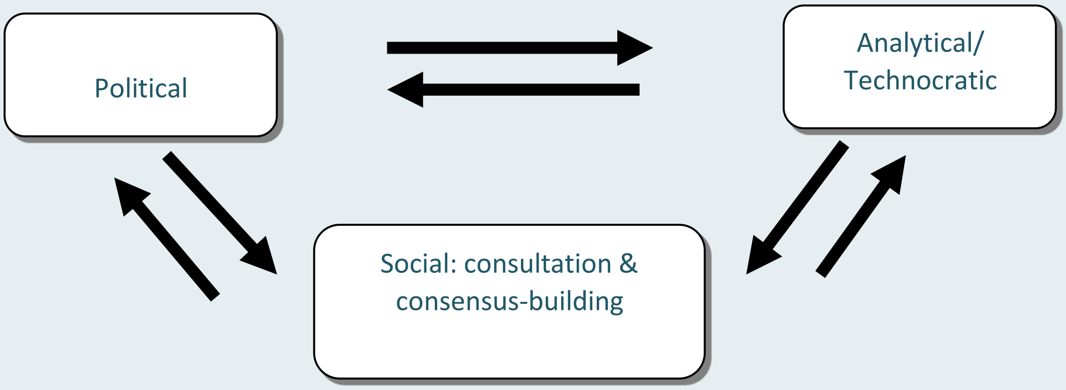
It is clearly necessary to continue to build the analytical basis of the decision-making process for reducing carbon emissions and addressing climate change. However, this remains a policy domain that is characterised by complexity, uncertainty and ambiguity. These characteristics limit both the scope of purely objective scientific analysis and the possibility of complete independence from both political contestation in society and the political decision-making of government. Commenting on the broader issue of infrastructure governance, Hammerschmid and Wegrich (2016a) contend that politics remains both central and necessary for effective, efficient and good decision-making on infrastructure policy.

> Complexity is inherent to infrastructure governance and will not cease with the application of more advanced tools of economic analysis or more rational planning cycles. Decisions under conditions of complexity and uncertainty require political choices (Hammerschmid & Wegrich, 2016).

This same perspective arguably holds true for good decision-making on urban planning and climate change.

NESC's work on infrastructure policy in the UK also highlighted that, in addition to technocratic analysis and politics, there is an important third element, namely societal consultation and decision-making (NESC, 2018). Again, we would argue that this framework is equally relevant to thinking about how policies related to sustainable urban development and mobility are made and implemented.

Figure 1: Understanding the Infrastructural Policy Challenge



Source: NESC, 2018.

1.4 Achieving Sustainable Mobility: the Enabling Role of Urban Structure

Although the various studies reviewed in this paper adopted different methodological approaches, as a body of work they highlight, in different ways, the key role of urban form and settlement in influencing patterns of mobility. While there will be many future pathways to achieving sustainable mobility in different cities, Hickman and Banister (2014) suggest that the commonalities of these pathways include the following six elements:

i. an urban structure that is supportive of sustainable mobility;

ii. major investment in an integrated public transport network;

iii. the development of walking and cycling facilities and the public realm;

iv. traffic demand management measures;

v. information and communication technologies; and

vi. technological developments, in particular low-emission vehicles.

These authors contend that urban structure has become a critical tool in transport planning as it can facilitate increased usage and access to public transport, walking and cycling modes, higher density around transport nodes, a quality and attractive public realm and mixed land-use. Indeed, while all of the above six elements are important, urban structure is viewed as having a critical enabling capacity in terms of realising the impact of the other component policies within an integrated package. Since changing urban structure takes time, many of the associated benefits will only be delivered in the medium to long term. Equally, failing to take action designed to change patterns of development and mobility will only serve to lock in unsustainable forms of development.

Tiwari *et al.* (2014) suggest that it is possible to frame the climate problem as an urban development and transport problem where significant reductions in CO_2 can be understood as a co-benefit of sustainable urban development and transport planning. Reframing transport in terms of sustainable mobility focuses attention on the key role of planning and spatial structure in determining transport mode and distance travelled, as it links the spatial distribution of population, jobs and other activities within the city to the pattern of trips. Indeed, Hickman and Banister (2014) maintain that urban structure provides the means by which sustainable transport can be achieved within cities.

Chapter 2
Research Report

2.1 Introduction

Ireland is at a critical phase of national policy on climate change and transition to a low-carbon economy and society. There is now growing recognition that a new and more ambitious policy framework is required in order to meet both our EU Emission Targets (2020 & 2030) and our longer-term national policy objective of achieving a transition to a competitive, low-carbon, climate-resilient and environmentally sustainable economy by 2050. The National Planning Framework (NPF) represents an attempt to establish a new strategic role for statutory planning linked to clear economic, social and environmental objectives. In relation to climate change, the NPF includes, as a national policy action, a commitment to reduce our carbon footprint by integrating climate action into the planning system in support of national targets for climate policy mitigation and adaptation objectives, as well as targets for greenhouse-gas (GHG) emissions reductions. This research paper seeks to explore the relationship between urban structure, spatial planning and climate emissions, in particular transport-related emissions. Section 2 briefly describes the NPF. Sections 3 to 7 review some of the key literature that has sought to explore the relationship between urban structure and transport-related emissions. Section 8 considers the case for developing new approaches to evaluating the impact of urban planning on sustainable mobility. The paper concludes with a focus on the enabling role of urban structure with regard to sustainable mobility.

2.2 Project Ireland 2040: the National Planning Framework

Project Ireland 2040 is the Government's overarching strategic policy framework for economic, social and environmental progress and is comprised of the *Project Ireland 2040: National Planning Framework* and *Project Ireland 2040: National Development Plan 2018-2027*.

