EPA STRIVE Programme 2007–2013

Environmental Sustainability and Future Settlement Patterns in Ireland

(2001-LU/CD-(2/3))

STRIVE Report

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by

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Executive Summary

Context

Within the National Development Plan 2007–2013, it is recognised that there is a need for additional housing for our growing population. The National Spatial Strategy (NSS) is designed to identify where such new housing might be located, so as to provide for regionally balanced and sustainable development. It was recognised that the effectiveness of the National Spatial Strategy would benefit from additional policy-relevant information on the current sustainability of Irish settlements. Subsequent research calls by the Environmental Protection Agency (EPA) recognised the need to bridge this gap in our knowledge. As a result of these calls, the EPA initially funded a pilot study and subsequently a larger scale study. The pilot project report *Methodologies for the Estimation of Sustainable Settlement Size* (Moles et al., 2002) described a method for assessing the sustainability of settlements. Results suggested that there existed a relationship between settlement size and sustainability, but data gaps and small settlement sample size limited the reliability of the results. The larger project reported here aimed to fill data gaps, further develop and apply quantitative methods to define the relationship between sustainability and settlement attributes such as population size and location, and to include a much larger sample of settlements.

Methods

- Sustainability was defined in terms of environmental, social and economic pillars: a sustainable settlement provided secure employment for its inhabitants, access to a wide range of services, a choice of transport modes and a good quality of life.
- Seventy-nine settlements were selected for study, in three clusters centred on Limerick, Sligo and Athlone/Mullingar. Settlements varied in size from city (Limerick) to village.
- Two methods were selected to evaluate the sustainability of settlements. Two were selected because (1) there was no single method described in the literature which would embrace all dimensions of urban sustainability, (2) it was not clear at the outset which was more likely to be successful, and (3) if it could be shown that application of two distinct methods produced similar results, then confidence in both methods and results would be enhanced. As a final step, both methods were amalgamated into a single measure of sustainability.
- Following the first method, assessment was based on sustainability indicators and indices. The second method measured material and energy flows to calculate an Ecological Footprint (EF) for each settlement. An EF is, in simple terms, the area of land that a settlement needs to provide the resources used by its inhabitants and assimilate waste produced by them.
- Published and otherwise available data relating to sample settlements were augmented by information gathered through a questionnaire for householders.

Results

- Both methods produced similar results, and the amalgamation of two methods into a composite method provided especially clear results. Population size, and other attributes of settlements, were clearly linked to the level of sustainability attained.
- Larger settlements (average population *c.*17,000) were found to be clearly more sustainable, and the city of Limerick was the most sustainable settlement in our sample. However, Limerick scored poorly on environmental indicators.
- Satellite settlements, especially those showing recent rapid growth, were clearly least sustainable.
- Some smaller settlements (average population *c.*900) showed low sustainability primarily because of low availability of employment.
- Some medium-sized (average population *c.*2,000) settlements achieved a relatively high level of sustainability.

- Attributes other than population size influenced the level of sustainability achieved; for example, rate of growth, location, local economy, availability of services, connection to gas network and distance to nearest larger settlement.
- Effectiveness of waste management was not related to settlement size, but rather to the level of services available in the area.
- It is possible for all settlements to enhance the level of sustainability achieved by households (household sustainability).

Policy implications

- Under current policies and practices, new housing has located especially in satellites and urban fringes. Services and public transport provision have not kept pace: therefore, the current pattern of growth is not balanced and this is having the overall effect of reducing Irish sustainability, for example in relation to carbon emissions.
- Fast-growing satellites are least sustainable: policy needs to be altered to avoid rapid growth where there are few services and public transport provision is inadequate, as this leads to unsustainable levels of private car use.
- Larger settlements provide the infrastructure required to ensure that population growth does not have a negative impact on household sustainability: this strongly supports the recommendation that more growth should occur within larger settlements, but it will be necessary to update and expand the infrastructure and protect the environment.
- Those medium-sized settlements which achieved relatively high sustainability represent locations for more sustainable population growth, in addition to gateways and cities.
- For many smaller and more isolated settlements, enhancing socio-economic development is a primary goal. Individual small settlements cannot support a wide range of services: planning for enhanced sustainability in smaller settlements needs to coordinate the development of services in groups of nearby settlements to maximise access without incurring long car journeys.
- Wider adoption of best practice in waste management will enhance settlement sustainability. Wastewater treatment should be required for all smaller settlements – otherwise population growth in them will further reduce sustainability.
- Quality of life varied little amongst settlements: greater sustainability was not reflected in enhanced quality of life. Ideally, adoption of more sustainable lifestyles should translate into an enhanced quality of life. This has implications, for example, in the provision of quality public transport.

Further information needed

- How some medium-sized settlements have achieved greater sustainability.
- If Limerick is typical of Irish cities in the level of sustainability achieved.
- How to plan for enhanced sustainability in groups of nearby smaller settlements.
- How to establish more sustainable urban neighbourhoods in Irish settlements.

1 Introduction

Within the National Development Plan 2007–2013, it is recognised that there is a need for additional housing for our growing population. The National Spatial Strategy is designed to identify where such new housing should be located, so as to provide for regionally balanced and sustainable development. It was recognised that the effectiveness of the National Spatial Strategy would be enhanced if there existed more information on the current sustainability of Irish settlements. Subsequent research calls by the EPA recognised the need to bridge this gap in our knowledge. As a result of these calls, the EPA initially funded a pilot study and subsequently a larger scale study. The pilot study (2000-LS-4.3-M1) focused on methods for generating this information and results are available in *Methodologies for the Estimation of Sustainable Settlement Size* (Moles et al., 2002). Categories of information needed in the assessment of settlement sustainability were identified, and an analysis of a small number of settlements suggested that sustainability was greater in larger settlements, but that settlement size was not the only attribute affecting its sustainability. The second project reported here (2001-LU/CD-(2/3)) and entitled *Sustainability and Future Settlement Patterns in Ireland* builds on the first project and aimed to further develop methods to define more clearly the relationship between sustainability and settlement attributes such as population size, and to include a much larger number of settlements, so as to provide the National Spatial Strategy with reliable and policy-relevant information.

Settlements are urban areas varying in size from villages to cities. Sustainability is a somewhat difficult concept to define: here it is taken that for a settlement to be sustainable, it should be able to maintain into the future a quality of life considered good by its inhabitants whilst at the same time not creating environmental problems or inefficiently using resources such as water and energy.[1] Because of the concentration of people living in a settlement, it is difficult to imagine any settlement being completely sustainable, that is, using only renewable resources produced within its boundary, and creating no significant environmental impacts. But some settlements are clearly more sustainable than others, so that there is great interest in identifying ways to improve the relative sustainability of settlements, so as to bring less sustainable settlements up to the standard achieved by the most sustainable settlements. This is particularly relevant in contemporary Ireland, as we have a rapidly growing population and economy, which requires us to build additional settlements or to increase the size of existing ones. A person living in a more sustainable settlement has good job security, has easy access to a wide range of social and other facilities and services, uses relatively small amounts of resources such as oil and creates little impact on the environment. The question is: How do we plan settlements, existing and new, which are as sustainable as possible? Previous studies have been undertaken in other countries to answer this question in relation to cities, but no clear picture has emerged. Some studies suggest that settlements should be large in population size but cover as small an area as possible, with high-density housing to make walking a practical means of getting around, with public transport viable, and facilities and services concentrated in a centre to maximise the range and choice available to inhabitants. Others suggest that if settlements grow beyond a threshold population size, traffic congestion, crime, noise, pollution and other negative factors tend to reduce the quality of life for their inhabitants. The purpose of this report is to evaluate the sustainability of Irish settlements. For this to be useful, for example within the context of the National Spatial Strategy, it needed to provide a secure basis for policy recommendations aimed at enhancing the sustainability of all settlements, but especially the less sustainable ones.

[1] For a more detailed explanation of sustainability and sustainable development, see the end-of-project report.

One of the biggest problems facing researchers in the past has been the lack of local-scale information about settlements and their inhabitants. In the absence of data, the conclusions drawn in previous studies were necessarily theoretical rather than evidence based, and often contradictory, therefore not providing a sound basis for policy making. Crucial for this project was that funding was made available for three researchers to spend 18 months collecting data on a sample of settlements ranging in size from village to city. This information is contained in a database held by the EPA. As a result, for the first time anywhere in the world, this project was able to overcome problems arising from serious gaps in information, and was able to analyse many settlements differing in size and location.

2 Brief Technical Literature Review

Contemporary Ireland faces a number of important issues, including infrastructural deficits. Transport, housing, urbanisation and national growth imbalances are highlighted in the National Development Plan (NDP) as weaknesses which the Irish economy and urban structure need to overcome to ensure continued economic and social progress (NDP, 1999b, p.35). A goal of the National Spatial Strategy (NSS) is to achieve more equal social, economic and physical development and population growth in Ireland, within the NDP, with sustainable development identified as a key objective (NDP, 1999a, p.45). Sustainable development forms a core element of policy documents of many other governments, international agencies and business organisations (Mebratu, 1998, p.494) but the concept has many definitions (Ho and Ulanowicz, 2005, p.40). The basic idea is very simple: a sustainable system is one that survives and persists (Constanza and Patten, 1995, p.193). Others argue that a normative element is inherent to the concept, involving trade-offs among social, ecological and economic objectives, so as to sustain the overall integrity of the system (Hediger, 2000, p.481). For the purposes of the study reported here, a distinction is drawn between ‘sustainability’ and ‘sustainable development’. The former is an aspirational future situation, and the latter is the process by which we move from the present status quo towards this aspirational future situation.

Sustainability is taken to be:

> … a dynamic balance among three mutually interdependent elements: (1) Protection and enhancement of natural ecosystems and resources; (2) Economic productivity; and (3) Provision of social infrastructure such as jobs, housing, education, medical care and cultural opportunities. (Bell and Morse, 1999, p.61)

Sustainable development is taken to be:

> A process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations. (WCED, 1998, p.47)

Planning for sustainable development is ultimately concerned with combining, balancing or trading-off aspects of these economic, social, environmental (and institutional) dimensions (Mazza and Rydin, 1997, p.3). Settlements are crucial within planning for sustainability: as important centres of origin for environmental impacts, urban settlements must also therefore be seen as the motors of sustainable development (Rees and Wackernagel, 1996, p.223; Rotmans et al., 2000, p.265).

> Sustainability in the urban setting refers to the potential of a city to reach a level of socio-economic, demographic, environmental and technological performance which in the long run reinforces the foundations of the urban system itself. (Capello et al., 1999, p.12)

However, in the longer term, even settlements with favourable local environmental conditions will be subject to the effects of global environmental problems such as climate change (Alberti, 1996, p.384). Therefore, planning for urban sustainability should fit into strategic plans for sustainable development at regional, national and international scales.

> The key issue is not ‘sustainable cities’ but cities whose built form, government structure, production systems, consumption patterns, waste generation and management systems are compatible with sustainable development goals for the city, its wider region and the whole biosphere. (Marcotullio, 2001, p.580)

While there appears to be general agreement on the need for planning for sustainable development, there is much less agreement on how this should be undertaken. Camagni et al. (2002, p.214) describe how a 'wisely compact' settlement with several centres offering a wide range of services, for example, may create the most sustainable urban form. If appropriately planned, it has been argued that urban settlements can achieve an efficient use of space and resources unattainable by a scattered rural population. High population densities offer opportunities for the efficient use of resources, such as electricity and transport facilities, as well as providing an efficient structure for waste disposal and sewage infrastructure (Giradert, 1999, p.61).

Cities provide opportunities to achieve economies of scale and use natural resources more efficiently. Compact urban settlements, for example, are generally more energy efficient than dispersed ones (Alberti and Susskind, 1996, p.213).

Advantages of the 'compact city' include the integration of structures, infrastructure and function (Mega, 2000, p.233), and reduce the ecological impact of mobility due to reduced average distances between home, work and leisure destinations (Muniz and Galindo, 2005, p.500). Public transit systems are much more likely to be economically viable in compact urban settlements (Giradert, 1999, p.51). Per capita, such systems use much less energy and require less space than private transport. Service provision may also be more efficient in compact settlements (Chiras, 2001, p.393). The importance of differentiating between high density and high-rise may be important (Mega, 2000, p.233). Measures such as smaller housing sites, increasing the proportion of multifamily dwellings such as apartment blocks, and more compact location of services (shops, for example) may help in the implementation of development in a compact manner, for example (Chiras, 2001, p.393). In addition, compact development may help to preserve ecologically and economically important land surrounding a settlement by concentrating people and services (Chiras, 2001, p.392).

The term 'edge city' refers to the development of low-density suburbs, well serviced with roads and car parking facilities and interspersed with tracts of pre-industrial rural land (Garreau, 1992). Low-density suburbs are common in economically prosperous countries and many reasons have been suggested for their development. These include reasons related to choice of residential location, such as the decline in the environmental quality of compact city centres, changes in lifestyles, the replacement of residential land use in the city centre by shops and other services, poor accessibility to city centres by car, the development of city-fringe retailing based on car transport, and the suburbanisation of housing, consumer markets and the labour force (Camagni et al., 2002, p.201). Such suburbs have been associated with many negative environmental consequences. The consumption of land for development purposes is an obvious effect, as farmland and biodiversity habitats are built over (Chiras, 2001, p.392). The provision of public transport becomes more expensive as population density declines because of the low density and scattered distribution of intending passengers and the long distances between destinations (Camagni et al., 2002, p.202). Built-over catchments reduce protection from flooding. Dispersion results in greater use of private transport for commuting, and increased commuting time. The cost of infrastructure and service provision may rise as distance to the urban centre increases (Chiras, 2001, p.392). Low-density development increases per-capita resource demand, as well as requiring expensive and increasingly expansive infrastructure such as roads and electricity, water provision and sewerage. In addition, many qualities of traditional urban environments, such as public spaces, parks and a variety of services within a small area, may be lost (Holden and Turner, 1997, p.317).

> Dispersed development ranks low on the sustainability scale. (Chiras, 2001, p.392)

The question has been asked: How should we plan urban areas so as to maximise their sustainability? The literature suggests no straightforward answer. Agglomeration economies and diseconomies may in practice counterbalance one another. Thus, on the one hand large population size and compact shape are considered likely to be associated with quality of life issues such as excess noise and limited privacy, and more serious environmental problems and traffic congestion (Munda, 2006, p.87; Capello and Camagni, 2000, p.1485–1487). But on the other hand increasing economies of scale available within large compact settlements may result in more efficient public transport provision (Giradert, 1999, p.51), shorter distances between destinations such as home, work and leisure (Muniz and Galindo, 2005, p.500) and better overall integration of structures, services and function (Mega, 2000, p.233). Generally applicable threshold levels for population and settlement size which offer greatest benefits, but above which agglomeration diseconomies become effective, have not been established in previous studies.