2.2.1 The National Planning Framework

The National Planning Framework (NPF) is the Government's high-level strategic plan for shaping the future growth and development of our country up to the year 2040. It is a framework to guide public and private investment, to create and promote opportunities for our people, and to protect and enhance our environment. The NPF stipulates that, to make up for lost ground in relation to carbon reduction targets and move towards a low-carbon and climate-resilient Ireland by 2050, it will be necessary to make choices about how we balance growth with more sustainable approaches to development and land-use, and to examine how planning policy can help shape national infrastructural decisions.

The NPF represents an attempt to establish a new strategic role for statutory planning linked to clear economic, social and environmental objectives. In relation to climate change, the NPF includes as a national policy action a commitment to reduce our carbon footprint by integrating climate action into the planning system in support of national targets for climate policy mitigation and adaptation objectives, as well as targets for GHG emissions reductions. The NPF also recognises that supporting sustainable development will also require a more integrated approach to land-use and transport planning. In this context, the NPF highlights the need to support more energy-efficient development through the location of housing and employment along public transport corridors to facilitate people using less energy-intensive public transport, rather than being dependent on the car. This approach also accords with the national strategic objective of facilitating more compact growth, particularly in urban areas. Compact urban growth is also to be supported through the design of tailored urban development strategies, an enhanced focus on urban regeneration and an increased emphasis on brownfield/infill development over peripheral locations.

In summary, the NPF highlights:

- the need for a long-term strategic approach to spatial planning;
- the need to adopt a more integrated approach to land-use and transport planning;
- a renewed focus on sustainable urban development; and

- the role of strategic land-use planning in addressing climate change and GHG reductions.

This note will now consider a number of studies that have sought to quantify the role that land-use planning and urban structure can play in supporting sustainable urban development, including a reduction in transport-related emissions.

2.3 Visioning and Backcasting for Transport (VIBAT)

The work of Hickman and Banister has been very influential in both highlighting the strategic potential of transport in reducing transport-related emissions and the necessity to integrate transport planning and urban spatial planning (Hickman & Banister 2007, 2014; Hickman *et al.*, 2013). In addition to addressing climate change, these authors also emphasise how a more strategic and developmental approach to transport planning can assist in achieving a range of medium to longer-term economic, social and environmental goals (Hickman & Banister 2014)

These authors recognise that the literature on the issue of whether and to what extent travel behaviour is associated with land-use and socio-economic variables has generated at times contradictory findings. In this context, their work has sought to build on this literature and in part address some of the perceived analytical and methodological gaps. They contend, however, that urban structure and mobility appear to be inextricably linked (Hickman & Banister, 2007a). Hickman *et al.* (2009) suggest that the debate is now more about the nature and strength of that role and how urban planning can play a more enhanced role in achieving sustainable mobility. A similar perspective is articulated in a recent paper by the UK's Royal Town Planning Institute (RTPI) (2018). It is accepted, however, that the inter-relationships between urban structure and travel are complex (Hickman *et al.*, 2009). In response, the analysis has become more sophisticated, with an increasing consideration of multivariate relationships and both attitudinal and cultural contexts (Hickman & Banister, 2014).

An influential feature of Hickman & Bannister's work is their emphasis on the need to adopt new approaches to transport planning in seeking to address key strategic issues such as climate change and sustainable urban development. They argue that the strong positivist and quantitative tradition in transport planning has created an over-reliance on forecasting––the extrapolation of existing trends––and the provision of technical solutions to these expected outcomes.

This tradition, however, has underestimated the enabling role of transport infrastructure in addressing complex societal challenges such as climate change or more balanced economic development. In seeking to make the case for the role of urban planning and urban structure in supporting sustainable mobility, Hickman & Bannister have drawn on a Visioning and Backcasting for Transport (VIBAT) analytical approach (2007a, 2007b, , and 2014).

A VIBAT study (2004–2006), commissioned by the UK Department of Transport, indicated that radical changes to travel behaviour were needed to meet the UK Government's emission targets (Hickman & Banister, 2007b). This would require the adoption of an ambitious package of measures, including specific land-use and urban planning polices, namely higher-density developments around upgraded public transport networks, major investment in walking and cycling routes and policies to improve the attractiveness of urban areas for working and living. This study estimated that such a suite of measures could contribute up to 10 per cent of a 60 per cent reduction in transport emissions by 2030 against a 1990 baseline. The study recognises that improved vehicle technologies and alternative fuels will make a major contribution to carbon reduction efforts in the future, but that on their own they will be insufficient due to the projected increase in population and traffic growth. Consequently, ensuring that the UK travels in a more carbon-efficient manner will necessitate a combination of technological, public transport, land-use and behavioural change measures. In a series of subsequent studies, this same methodological approach was used to reinforce the case for integrating land-use and transport in seeking to reduce transport-related CO_2 emissions.

Although backcasting has elements in common with general scenario analysis, its distinctive feature is that it is not reliant on historical and current trends but rather focuses on considering the pathway back from a future state. Envisioning the future and then 'casting back' facilitates more creative and innovative thinking. It is argued that it is suited to addressing complex problems where existing trends are part of the problem.

The starting point of this approach is the calculation of a business-as-usual (BAU) projection as this is viewed as representing the upper limit for CO_2 emissions and other indicators of sustainable transport in the future. A new image of the future is then described and targets are used to quantify the level of reduction required in CO_2 emissions or changes in other indicators. The combination of policy measures required to reach this new image is then considered. Unlike conventional forecasting, therefore, the future change trend is a choice for decision-makers rather than something to react to. Participatory backcasting involving key stakeholders has also become more frequently used as it is viewed as way of facilitating buy-in for policy measures. A key motivation for and emphasis in this work is the need to build the discussion of strategic choices into transport analysis and planning.

Hickman and Banister's work has continued to develop this VIBAT approach. For example, it was applied to two case studies in London and Oxfordshire (Hickman *et al.*, 2013). For each location, four scenarios representing different transport strategies were developed;

- the BAU approach;
- low-carbon driving;

- more local travel; and
- sustainable mobility.

Using the VIBAT approach, a range of policies were reviewed, packaged and grouped to represent each of these four scenarios, and then modelled to compare the projected CO_2 reductions compared to the BAU projection. The results are shown in Table 1.

Table 1: CO_2 Emissions per Capital (Tonnes)

	1990	2006 Baseline	BAU	Low-Carbon Driving	More Local Travel	Sustainable Mobility
London	1.49	1.28	1.17	0.73	0.7	0.3
Oxfordshire	2.10	3.1	4.1	2.47	2.00	0.8

Source: Hickman *et al.*, 2013:212.

London is already on a downward trajectory and emissions per person will therefore reduce under all scenarios, with the largest reduction associated with sustainable mobility. For Oxfordshire, it is estimated that a BAU approach will actually result in an increase in emissions per person. A package of policy measures associated with sustainable mobility offers the greatest potential for reducing transport-related emission in this locality. It is accepted that this would also be the most difficult strategy to implement.

Hickman *et al.* (2013) contend that the imperative for adopting a more integrated approach to urban planning and transport planning has increased due to the challenge posed by climate change. Reducing CO_2 requires a highly ambitious strategy underpinned by sufficient funding and the political authority to implement the policies required. These authors highlight that achieving sustainable mobility necessitates a supportive urban form and layout, as these serve to maximise the benefits of substantial investment in public transport, cycling routes and pedestrian pathways. It is accepted that developing and implementing this type of radical strategy to reduce transport-related emissions is extremely problematic and challenging. They indicate that the main barriers are not the lack of evidence or practical examples of such strategies working but rather a weak strategic planning framework, insufficient funding (including a lack of value capture) and lack of sufficient political and societal consensus in favour of such strategies.

2.4 OECD: Spatial Planning Instruments and the Environment (SPINE)

Introduced in 2015, the OECD Spatial Planning Instruments and the Environment (SPINE) project analyses the environmental and economic effectiveness of spatial and land-use planning instruments as well as the potential gains from policy reforms. SPINE relies on a variety of analytical, modelling and empirical methods to investigate the relationships between land-use patterns, socio-economic outcomes, environmental pressures and the use of specific policy instruments.

There are currently three main strands to this work:

i. **Urban sprawl and the effects of structure on the environment, the economy and well-being**: This work stream is based on a cross-country analysis of various dimensions of urban structure and their effects. One pillar of this work is an empirical investigation of the relationship between urban structure and the concentration of air pollutants.

ii. **The environmental and economic effectiveness of existing urban policies:** This stream relies on *ex post* analysis of policy instruments focused on open-space conservation and parking.

iii. **The long-term consequences of potential land-use and transport policy choices:** This stream focuses on the application of SPINE's integrated land-use and transport model (MOLES) to specific city contexts. Currently this model is being used to evaluate the environmental effectiveness and welfare implications of policies to mitigate GHG emissions in Auckland and policies to tackle air pollution in Santiago, Chile.

The OECD contends that, by assessing the environmental and economic effects of urban land-use patterns, spatial planning and transport policy instruments, SPINE highlights the potential gains from policy reform, and enables informed evaluation of the costs and benefits associated with different policy options.

2.5 The Multi-Objective Local Environmental Simulator (MOLES)

As noted above, the third strand of SPINE relates to the use of MOLES, an integrated environmental economic model focusing on the quantification of the costs and benefits arising from various urban policies targeted at land-use and urban mobility patterns. The MOLES model is an amalgam of an urban general equilibrium model (U-GCE) and an urban microsimulation model designed to represent the long-run evolution of urban areas (Tikoudis & Oueslati, 2017). The perceived advantages of this model are that it combines the internal consistency of an U-CGE with the detail and additional predictive power of a microsimulation model.

The MOLES model is tailored to evaluate the environmental and economic impact of a mix of policies designed to target land-use and urban mobility patterns (Table 2). This model recognises that the policy impact of these measures is both dependent on the specific urban context—spatial layout, transit network configuration, morphology—and the evolution of key exogenous factors.

Figure 2 provides a schematic overview of the MOLES. The upper box represents the exogenous factors that entered into the core module (the spatial equilibrium model). The core of this model is a non-linear system of market clearing equations in housing and land markets solved for the corresponding equilibrium prices. The solution of this system generates the core's output—the long-run urban development profile—including prices, structural densities, population density, and traffic and emission intensity at each urban zone. The model's core outputs are applied to the three key variables—transport, emissions and land-use—to produce new feedback effects (pollution levels, travel times, etc.) which are then incorporated into the core of the MOLES. The model also draws on leading-edge GIS data to facilitate visualisation and analysis.

Currently the MOLES model is being applied to two empirical research projects;

- Mitigating GHG emissions in sprawled urban areas: the case of Auckland, NZ (see Box A); and

- Tackling air pollution in dense urban areas; the case of Santiago, Chile.

The OECD contends that this model will assist policymakers in distinguishing between potential 'best' practices—interventions that increase economic efficiency and environmental quality—and regressive actions. MOLES also seeks to provide insights into the trade-offs between the environmental and economic impacts of second-best interventions if the first option is not available. Finally, the model has been designed to systematically explore the environmental and economic consequences of fragmented governance structures in which different authorities with competing objectives are responsible for different policy instruments.