This is perhaps not surprising. In relation to Irish settlements, Meldon (1998, p.67) pointed out that settlement size was not the only issue in relation to planning for sustainability: she suggested that the number of settlements of different sizes in a region and the spacing between settlements were of great importance in informing planning (Meldon, 1998, p.63). O'Farrell (1979, p.27) posed many questions fundamental to the identification of policy options for sustainable development of Irish settlements, especially the question: What sizes and spatial arrangement of settlement leads to the most efficient use of resources? Both authors recognise that planning for the most efficient use of resources requires consideration of attributes of settlements in addition to population size. O'Farrell (1979, p.44) took the view that there is no one optimal settlement size, but rather that there may be an appropriate size for each settlement, and that settlements require planning for enhanced sustainability tailored to their size and location, with a focus on spatial structure, and that planning is more effective at regional scale, rather than targeted solely at individual settlements (O'Farrell, 1979, p.56).

3 Methods

3.1 Key Ideas

For its results to be policy relevant, it was necessary that this project be undertaken following scientific method and its results subjected to standard tests for significance. A literature search found no previously published studies which evaluated the sustainability of a set of settlements. We developed our overall research approach by linking many constituent methods, the strengths and weaknesses of each of which are reviewed in detail in the end-of-project report 1, and the end-of-project report 2. In this way two methods were selected as being most likely to be successful in achieving the project objectives. Two were selected because (1) there exist no methods which embrace all aspects of sustainability into a single measurement, (2) it was not clear at the outset which was more likely to be successful, and (3) if it could be shown that application of two distinct methods produced similar results, then confidence in both methods and results would be enhanced. The first method is based on the selection of indicators for sustainability and the aggregation of indicators to form indices for sustainability. The second method was designed to measure material and energy flows within settlements, so as to allow the calculation of an Ecological Footprint (EF) for each settlement. An EF is, in simple terms, the area of land that a settlement needs to provide the resources used by its inhabitants and to assimilate the waste produced by them. The methods involved data collection, manipulation and analysis, and are necessarily complex. Environmental, social, quality of life and economic data are not easily assessed on a common scale. The methods selected were adopted or adapted from previous research in a range of disciplines, and relied on information derived from studies in several countries. The methods are described briefly in this Synthesis Report and fully in the end-of-project report. Both methods are innovatory and represent state-of-the-art analyses of settlements. The scientific rigour and usefulness of both methods has been tested in many ways; for example, through peer review of publications, the successful examination of two PhD theses and presentations at international conferences.

The study included settlements outside Dublin and the Dublin region, as part of its aim was to point up means of achieving sustainable growth outside the Dublin region as a counterbalance to the very rapid recent growth within it. The 79 settlements selected for study are located in three clusters around Limerick, Sligo and Athlone/Mullingar, settlements identified in the National Spatial Strategy as gateway towns with a prime function in enhancing regional economic and cultural growth (Figure 1). This number of settlements was selected on the basis that it was the greatest number for which data could be collected, given time and resource constraints, and the settlements in the sample were broadly representative of Irish settlements outside the Dublin region.

Because the definition of sustainability adopted embraced the three pillars of economics, society and environment, data were sought on all three, but with a particular emphasis on environment. Given time and resource limitations, it was not possible to collect all possible data on all aspects of these three pillars for each settlement. In the earlier project report, *Methodologies for the Estimation of Sustainable Settlement Size* (Moles et al., 2002), this issue was addressed, and the conclusion drawn was that data collection should focus on a set of categories of indicators of sustainability. These categories (see Table 1) provided a framework for data collection in the study reported here.

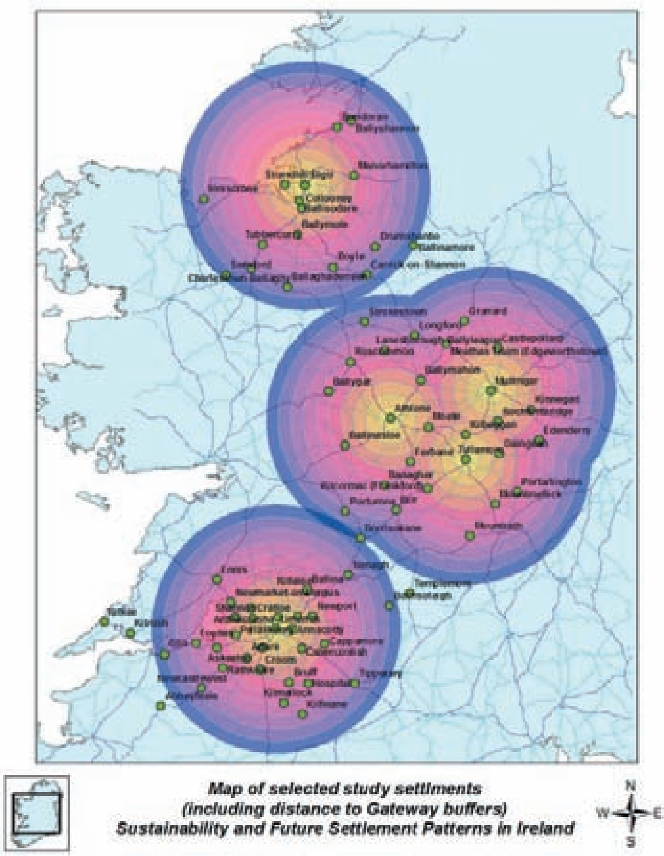


Figure 1. The 79 settlements selected for study are located in three clusters. The concentric coloured rings indicate increasing distance from the gateway settlements in each cluster.

Table 1. Categories of indicators of settlement sustainability as identified in the previous pilot-scale study which provided a framework for data collection in the study reported here.

Categories of Indicators of Settlement Sustainability
Waste (municipal solid waste, hazardous waste, waste treatment/disposal)
Water (quality of drinking water, level of wastewater treatment, surface and groundwater quality, percentage population connected to wastewater treatment plants)
Transport (range of public transport services, cycle ways, pedestrianisation, quality and network of roads, travel control measures, travel time and distance to services and work)
Energy (source – renewable energy share, per-capita usage, industrial usage, presence of combined heat and power [CHP] energy efficiency rating of housing)
Renewable and non-renewable resource consumption (food, water, construction materials etc.)
Air (quality, emissions to air, greenhouse gases)
Noise (loudness, type, frequency, duration)
Biodiversity (sensitive species – number and frequency, special protection areas)
Education (access, number of children per teacher, school leaving age, number attending third level)
Income (per-capita income, percentage claiming social welfare assistance, percentage in top and bottom 10% of earners, sources of income)
Housing (quality, cost, ownership, number of people per square metre of floor space, rent costs)
Employment (type, foreign- or indigenous-owned business, average working life, average age starting work and retiring)
Access to basic services (type and range of services provided)
Health (mortality, health services, type and frequency of diseases requiring medical aid)

As a first step, all sources of published and otherwise available data were identified, and the data collated and evaluated for completeness and accuracy. Important data sources consulted included: EU databases such as EuroStat, EU directives, national sources such as the British Department for Environment and Rural Affairs and the American EPA, the Irish Central Statistics Office (CSO), Small Area Population Statistics (SAPS), the Central Statistics Office Household Budget Survey, National Spatial Strategy (NSS) reports, Sustainable Energy Ireland (SEI) reports, Irish government department reports, Irish and international non-governmental organisation reports, Economic and Social Research Institute (ESRI) reports, regional and local authority reports, academic and technical journals and many websites.

As anticipated, it became evident very early in the study that major data gaps existed at settlement scale in the published data, such that few of candidate indicators identified could be quantified. Problems encountered included data gaps on individual settlements, few up-to-date data, and few data-in-time series. In many instances, data were published at national scale only, and there was no way of evaluating the extent to which a settlement might differ from national averages. Published or otherwise available data available at settlement scale were collated: data availability and reliability were checked through pilot studies of Ennis and Midleton. To fill the identified data gaps, a campaign of primary data collection was undertaken. This was carried out over 18 months by three postgraduate researchers. It became evident that data from industry was not likely to be made available for reasons of confidentiality, and there were often no other sources available to the researchers. Data collection was therefore confined to households, but the influence of industry was assessed indirectly through analyses of published data on resource and energy use. Household data were collected through the administration of a questionnaire (piloted in Annacotty) formed of 76 questions in 12 sections dealing with topics such as energy, transport, waste, water, health, education, resource use and quality of life. Subsequently the questionnaire was distributed by the three researchers in the settlements on a stratified random basis, so that individual houses were selected randomly but in such a way as to include as far as possible all neighbourhoods. The researchers often needed to spend considerable time explaining the questions and the sort of information that was being sought, and providing reassurance that anonymity would be fully respected. The number of questionnaires distributed in a settlement related to its population, but in order to maintain a minimum sample size for all settlements, necessarily a larger proportion of houses were sampled in smaller settlements. Stamped addressed envelopes were provided for the return of completed questionnaires. In total 8,885 questionnaires were distributed and 3,431 completed questionnaires were returned, giving a return rate of 39%, which compares very favourably with rates reported in the literature for comparable studies, and perhaps remarkable in the context of the time required to complete the questionnaire, estimated to be at least 30 minutes. Questionnaire responses were read by computer and stored in SQL and SPSS databases, which also included all relevant published data. Data analyses were undertaken using SPSS, MVSP and ArcGIS programmes. The questionnaire is reproduced in the end-of-project report.

3.2 Classification of the Settlements

The study aimed to provide information useful to stakeholders at both individual settlement scale and also at regional scale. The results generated for 79 settlements proved very unwieldy when attempts were made to draw more general conclusions. In order to facilitate the communication of broader patterns found in the results, it was decided to group settlements into classes, which differed in basic attributes. This also facilitated statistical analyses. The classification of settlements was undertaken using a statistical package (MVSP) and was based on socio-economic and environmental attributes for which accurate data were available from published sources and questionnaire returns (see Table 2). The attribute in the bottom-right corner of Table 2 , the Services Index, sums up the number of tertiary services available in a settlement (described in detail in the end-of-project report).

Table 2. Attributes of settlements used in their classification.

Settlement Attributes				
Distance to settlement of equal or greater size, and average distance travelled to work	Distance to capital city (Dublin)	Population in 2002	Percentage population change 1996–2002	Average monthly income
Percentage unemployed	Percentage education ceased pre age 15	Percentage education ceased post age 21	Percentage employed in services	Percentage employed in agriculture
Percentage employed in construction	Percentage employed in manufacturing	Percentage employed in commerce	Percentage employed in transport	Percentage employed in public administration
Percentage workforce professional	Population density (persons per sq. km)	Percentage homes built post 1996	Distance to nearest NSS gateway settlement	Services Index score

The programme output is in the form of a branching diagram (a dendrogram) reproduced in Figure 2. Similar settlements are linked near the bottom of the scale on the vertical axis. The less similar the settlements, the higher up the scale is the linkage. From this dendrogram, seven distinct classes of settlement were identified. This number was chosen in order to facilitate analyses and the communication of results. Limerick city is very different from all other settlements in the sample, so it formed a class by itself. Table 3 provides a summary of the major attributes which separated the classes.

In Figure 2, the settlements are divided into seven classes on the basis of this dendrogram diagram. The settlements in each class are named in Table 3. Similar settlements are linked together by lines near the bottom of the vertical axis, while dissimilar settlements are linked further up the vertical axis.

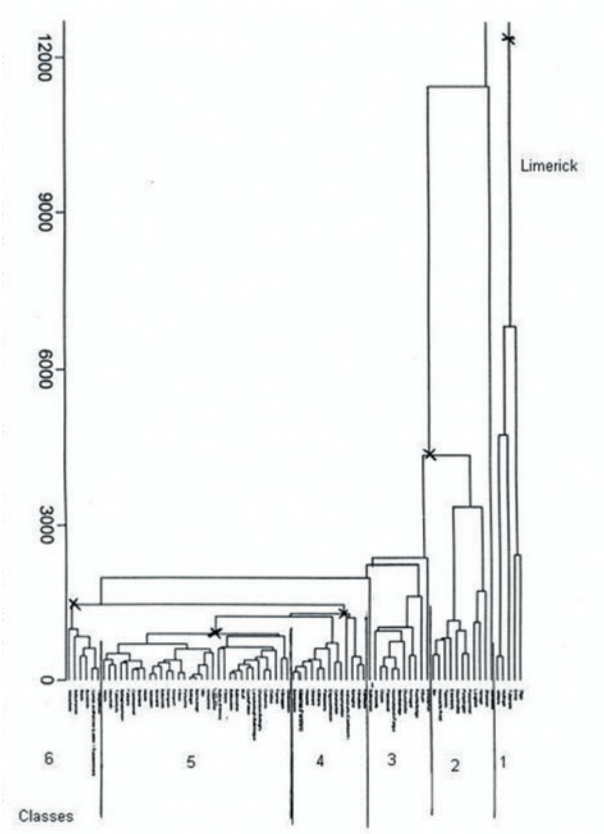


Figure 2. Settlements divided into seven classes in a dendrogram diagram.

Table 3. The settlements forming the classes, and selected information on important ways in which the classes differ from one another.

Class	Size and Functions	Growth/Decline in Population	Transport and other Characteristics	Settlements
1	This class includes the NSS gateway settlements of Tullamore, Mullingar, Athlone and Sligo and the hub settlement of Ennis. The average population size is 16,888. The Services Index is 65. These are generally important regional and county administrative and employment centres.	Class 1 settlements on average experienced population growth during 1996–2002 of 14%. The median rate of growth was 11%. This suggests increasing employment opportunities.	Settlements suffered congestion problems with 69% of individuals reporting frequent or continual traffic congestion. Few walk to work and services and most drive, suggesting that public transport is infrequently used and perhaps not generally available or not widely used.	Athlone Sligo Tullamore Mullingar Ennis
2	Class 2 settlements had smaller populations and lower Services Index scores than Class 1 settlements. The largest settlement in this class was Shannon (population 8,561). The average population size was 5,329. The Services Index score is 36. These settlements also are important county administrative and employment centres. For example, Ballinasloe is a transport administration centre and Nenagh is a local government council centre.	Population growth in Class 2 settlements was similar to that for Class 1 with a mean rate of 11% and median rate of growth of 9% during 1996–2002. These rates indicate an influx of individuals to Class 2 settlements, which is most likely due to increasing employment opportunities.	49% of individuals reported frequent or continual traffic congestion. The faster the population growth, the smaller the proportion of people travelling on foot to work, school and services.	Tipperary Birr Ballinasloe Longford Portarlington Mountmellick Edenderry Nenagh Newcastle West Roscommon Shannon
3	Class 3 settlements had smaller populations than Class 2 settlements with an average population size of 1,290 and a Services Index score of 17. Settlements in this class varied considerably in population and Services Index score.	These settlements had a mean population growth rate of 38% during 1996–2002. However, not all settlements in this class showed such strong growth, and the mean is greatly affected by the very considerable growth in Annacotty and Rochfortbridge, The median population growth rate is 4%.	There is an inverse relationship between the proportion of people using a car for journeys to work, school and college and distance to gateway. This indicates that the closer a Class 3 settlement is to a gateway settlement, the more common car use becomes. People living in settlements in this class which are located close to gateways travel to them by car to avail of services which Class 3 settlements lack.	Kilrush Croom Patrickswel Ballinamore Drumshanbo Annacotty Newmarket-on-Fergus Kinnegad Rochfortbridge Sixmilebridge
4	Class 4 is formed of the settlements with the smallest populations with an average population of 934 people. It also has the lowest average Services Index score of 15.	Class 4 settlements during 1996–2002 had a mean population growth rate of 1% and a median population decline of –1.5%.	There is a very strong positive relationship in Class 4 settlements between population growth and percentage of individuals using a car for transport. There is a strong inverse relationship between population growth and percentage of individuals unemployed.	Rathkeale, Granard Caherconlish Pallaskenry, Kilfinane Manorhamilton Ardnacrusha Kilcormac, Hospital Borrisokane Edgeworthstown Banagher, Kilmallock