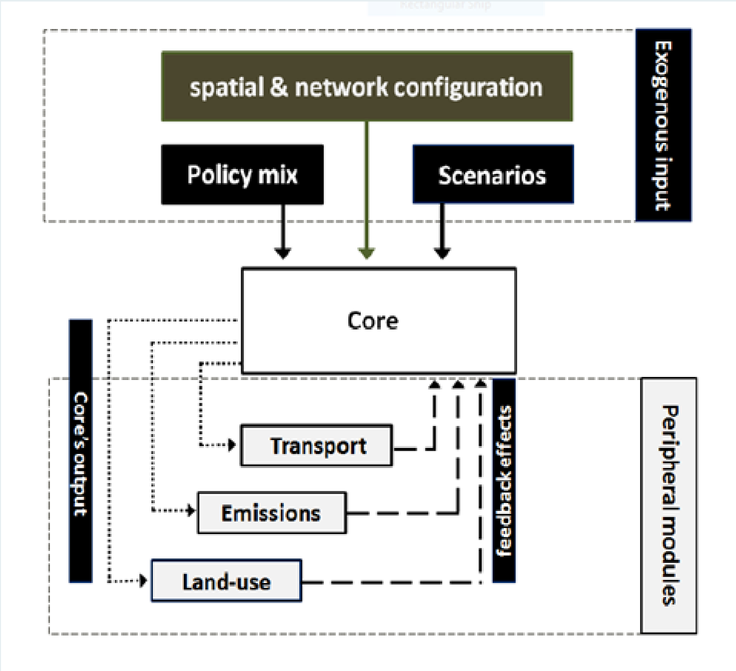
Table 2: Summary of Policy Instruments in MOLES

Policy Target	Policy Type	Policy Instrument
Land-use	Tax-based	Property taxation Land Development Tax
	Command & Control	Building height regulations Urban growth boundary Land supply regulations Residential zoning regulations Industry relocation
	Investments	Open space & natural amenities Urban reforestation
Transport	Tax-based	Cordon tolls Flat kilometre tax Varying kilometre tax Area charging Fuel taxes Parking fees Annual circulation taxes Vehicle registration tax
	Command & Control	Car-free areas Near-zero emissions zones
	Subsidies	Public transportation
	Investment in Infrastructure	New public transport networks Lower-emission public transport* Electric vehicle charging stations* Road capacity augmentation Road network expansion Support infrastructure for automated driving *

* Denotes that the investigation of the specific policy instrument requires further development or modification of the model.

Source: Tikoudis & Oueslati, 2017: 9–10.

Figure 2: Overview of MOLES



Source: Tikoudis & Oueslati, 2017).

Box 1: Mitigating GHG emissions in Auckland, New Zealand

This project is focused on the challenge of how to decarbonise the transport sector in a sprawling, growing and car-dependent city. MOLES is being used to evaluate the potential effectiveness and welfare implications of various land-use and transport policies that are designed to support the transition towards low-carbon mobility and a more environmentally sustainable form. In particular, the study focuses on urban policies designed to achieve three key policy shifts:

- **a move from car dependency to public transport;**
- **a shift from conventional vehicles to electric; and**
- **a shift from urban sprawl to more compact development.**

Source: OECD, 2019.

2.6 Transit-Oriented Development, Sustainable Mobility and Emissions Reductions

There is quite a rich literature that has highlighted the role of transit-oriented development (TOD) in supporting the transition to sustainable mobility and reducing transport-related carbon emissions. TOD is a form of urban development that focuses on quality of life, transportation, and reducing car ownership and dependency.

Tiwari *et al.* (2014) contend that it is possible to frame the climate problem as an urban development and transport problem, where significant reductions in CO_2 can be understood as a co-benefit of sustainable urban development and transport planning. Using the case of the Bentley Technology Precinct (BTP), located in the car-orientated city of Perth, these authors sought to develop a coherent policy framework for the development of a sustainable green town. This strategic framework consisted of a variety of land-use and urban policy improvements, transport policies and technology changes drawing on the density, design and diversity model of sustainable urbanism and the ASIF2 (avoid, shift, improve and finance) paradigm.

BTP is home to a number of institutional, research and technology centres. As part of Directions 2031, the draft Spatial Framework for Perth and Peel, BTP has been identified as a strategic specialised centre with anticipated growth in both economic activity and population in the period covered by the spatial plan. Tiwari *et al.* (2011), in this study, undertook an audit which estimated vehicle kilometres travelled (VKT) and CO_2 emissions associated with three situations:

- the current context for BTP;
- a BAU car-based approach to BTP's strategic development to 2031; and
- a mixed-use TOD approach to BTP's strategic development to 2031.

Given the 2031 strategy's emphasis on increasing the number of students and workers in the BTP area and increasing the level and range of economic activity, it is not surprising that it was estimated that carbon emissions would increase by 2031. Under the BAU approach, it was estimated that there would be an approximate 200 per cent increase in total emissions from all users, as measured by kg per day. In contrast, the adoption of a mixed-use TOD approach would dramatically slow the future increases in carbon emissions despite the substantial increase in residential dwellings, retail and office employees and students. The Tiwari *et al*. (2011) forecasts suggest that the carbon emission for all users by 2031 would be 47 per cent less for the ambitious TOD strategy compared to the BAU approach. This difference was driven primarily by a combination of:

- increased usage of public transport; and

- increased potential for self-containment, in that more people are engaged in work, study and social activities within the area.

It is possible therefore to combine substantial urban economic development with carbon emissions reduction through a commitment to sustainable urbanism. It should be noted that the authors recognise that their forecasts are indicative and probably optimistic in terms of the reduction shift in CO_2 emissions associated with TOD compared to a non-intervention strategy. They also recognise that implementing such an ambitious strategy would have to overcome a number of obstacles, in particular:

- the political and financial costs associated with land acquisition;

- the difficulty of ensuring a sufficient and mixed supply of housing (otherwise key groupings would continue to face long journeys);

- opposition to the loss of road capacity;

- building strong support for such a plan;

- the difficulty of ensuring mixed-land-use; and

- the challenge of encouraging people to shift from private car to public transport.