Table 3. The settlements forming the classes, and selected information on important ways in which the classes differ from one another. (continued)

Class	Size and Functionality	Growth/Decline in Population	Transport and other Characteristics	Settlements
5	Class 5 has similar size and functionality characteristics to Class 4 with a population of 957 people and a Services Index score of 17. A number of satellite settlements are contained in this class.	Class 5 has a median growth rate of 6% during 1996–2002 as it contains some more rapidly growing settlements.	There is a strong relationship in Class 5 settlements between "education ceased after 21" and percentage of individuals using a car to travel to work, school and college. Where car use is high in a settlement, distance to gateway is low, possibly due to the presence of satellite settlements. As the Services Index score decreases, car use increases.	Ballaghaderreen Swinford, Mountrath Kilkee, Tubbercurry Killaloe, Ferbane Portumna, Collooney Glin, Inniscrone Lanesborough-Ballyleague, Ballymahon, Cratloe Foynes, Kilbeggan Askeaton, Ballygar Bruff, Castlepollard Newport, Daingean Ballymote, Ballisodare Charlestown-Bellaghy Borrisoleigh, Moate Cappamore, Adare, Strokestown, Ballina Castleconnell, Strandhill
6	Class 6 has a Services Index score of 29 and an average population size of 2,159 people. The settlements in this class are similar in size to some Class 3 settlements but have on average a higher Services Index score. Settlements in this class are furthest away from gateway towns.	Class 6 settlements had a median growth rate of just under 2% during 1996–2002. Despite being relatively isolated from larger settlements, Class 6 settlements have maintained an employment base and relative to population size provide a wide range of services.	There is a positive relationship between the Services Index scores and the percentages of individuals in professional employment. Exceptionally, the percentage of individuals using a car to travel to work, school and college correlates positively with the Services Index score, further highlighting the distinctiveness of this class.	Bundoran Ballyshannon Boyle Abbeyfeale Templemore Carrick-on-Shannon
Limerick	Because of its distinctiveness, and especially its large population (86,998 including environs in County Clare) and high Services Index score, Limerick was placed in a separate class.	Limerick had a growth rate of 10% during 1996–2002. This was mainly due to growth in the suburbs, which was above 20%, as within the city limits the population size is nearly static.	Limerick residents on average travel shorter distances to recreation and shopping suggesting that the Services Index score is significant. 59% of individuals surveyed reported traffic congestion.	Limerick

3.3 Method 1: Metabolism Modelling and Ecological Footprints

A living plant or animal maintains itself and grows through its metabolism, which relies on movements of energy, water and nutrients within its body. By analogy, a settlement functions to maintain itself and grow through its metabolism, involving flows of energy, water, materials and information. Time and resource constraints make it impracticable to study all the aspects of settlement functioning. Therefore, it is necessary to select certain aspects of the metabolic flows within settlements, and to assume that these are crucial and indicative of the total metabolism. The flows selected for study were those which, based on a review of the literature, were most likely to result in negative environmental impacts, and which had clear policy relevance (that is, were capable of being altered as a result of policy development). Thus, it was not possible to describe the totality of settlement functioning (a very complex system), but it was possible to model this functioning. Five flows were selected for data collection and analysis: these relate to transport, energy, waste, water and food. For each settlement, an Ecological Footprint (EF) was then calculated: this provided a single value which summed up the sustainability of each settlement, and therefore facilitated comparisons amongst settlements. The footprint represents the area of land in hectares which the average inhabitant of the settlement requires to provide the resources and energy consumed, and to assimilate the wastes produced. It includes as far as possible all the activities and functions of the settlement. A variety of methods for calculating footprints are described in the literature, and the method adopted here is comparable to that used in previous studies of settlements and regions in other countries. Footprints for each settlement were calculated for each of the five flows individually, and then these were aggregated into an overall footprint, in all cases expressed as per capita footprint. The great advantage of calculating footprints is that the results are easily understood as they provide a single value for each settlement which can be compared easily with values for other settlements. As the concept of sustainability is complex, this is a particularly important consideration. However, achieving this simplicity necessitates a trade-off: the footprint does not attempt to directly include social, quality of life and economic dimensions of sustainability. The footprint essentially measures the extent to which the inhabitant of a settlement exerts pressure on the environment. However, it was possible to compare settlements using footprints for the five flows selected and the overall footprint values. This was done by comparing each with the most sustainable settlement in the sample; that is, the scores for each settlement were normalised to the score for the most sustainable settlement. Settlements were then placed in rank order in terms of each of the flows and the overall footprints. Where possible, data for the year 2002 were used in calculations. This was the most up-to-date data available.

Methods for the calculation of each flow are described in detail in the end-of-project report 1. For the transport flow, the unit of measurement selected was carbon (CO_2) emissions. To convert distance travelled and vehicle type into carbon emissions, conversion factors previously used by the Stockholm Environment Institute (SEI) were adopted. SEI also provided information on the rate at which carbon is absorbed (sequestered) by vegetation. Questionnaire returns provided data on journeys made, mode of transport, and car engine size. Data from SAPS and questionnaires were used to calculate CO_2 emissions resulting from domestic energy consumption. Conversion factors adopted were taken from SEI, EPA and internet sources.

Solid waste produced by households (in kg per annum) was estimated on the basis of questionnaire-generated data. A large waste management company provided unpublished data on the average composition of domestic waste by category (paper, metal, organic, and so on), which allowed us to estimate the make-up of waste from all settlements. To calculate the footprint associated with waste, the unit of measurement adopted was embodied energy (in kilowatt hours per tonne: kWh/t). The embodied energy of an item of waste, for example a bottle, is the total energy used in the manufacture of the bottle, its transport and final disposal. Values for the embodied energy of various forms of waste were taken from the literature. The embodied energy (in kWh/t) for each waste category was then multiplied by the weight of waste estimated to be produced by an average person in a settlement in a year. To estimate the footprint associated with waste, further calculations converted embodied energy into the area of land required for its creation and assimilation: these are described fully in the end-of-project report 1.

Data for Freshford, Co. Kilkenny, on the amount of electricity required to supply each cubic metre of water to households were made available to the research team. This value was assumed to be valid for all settlements. A published conversion factor was used to estimate the CO_2 emissions resulting from the generation of each kWh of electricity required to supply water. Further calculations converted the carbon emissions to the land area required to assimilate (sequester) it.

A similar method was adopted for wastewater treatment. Many residents in smaller settlements and on the fringes of larger settlements are not connected to mains sewerage systems and rely on on-site wastewater treatment, most frequently using septic tanks. For each settlement, the number of households not connected to mains sewerage was estimated. Based on values published by the EPA and others, it was taken that the average area of land required for a septic tank to function properly is approximately 0.2 ha. By combining values derived for both mains sewerage and septic tanks, the overall footprint associated with wastewater treatment was calculated for each settlement.

The weight in tonnes of each food product consumed by the average inhabitant of each settlement per annum was calculated, and these values were then multiplied by published conversion factors to estimate the contribution of each to the overall food footprint. The calculations are complex as account had to be taken of differences in footprints between food products derived from tillage and pasture land, plus the fact that crops are also responsible for carbon sequestration. The final calculations for the footprint associated with food consumption in each settlement brought together separate calculations for pasture and tillage products.

The detailed methods for each of the above flows are fully documented in the end-of-project report 1.

3.4 Method 2: Modelling Based on Indicators and Indices

Most environmental systems are very complex, and socio-economic–environment systems even more so. It is not possible to study them in their entirety. Therefore, certain aspects of the systems are selected for study, and it is assumed that by studying these indicators, it is possible to understand (or model) the most important characteristics of the system. A good indicator therefore is an attribute which is both easily quantified and representative of an important part of the system. Indicators are widely used in many applied sciences related to the environment: for example, both biological and chemical indicators for surface water quality are widely adopted and understood. Issues may arise in relation to the selection of indicators: views may differ on which indicators are most important in representing the most significant aspects of, in this case, a settlement. Selection of one indicator is likely to have the knock-on effect of rejection of another. As this is a key concern in the selection of indicators, the method by which they were selected for this study is described briefly here. The first question to be asked was: What aspects of the settlements are important in relation to sustainability, and therefore should be included within the selection of indicators? This issue was addressed in the report of the pilot-scale study *Methodologies for the Estimation of Sustainable Settlement Size* in which categories of indicators for settlement sustainability were identified (see Table 1). Initially 175 candidate indicators were selected to represent these categories, but this number was much too big given time and resource constraints: a target number of 40 indicators was set. Selection of indicators from this initial set started by establishing whether or not data were available to quantify them. Gaps in data availability prevented quantification (here called ‘development’) of some candidate indicators. Only those indicators for which data were available for all settlements were selected as candidates for further consideration. Indicators measure different aspects of a system and, to be effective, it is often argued that the set of indicators selected for a study should represent as many aspects of the system as possible. Therefore, indicators for which data allowed development were then classified within the driving force, pressure, state, impact, response (DPSIR) framework, and sorted so as to ensure that approximately equal numbers of candidate indicators fell into each category, and that duplication was avoided. This reduced the number of candidate indicators to 109. To ensure as far as possible that data to be used in developing indicators were complete and meaningful, all data were tested for normality using standard statistical tests. All data which failed to pass tests for normality were not included in further calculations, and data with obviously skewed distributions when graphed were similarly rejected: this reduced the candidate indicator number to 82. These indicators were then tested for sensitivity in relation to the control settlement attributes, that is, settlement class, population size, distance to nearest gateway town and the Services Index. This was undertaken through visual inspection of scattergraphs to ensure that the indicators were representative of attributes which varied amongst settlements. Candidate indicators which suggested no variation amongst settlements in relation to any of these control variables were excluded from further study, reducing the candidate list to 78.

As mentioned above, to be of value, indicators must represent more complex phenomena and, through summarising or typifying the characteristics of a system, highlight the trends of system functioning In the context of this project, indicators needed to represent key issues relevant to sustainability and policy development. Therefore, a further sorting process was undertaken to ensure that the 78 candidate indicators were clearly related to the indicator categories set out in Table 1, and that indicators approximately equally represented all the key ideas. This final step necessarily involved judgement calls on the relative usefulness of candidate indicators: the final outcome of the process was a set of 40 indicators for inclusion in further analyses.

These 40 indicators were then grouped into four domains: Environment, Quality of Life, Socio-Economic and Transport. Indicators in each domain were subsequently aggregated to create indices for environment, quality of life, socio-economic attributes and transport, and as a final step these four indices were aggregated to give an overall Sustainable Development Index for each settlement (see Table 4). A full explanation of methods, including weightings, is provided in the end-of-project report 2.

In Table 4, the indicators are classified within the DPSIR framework. Columns to the right indicate where indicators correlate significantly with settlement attributes (i.e. are sensitive to these attributes).

3.5 Innovatory Aspects of the Methods Applied in this Study

Innovatory aspects of the methods adopted in this study include the following:

- Analysis of a sample of 79 settlements varying in population size, function and location relative to other settlements.
- Creating a database of information at settlement scale, formed of a wide range of information relevant to the concept of sustainability. Data were brought together from numerous national, regional and local agencies and associations, and transformed where necessary to make them compatible.
- Unpublished data were obtained from various sources.
- Filling data gaps identified in published sources through an extensive questionnaire survey.
- Adopting the household as the unit of study.
- Adopting a multivariate classification method for settlements previously used in ecological studies.
- Adapting published methods previously applied in national and regional-scale studies to develop tools for the quantification of settlement sustainability, both for individual settlements and for groups of similar settlements.
- Applying Geographical Information System technology in novel ways.
- Creating a framework for analysis which brings together information on resource use, socio-economic status and environmental performance, linking environmental impacts to settlement functioning and interaction.
- Adopting an interdisciplinary approach to statistical analyses of data, and basing conclusions on statistically significant relationships.
- Developing two different methods for appraisal of the level of sustainability achieved by settlements so as to validate each method (as results from the two methods were in general similar) and use the results from one method to more fully explain results from the other.
- Bringing the two methods together to create a more robust measure of settlement sustainability.
- Providing results of direct policy relevance.

Table 4. The final set of indicators and indices selected for this study.

Indicator	Domain	DPSIR Classification	Sensitivity to Population Size	Sensitivity to % Population Change	Sensitivity to Distance to Gateway	Sensitivity to Services Index
Sustainable Development Index	All domains	State	Yes		Yes	Yes
Environment Index	Environment	State	Yes			Yes
Quality of Life Index	Quality of life	State				
Socio-Economic Index	Socio-economic	State	Yes	Yes	Yes	Yes
Transport Index	Transport	State	Yes			Yes
Services	Socio-economic	Driving force	Yes		Yes	
Population density	Socio-economic	Driving force	Yes			
Annual income	Socio-economic	Driving force		Yes	Yes	Yes
Per capita waste volume	Environment	Pressure				
%Sewerage connection	Environment	Pressure	Yes	Yes		Yes
Transport CO_2 emissions	Environment	Pressure	Yes		Yes	
Electricity CO_2 emissions	Environment	Pressure			Yes	
Level of wastewater treatment	Environment	Pressure				
Distance to hospital	Quality of life	Pressure	Yes	Yes	Yes	Yes
%45+ hours employment	Quality of life	Pressure				
%Households in whole houses	Socio-economic	Pressure	Yes			Yes
%Primary education as highest level	Socio-economic	Pressure	Yes		Yes	Yes
%Cert/Diploma as highest level	Socio-economic	Pressure	Yes			Yes
Kms to nearest train station	Transport	Pressure	Yes		Yes	Yes
FIPS_10000 radius (forest within 10-km radius)	Environment	State				
NHA_5000 (national heritage area within 5-km radius) radius	Environment	State				
Drinking water NO_3	Environment	State			Yes	
Doctors per 1,000 population	Quality of life	State	Yes			
%Rented from local authority	Socio-economic	State		Yes	Yes	Yes
House price income ratio	Socio-economic	State				
% Work in same town	Transport	State	Yes		Yes	Yes
% Work distance < 8 km	Transport	State	Yes		Yes	Yes
% Work Distance > 24 km	Transport	State	Yes		Yes	Yes
Distance to shops	Transport	State	Yes		Yes	
Distance to work	Transport	State			Yes	
% Health Insurance cover	Quality of life	Impact				Yes
% Odour problems	Quality of life	Impact				

Table 4. The final set of indicators and indices selected for this study. (continued)

Indicator	Domain	DPSIR Classification	Sensitivity to Population Size	Sensitivity to % Population Change	Sensitivity to Distance to Gateway	Sensitivity to Services Index
% Noise problems	Quality of life	Impact				
% Sports area satisfaction	Quality of life	Impact				
% Green area satisfaction	Quality of life	Impact		Yes	Yes	
% Quality of life satisfaction	Quality of life	Impact				
% Households with Central Heating	Socio-economic	Impact	Yes		Yes	Yes
% Home internet access	Socio-economic	Impact		Yes	Yes	Yes
% Relative car use	Transport	Impact		Yes		
% Households 2+ cars	Transport	Impact	Yes		Yes	Yes
% Public transport use	Transport	Impact				
Index of traffic flow	Transport	Impact			Yes	Yes
% Recycling	Environment	Response				
% Green energy interest	Environment	Response		Yes		
% Community involvement	Quality of life	Response	Yes		Yes	

4 Results

4.1 Introduction

Results from this study provide clear evidence of relationships between settlement attributes and sustainability. This has not been achieved in any published studies to date, and represents a very important development which supports clear and evidence-based policy recommendations. Results are presented here in summary form, but the Conclusions and Policy Implications sections of this report are based on all analyses, described in detail in the end-of-project report 1 and 2.