Despite these obstacles, Tiwari *et al*. (2011) maintain that strategies for sustainable urbanism, when combined with the use of sustainable technologies, are critical in seeking to arrest societal dependence on fossil fuels, rising emissions and escalating air pollution. With regard to Perth, these authors assert that their framework demonstrates the impacts that changes in land-use, transport and other forces have on vehicle movements and thus carbon emissions. The TOD approach of concentrating residential and commercial development in areas adjacent to good-quality public transport infrastructure reaffirms the need to integrate land-use and transport planning in seeking to address climate change. Policies targeted at the density, design and diversity of the urban structure are central elements of a TOD approach. The adoption of sustainable urbanism also requires the attainment of a certain level of urbanity through place-making strategies, that is a making urban centres more liveable and attractive places. This reflects Hall's (2014) view that the authoritative public institutions that drove good practice in urban development in various European cities displayed a strong, collective sense of '*urbanisme*'. Sustainable urbanism, when combined with an approach designed to not only estimate the factors that are driving rising emissions but that seeks to change them, can, it is argued, provide a framework for achieving low-carbon green urban development.

A similar case-study approach is used by Seo *et al.* (2013) in their work on measuring and estimating the potential environmental and economic impacts of introducing transit-orientated corridors (TOCs) in Korea. The TOC concept shares many of the key characteristics of TOD in terms of the emphasis on development adjacent to transit stations, an integrated public transport network, mid- to high-density mixed-use buildings and investment in pedestrian and cycle routes. The main differential is that a TOC approach is premised on the planned development of each station along a designated corridor, with the aim of linking each station area with a transit route at the centre.

In the Seo *et al.* (2013) study, a TOC planning model was developed and applied to Anyang City, one of the many satellite cities located in the Seoul Metropolitan Area. Regression analysis was then used to determine the hypothetical impact of the TOC model on the local environment and economy. In particular, this analysis was used to examine the relationship between TOC planning factors and transport modal share, and the impact of transit accessibility on modal choice.

Several conclusions were drawn from the results. First, to promote mass transit, the area's residential and commercial features must be intensified through a combination of mixed-use and a low ratio of road. Second, the transit modal choice analysis revealed that accessibility to mass transit is an important variable in determining its usage, along with the number of blocks per unit area and the pedestrian environment of the vicinity. Third, the results suggest that strengthening city-wide reliance on mass transit is effective in reducing environmental hazards to a significant degree. The modelling results indicate that, by increasing the ridership ratio of public transport, the decreased road traffic would reduce CO_2 emissions by between 40.2 and 73.1 million tons yearly. Finally, in terms of boosting the regional economy, higher pedestrian volumes of commuters would increase annual income for neighbourhood retailers in the range of $7.4m to $13.6m.

The role of TOD in addressing carbon emissions is further developed by Cervero and Sullivan (2011) in a paper that looks at the potential synergies that can be created by combining TOD with green urbanism. The key element of a green TOD is:

- investment in high-quality public transport and mixed-use high-density development; combined with

- investment in sustainable buildings, renewable energy and zero/low-waste strategies.

Although both TOD and green urbanism have the potential to reduce CO_2 emissions, these authors argue that combining the two approaches in the one strategy will create additional synergies that will generate even greater savings.

In making the case for green TODs, this paper describes a number of case studies that resemble this approach, namely:

- Hammarby Sjostad (Stockholm);
- the Rieselfeld and Vauban Districts of Freiburg; and
- Kogarah Town Square (Sydney).

For each of these localities the authors draw on various *ex post* evaluations that have highlighted the environmental benefits associated with the policies adopted. Cervero and Sullivan (2011) estimate that the inherent synergies offered by green TOD, such as higher densities producing co-benefits of higher ridership and reduced heating costs from shared wall construction, could shrink its environmental footprint relative to conventional developments by upwards of 30 per cent.

2.7 The Greater Dublin Area: Carbon Emissions and Location

Byrne and Donnelly's (2012) work focused on developing a model that provided a destination-based assessment of the carbon emissions associated with 569,000 daily travel-to-work journeys in the Greater Dublin Area (CSO, 2006). In this work, two datasets—the CSO 2006 Place of Work Census of Anonymised Records (POWCAR) and CO_2 emissions per mode of transport—were used. The CO_2 weighting was computed by creating a model that included distance from home to work, the mode of transport taken to work and the CO_2 emissions factor for each mode. The destinations were aggregated to a 250 million square grid that was superimposed on a map of the GDA. The model was used to calculate a fine-grained carbon emissions value for every person travelling to work in each of the work destination grid squares in the GDA. The advantage of this model, according to the authors, is that it demonstrates the environmental impact of land-use at various locations in as quantitative a manner as possible. The model output was entered into a geographical information system (GIS) to facilitate visualisation and analysis.

The authors concluded that the model's results reveal a link between the location of workplace destination and carbon emissions generated per person to travel to that location. As is evident from Table 3, those travelling to destinations close to public transport options in city-centre locations show lower CO_2 emissions readings than those in more out-of-town locations that do not have access to the same range of public transport options. The CO_2 per employee in city-centre locations is up to four times lower than that associated with travel to or outside the M50. According to the authors, their results indicate that the model can be an integral part of a tool that could bring a stronger environmental component into spatial planning policies related to the location of workplace developments by incorporating a ranking of destinations in terms of transport-based CO_2 emissions.

Table 3: Overall CO_2 Emission Results for Model at Three Sample Test Sites

Test Site	CO_2 Emissions (kg per person)	Destination Population
City Centre	1.09	4586
M50 Suburban	5.05	393
Outer Suburb	5.97	86

Source: Byrne and Carty, 2012:6.