Table 5. For selected settlements, key attributes, component ecological footprints and the overall footprint for the average inhabitant.

Settlement	Distance to Nearest Gateway Town (km)	Population Size 2002 (number)	Population Change 1996–2002 (%)	Service Level (score)	Water EF	Transport EF	Energy EF	Food EF	Waste EF	Overall EF
					Hectares per capita					
Swinford	48	1,497	8	26	0.24	0.28	0.42	0.01	0.06	0.20
Annacotty	7	1,342	129	4	0.03	0.58	0.01	0.90	0.09	0.32
Ballinasloe and environs	21	6,219	9	46	0.47	0.28	0.53	0.10	0.25	0.33
Limerick and suburbs	0	86,998	10	79	0.17	0.10	0.11	0.99	0.49	0.37
Killaloe	20	1,174	21	23	0.41	0.46	0.10	0.84	0.05	0.37
Hospital	25	621	-14	10	0.52	0.20	0.27	0.29	0.58	0.37
Mullingar and environs	0	15,621	25	62	0.10	0.44	0.61	0.48	0.24	0.37
Ballyshannon and environs	32	2,715	-2	31	0.05	0.13	0.96	0.68	0.53	0.47
Tullamore and environs	0	11,098	10	54	0.06	0.41	0.75	0.49	0.76	0.49
Askeaton	25	921	8	12	0.99	0.76	0.18	0.29	0.35	0.51
Ballaghaderreen	42	1,416	14	18	0.23	0.09	0.58	0.87	1.00	0.55
Castleconnell	10	1,343	-5	13	0.67	0.98	0.06	0.96	0.13	0.56
Strandhill	8	1,002	31	11	0.19	1.00	0.87	0.09	0.77	0.58
Sligo and environs	0	19,735	7	76	0.94	0.35	0.65	0.60	0.42	0.59
Newmarket-on-Fergus	21	1,496	3	17	0.76	0.90	0.62	0.54	0.92	0.75

4.2 The Sustainability of Individual Settlements

4.2.1 Ecological Footprints of Selected Settlements

In Table 5 the larger the EF score, the greater the ecological footprint, and therefore the lower the sustainability. EF scores are all per capita, normalised, i.e. the score for each component is expressed as a fraction of the score for the settlement with the lowest score.

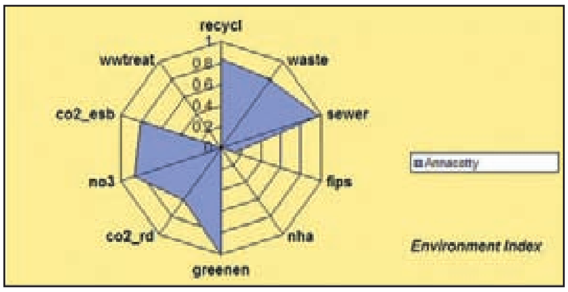
Component and overall Ecological Footprint (EF) scores for selected settlements are provided in Table 5. This information for all studied settlements is provided in the end-of-project report 1. The values point up the fact that describing the level of sustainability achieved by individual settlements is not straightforward and simple, and show some of the reasons why the situation is complicated. Clearly, while overall EF scores vary considerably amongst settlements, population size is not the only factor influencing the level of sustainability achieved. Each settlement is to a certain extent unique, and planning measures aimed at enhancing sustainability need to be tailored in part to individual settlement circumstances. For example, the inhabitants of Limerick and its environs are relatively efficient in relation to energy consumption, but relatively inefficient in relation to food consumption. An effective way to enhance the sustainability of Limerick might be to develop policy interventions that tackle the inefficiencies in the use of this resource. Overall EF scores allow planners to identify individual settlements that are performing relatively poorly in relation to sustainability, and are therefore most in need of attention in the short term. Component EF scores provide valuable insights into where policy interventions can be most effective in enhancing the sustainability achieved by a settlement. In combination they provide a tool to facilitate efficient planning at local authority scale.

4.2.2 Indicators and Indices of Sustainability for Selected Settlements

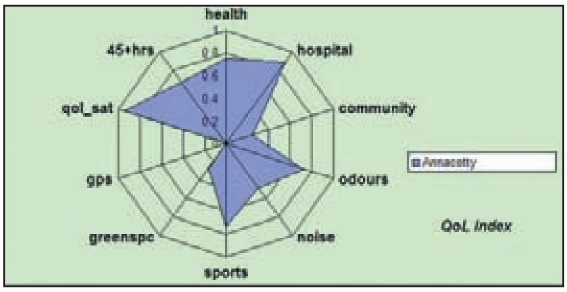
For each settlement, indicators of sustainability were developed which were then aggregated into four indices related to environment, quality of life, socio-economics and transport. These four indices were further aggregated to create an overall Sustainable Development Index for each settlement, as explained in the Methods section. This provided a further set of information on which to plan policy interventions designed to enhance sustainability at individual settlement scale. These indices are presented here in graphical form for ten settlements: information for all settlements is provided in the end-of-project report 2. In each of Figures 3–12, indicators are abbreviated as shown in Table 6.

Table 6. Indicators and their abbreviations as used in Figures 3–12.

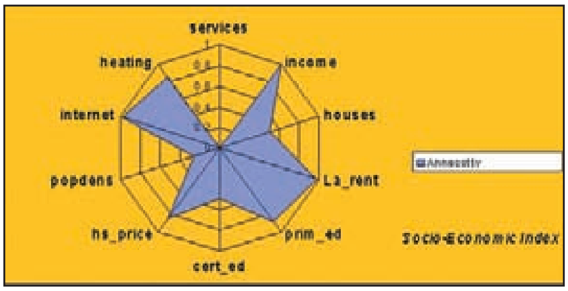
Indicator	Abbreviation
% Recycle on a regular basis	recycl
Per-capita annual volume of waste produced	waste
% Households connected to public sewerage	sewer
Area of forest	fips
Area of National Heritage Areas	nha
% Interested in buying green energy	greenen
Per-capita CO_2 emissions from road transport	co2_rd
Average NO_3 Mg/l in water	no3
Per-capita kg CO_2 from electricity use per annum	co2_esb
Wastewater treatment index	wwtreat
% With health insurance	health
Distance to nearest hospital	hospital
% Involved in community activities	community
% Experiencing offensive odours	odours
% Experiencing noise problems	noise
% Agreeing that are sufficient sports areas	sports
% Agreeing that are sufficient green areas	greenspc
Number of doctors per 1,000 population	gps
Quality of life satisfaction	qol_sat
% Workers with 45+ hours employment	45+hrs
Services Index	services
Mean total annual income	income
% Whole houses	houses
% Rented from local authority	La_rent
% Primary education completed	prim_ed
% Certificate/diploma completed	cert_ed
House price income ratio	hs_price
Population density	popdens
% Home access to the internet	internet
% With central heating	heating
% Car use	caruse
% Work in same town as residence	townwork
% Households with 2+ cars	2pluscars
% Travel less than 8 km	8kmcomm
% Travel more than 24 km	24kmcomm
% Using public transport	pubtrans
Distance to train station	trainst
Average distance travelled per minute to work	trafficflow
Distance to shops	shopsdst
Distance to work	workdst