2.8 The Royal Town Planning Institute: Urban Planning and Sustainability

The UK's Royal Town Planning Institute (RTPI) in 2018 published a research paper, *Settlement Patterns, Urban Form and Sustainability: An Evidence Review*. This paper focused on the manner in which urban planning can generate potential benefits with regard to economic productivity, climate change, public health and lifestyle outcomes for an ageing population. This note will focus only on the climate-change aspects but it is worth noting that, in making the case for a more ambitious and robust approach to spatial and urban planning, its potential to deliver a range of co-benefits needs to be part of the national policy dialogue.

The RTPI (2018) paper argues that urban planning can help to deliver a radical reduction in GHG emissions through its ability to shape urban form in terms of size, location, density, land-use mix, connectivity and accessibility to developments. These elements of urban form can influence the patterns of settlement growth over time. A key conclusion from this review is that settlement patterns and urban forms that promote sustainable mobility can play a critical role in reducing transport emissions, with larger settlements characterised by higher densities and mixed land-uses reducing the need to travel by car.

This review is very much in the tradition of the work undertaken by Hickman and Banister and Tiwari *et al.*, in terms of highlighting both the pivotal role of urban planning in mitigating GHG emissions and the need for closer integration of land-use and transport planning. As do these other authors, the RTPI paper stresses that planning policies designed to support compact higher-density urban forms require complementary policies; for example, policies to deliver affordable housing for renting and/or purchase.

The RTPI review refers to three studies that have sought to model the impact of settlement patterns and urban form on transport emissions in the UK:

- the Department of Transport 2007 VIBAT Study (Hickman & Banister 2007b, discussed in Section 3);
- an Ecotec 1993 study; and
- a study of commuting patterns in Surrey (Hickman & Banister, 2007a).

Ecotec's paper used simulations to suggest that a combination of urban regeneration, improved public transport and limited additional highway capacity could reduce transport emissions by 20 per cent over a 20-year period compared to a 'do minimum' scenario. Sill (1995) suggests that the Ecotec report emphasises 'policies most pertinent' to reduce travel demand and draws mainly on circumstantial evidence regarding patterns of urban form and energy use.

Regression analysis of commuting patterns in suburban Surrey was shown to demonstrate that different settlement patterns and urban forms accounted for approximately 10 per cent of the variation in travel energy consumption (Hickman & Banister, 2007a). Between 20 and 30 per cent of the variations in this study were attributed to socio-economic characteristics. The authors concluded that their results suggest that strategic and local-level urban planning can reduce energy consumption in car use. Realising this potential requires the careful integration of transport and urban planning. It is accepted that this type of integration is challenging as it is dependent on co-ordinated action by a wide range of actors across many fields.

The RTPI study also notes that in the UK average trip length has stabilised and that the modal shift to the private vehicle has started to decline. It suggests that this can be attributed to the emergence in the early 2000s of a more integrated approach to transport and land-use, and the application of Planning Policy Guidance that encouraged brownfield regeneration and set standards for density and maximum levels of parking, along with wider social and economic objectives.

Although the RTPI stresses that seeking a reduction in GHG emissions requires a renewed focus on the role of urban spatial planning, it does not seek to justify this position on the basis of any sophisticated modelling techniques or quantitative methodologies. Indeed, it recognises that it is difficult to quantify the important roles of settlement patterns and urban forms in achieving emission reductions in the transport sector. To an extent, it adopts the position that the case for the relationship between urban structure and mobility has been made, and that therefore the debate is now about how urban planning can play a more enhanced role in achieving sustainable mobility. At the same time, it concedes that there is a need to dramatically improve the collection of basic but key data related to urban planning; for example, the location of housing developments, their physical characteristics and their impact on the shape and form of villages, towns and cities.

In line with most studies already discussed in this note, the RTPI emphasises the need to both integrate land-use and transport policy and implement an ambitious package of measures, including mixed-use development in new and existing developments, brownfield development, investment in walking and cycling infrastructure and the delivery of high-frequency, good-quality public transport connections (bus and rail) between settlements.

An integrated approach in conjunction with complementary economic and social policies can drive a series of mutually reinforcing positive outcomes, including a more compact and liveable city and reduced emissions. There is also the potential to achieve higher emissions reductions in the long term by increasing the levels of self-containment and influencing the locational choice of people and jobs within the existing stock of buildings.

It is worth noting that the RTPI also makes the case for investment in public transport ahead of housing development, as preferences for car-based travel can be hard to change even when investment subsequently takes place. Finally, the RTPI also sees a role for demand management strategies and policies designed to support behavioural change.

2.8.1 Settlement Patterns and Urban Forms: Building Emissions

The RTPI study also considers how settlement patterns and urban forms can influence building emissions. Differences in house size and density between urban, suburban and rural locations are associated with differences in average building emissions. The report refers to studies that suggest a positive correlation between higher densities and lower emissions, with medium-rise developments in urban settings consuming the least energy. This positive correlation between density and emission tails off for the highest densities due to the embodied emissions associated with construction methods and material for higher-density developments. Standalone developments also generate high levels of embodied emissions due to the construction of new infrastructure services. This report notes, however, that the most effective strategy for reducing building emissions is to invest in improving the existing stock of buildings and infrastructure.

Finally, the study highlights the critical role that district heat networks can play in reducing emissions through their capacity to convert waste heat into renewable energy for domestic and commercial consumption. The cost of constructing and laying underground pipes combined with the need to ensure a balance between the supply of waste energy and demand suggests that this form of infrastructure is best suited to higher-density mixed-use urban areas.

2.9 Evaluating the Impact of Urban and Transport Planning: the Case for a New Approach

As outlined above, there is quite a rich literature on the role that spatial planning and urban form can play in supporting sustainable mobility and contributing to the much-needed reduction in CO_2 emissions. The studies reviewed adopted a variety of methodological approaches in seeking to quantify the relationships between the built environment, mobility and emissions, including:

- Regression analysis;
- *ex post* evaluations;
- VIBAT;
- multi-criteria analysis;
- GIS modelling;
- scenario building and modelling; and
- the Multi-Objective Local Environmental Simulator model (MOLES).

At one level, it is important to continue to develop the quality and sophistication of quantitative models as such approaches clearly have a role to play in making the environmental case for better spatial planning. At the same time it would be a mistake to assume that quantitative models are the answer to the complex challenge of transitioning to a more sustainable form of urban development. To put it another way, it would be too simplistic to think that, if we could just get a robust model that would generate irrefutable evidence, then the appropriate package of urban planning and transport measures would be adopted and implemented. As noted above, it can be argued that the lack of evidence is not the main barrier to transitioning to a model of sustainable mobility.

An influential feature of Hickman & Bannister's work is their emphasis on the need to adopt new approaches to transport planning in seeking to address key strategic issues such as climate change and sustainable urban development. As outlined earlier, they contend that an overreliance on conventional forecasting—the extrapolation of trends—has served to underestimate the enabling role of transport infrastructure in addressing complex societal challenges such as climate change or more balanced economic development. This accords with other commentators who have argued that conventional appraisal techniques are not particularly appropriate for considering the non-marginal impacts of transformative or game-changing infrastructure investments, in particular major transport projects (Brown & Robertson, 2014; Rosewell, 2010; Rosewell & Venables, 2014).

Hickman and Banister are also highly critical of the emphasis in transport planning analysis on calculating time savings and comparing the relative costs of the transport investment (see also Rosewell, 2010). This, they argue, ignores the major issues such as climate change. It is accepted that intangible outcomes like sustainable development are difficult to identify and monetise but at the same time they are the very strategic issues that major investments in transport and urban development need to be addressing (see also Roelich, 2014).

Hickman and Banister (2014) suggest that making the case for the role of transport planning in contributing to the achievement of longer-term developmental goals, including reducing GHG emissions, requires a number of elements. First, there is a need to reframe transport planning, moving from the conventional transport planning and engineering focus towards an emphasis on sustainable mobility (see Table 4). Secondly, there is a need to embrace and work with uncertainty, rather than assuming that this can be modelled away. Thirdly, transport planning has to be deeply integrated with land-use and urban planning. These two areas, moreover, need support from complementary economic and social policies. Fourthly, there is a need for major changes in the theory and practice of transport planning. To date the focus has been mainly on how to move people around efficiently while the issue of why people move has been somewhat neglected. Finally, there is a need to develop and adopt alternative methodologies.

> The limits of forecasting have been reached and their use should be restricted to short-term more technical local-scale traffic problems. The larger scale, longer term and more open-ended strategic decisions—which address technologies, climate change, energy use and emissions, demographic change, societal priorities and the types of cities we want to live in—all require innovative thinking. This has large implications in research and practice as conventional approaches often have considerable inertia. However, where they are not suited to the problems being faced, alternative methods are required (Hickman & Bannister, 2014:72-73).

In part, addressing the challenges of evaluating and appraising infrastructure projects—including those related to major transport investment—requires the use of a wider set of quantitative and qualitative research tools and methodologies (OECD, 2017; Rosewell & Venables, 2014). Brown and Robertson (2014), for example, highlight the need to carefully develop standard approaches and techniques, while also introducing more non-standard approaches for estimating the costs and benefits of major infrastructure investment.

There is, as has been noted, a strong tradition of scenario building and modelling in transport analysis, and indeed such techniques have been used in the literature reviewed. In undertaking their national infrastructure assessment exercise, the UK Government's National Infrastructure Commission (NIC) adopted a range of quantitative and qualitative research methodologies (NIC, 2016). This included detailed quantitative modelling of the baseline outcomes identified by four scenarios and particular packages of policy measures. Interestingly, although such modelling was seen as providing insights, it was accepted that it also simplifies reality. The NIC contends that its role is essentially to provide some context for the commission's judgements on future infrastructure needs.

Interestingly, Hickman and Banister suggest that one of the benefits of VIBAT, particularly when there is a strong participatory dimension, is that it can encourage more open discussion of the strategic choices that are available and indeed necessary. This can lead to changes in public awareness of the issues and potentially more public demand for action. It is important to recognise that, in making the case for new evaluation methodologies, Rosewell was not simply suggesting that a narrow technical analysis be replaced by a more sophisticated one. As the range of possible economic, social and environmental effects taken into account widens, the relevant data and cause-effect relationships become more uncertain and subject to divergent understandings. This requires not only a change in the actual analysis undertaken, but also in the place of technical analysis in the overall decision-making process:

> Between political negotiation and technocratic decision making there is a big gap. If models were only seen as exploratory and partial, it would be easier to use them as tools to play with rather than tools for answers and this would give much more potential for the processes to create consensus rather than creating divisions which can only be resolved by direct intervention (Rosewell, 2010).

Analysis, she emphasises, is crucial, but it needs to be concentrated on those aspects that are amenable to such treatment. This means those aspects where we are clear about the assumptions so that we can present the risks most clearly. It also means downgrading analysis in which we cannot sensibly judge the correct assumptions: for example, when we assess the value of time (Rosewell, 2010: 62). There is clearly a role for the development of more sophisticated quantitative and qualitative methodologies in seeking to explore how urban form and settlement can influence sustainable mobility and reductions in CO_2 emissions. At the same time, the outputs of such work should be an input into a broader decision-making process rather than being the key determinant of policy choices. Furthermore, while sophisticated methodological approaches can evaluate whole packages of measures, in themselves they are not a tool for generating the necessary policy options and actions that must be adopted and implemented in seeking to address the challenge of climate change.

Table 4: Changing Approaches to Transport Planning

The Conventional Transport Planning and Engineering	The Emerging Sustainable Mobility
Abundant supplies of energy, with usage reduced by efficiency	Premised on the need to reduce resource consumption in transport and dependency on oil
Market/pricing mechanisms to drive efficiency	Strategic planning and investment to help shape the rules of the market
Travel decisions based on rational decision-making	Travel decisions as the product of a complex mix of routines, habits and constraints
Traffic mobility framed as increasing vehicle volume and throughput	Travel as a social activity, improvements to accessibility, journey experience and multi-modal focus
'Predict' and 'Provide' approach to analysis	Traffic demand management
Focus on transport modes rather than overall journey	Door-to-door travel and whole-journey experience
Street as a road	Street as a space with multiple users/uses
Motorised transport dominates	Hierarchy of transport modes, with walking and cycling at the top
Strong focus on major road projects	Integrated strategies and package of complementary measures
Accept existing trends and how to manage them in the short term	Focus on the role of transport in achieving a desirable city over the longer term
Disregarding of context	Strategic and local urban planning as a central element in achieving sustainable transport
Demand forecasting mainly traffic-based with some public transport	Visioning, backcasting and scenario analysis, benchmarking for cities and transport
Economic objectives (cost) prioritised over social and environmental objectives	All three pillars of sustainability considered important and recognition of role of cultural context and political and public acceptability
Dominance of economic evaluation (cost/efficiencies) and quantitative analysis	Multi-criteria analysis to take account of environmental, social and implementation concerns; quantitative and qualitative analysis given equal balance
Travel as a derived demand, instrumental factors important	Travel as a valued activity as well as derived demand—instrumental and affective factors often interlinked
Traffic to be speeded up to reduce journey time	Concept of slower travel, reasonable travel times and reasonable energy usage
Segregation of traffic and pedestrians	Integration of pedestrians, cyclists and traffic

Source: Hickman and Banister, 2014:346.

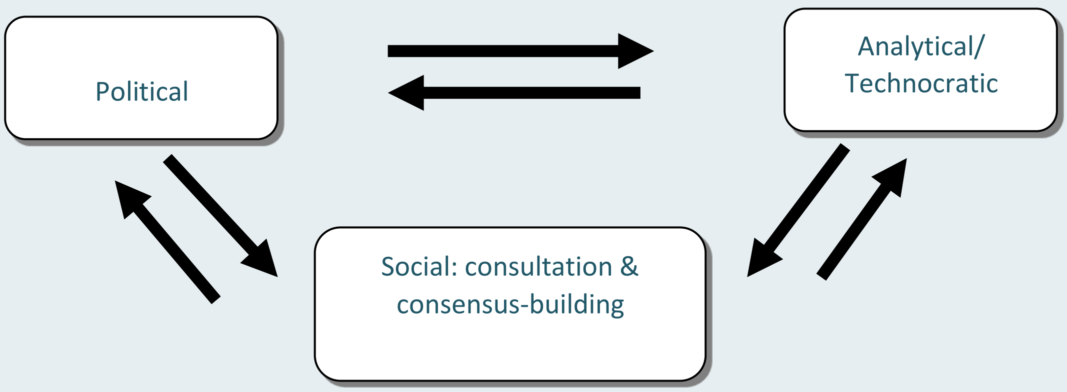
It is clearly necessary to continue to build the analytical basis of the decision-making process for reducing carbon emissions and addressing climate change. However, this remains a policy domain that is characterised by complexity, uncertainty and ambiguity. These characteristics limit both the scope of purely objective scientific analysis and the possibility of complete independence from both political contestation in society and the political decision-making of government. Commenting on the broader issue of infrastructure governance, Hammerschmid and Wegrich (2016, a) contend that politics remains both central and necessary for effective, efficient and good decision-making on infrastructure policy.

> Complexity is inherent to infrastructure governance and will not cease with the application of more advanced tools of economic analysis or more rational planning cycles. Decisions under conditions of complexity and uncertainty require political choices (Hammerschmid & Wegrich, 2016: 36).

The same perspective arguably holds true for good decision-making on urban planning and climate change.

NESC's work on infrastructure policy in the UK also highlighted that, in addition to technocratic analysis and politics, there is an important third element: societal consultation and decision-making (NESC, 2018). Again, we would argue that this framework is equally relevant to thinking about how policies related to sustainable urban development and mobility are made and implemented.

(repeat) Figure 1: Understanding the Infrastructural Policy Challenge



Source: NESC, 2017.

2.10 The Enabling Role of Urban Structure

Although the various studies reviewed in this paper adopted different methodological approaches, as a body of work they highlight, in their different ways, the key role of urban form and settlement in influencing patterns of mobility. While there will be many future pathways to achieving sustainable mobility in different cities, Hickman and Banister (2014) suggest that the commonalities of these pathways include the following six elements:

i. an urban structure that supports sustainable mobility;

ii. major investment in an integrated public transport network;

iii. the development of walking and cycling facilities and the public realm;

iv. traffic demand management measures;

v. information and communication technologies; and

vi. technological developments, in particular low-emission vehicles.

The authors contend that urban structure has become a critical tool in transport planning as it can facilitate increased usage and access to public transport, walking and cycling modes, higher density around transport nodes, a quality and attractive public realm, and mixed land-use. Indeed, while all of the above elements are important, urban structure is viewed as having a critical enabling capacity in terms of realising the impact of the other component policies within an integrated package. For example, the development of appropriate urban planning policies not only works alongside but can arguably augment the impact of investment in public transport, walking and cycling facilities. Reframing transport in terms of sustainable mobility (Table 4) focuses attention on the key role of planning and spatial structure in determining transport mode and distance travelled. In particular, it links the spatial distribution of population, jobs and other activities in the city to the pattern of trips. Hickman and Banister contend that urban structure provides the means by which sustainable transport can be achieved in cities. It is recognised that changing urban structure takes time and that the benefits associated with it will take time to accrue. However, failing to change current approaches will serve to lock society into an unsustainable form of urban development and mobility.

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