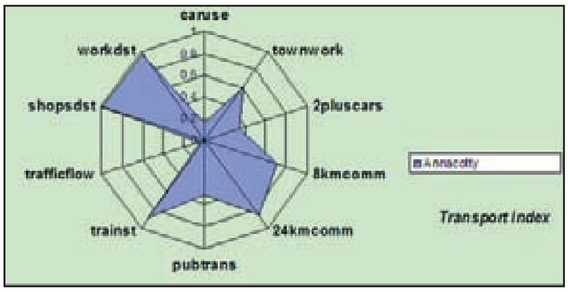
Environment Index = 6.00



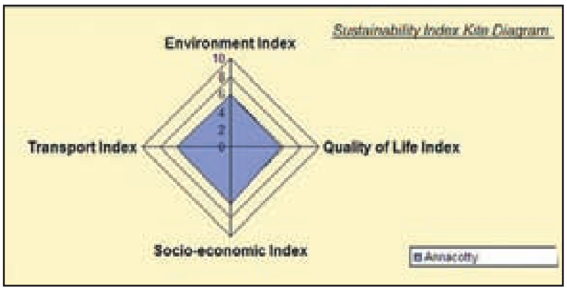
Quality of Life Index = 5.68



Socio-Economic Index = 6.43



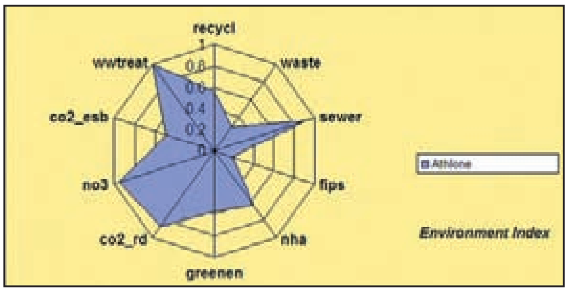
Transport Index = 6.06



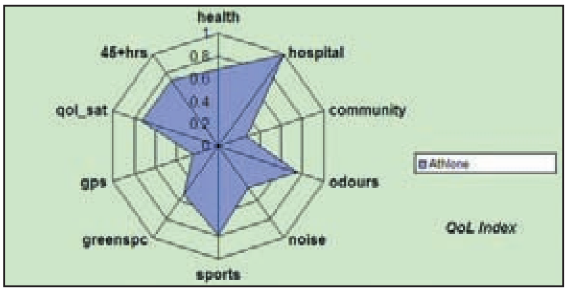
Sustainable Development Index = 60.43

Figure 3. Graphical representation of indicators and indices for environment, quality of life, socio-economics and transport. In the four 'spider web' diagrams, for each indicator the score of 1 is most sustainable and 0 least sustainable. Environment, Quality of Life, Socio-economic and Transport Indices are each scored out of a total of 10, with 10 indicating greatest sustainability. The 'kite' diagram shows the overall Index of Sustainability, and how each of the four component indices contributed to this overall score. The Sustainable Development Index is scored out of a total of 100, with 100 indicating greatest sustainability.

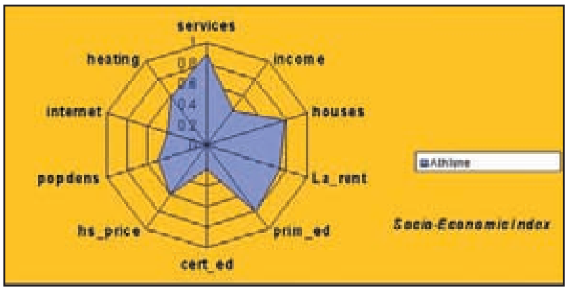
For Annacotty (Figure 3), the diagrams may be interpreted as follows. In relation to the environment, while most households are connected to mains sewerage, there is no wastewater treatment plant. A high proportion of residents are interested in buying green energy, and carbon emissions resulting from electricity consumption is relatively low because most households are connected to a natural gas supply. Amounts of waste generated are relatively low, reflecting higher rates of recycling. Overall, quality of life is considered by residents to be satisfactory. Connection to the internet is very common, but few are involved in community activities. Services are lacking, as are doctors and green open spaces. Car use is high, resulting in congestion and slow journeys to work. It is clear from this summary how specific policy interventions might be targeted to improve overall sustainability.



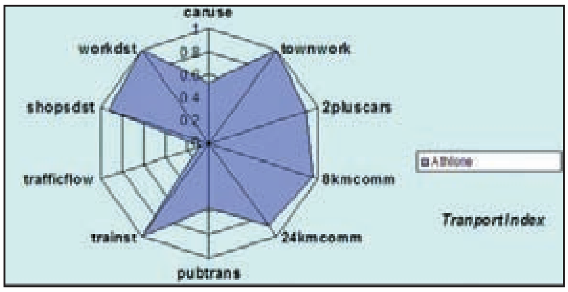
Environment Index = 6.42



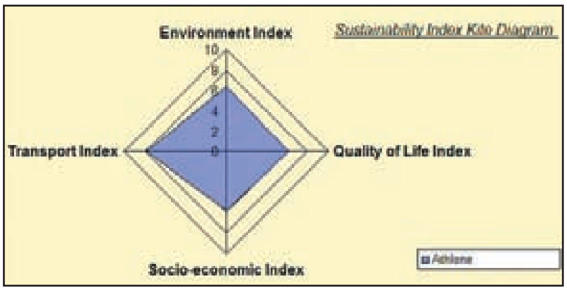
Quality of Life Index = 6.15



Socio-Economic Index = 5.73



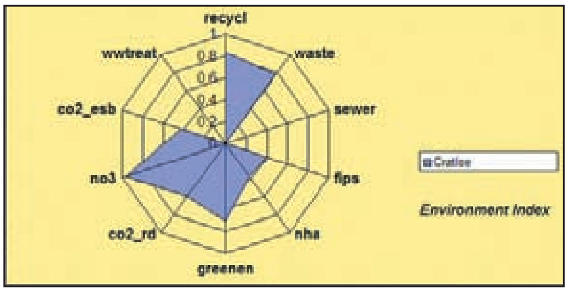
Transport Index = 7.84



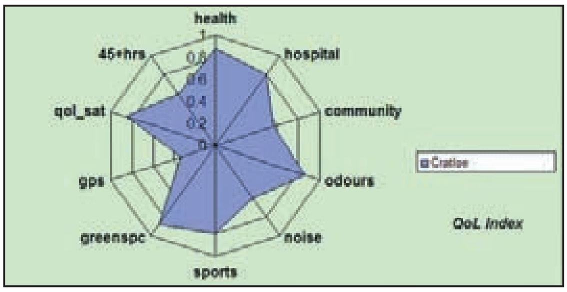
Sustainable Development Index = 65.36

Figure 4. Athlone: Graphical representation of indices for environment, quality of Life, socio-economics and transport, and Sustainable Development Index.

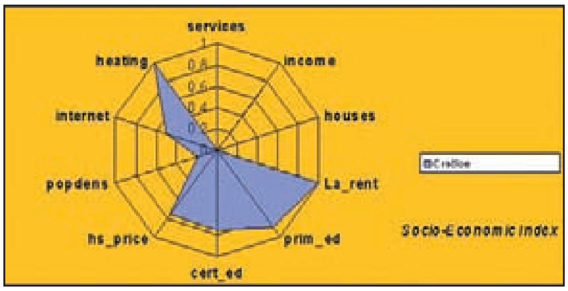
Figure 4 can be interpreted as follows. Overall, Athlone is considerably more sustainable than satellite settlements such as Annacotty. There is a wastewater treatment plant and most households are connected to mains sewerage. However, waste produced is higher and recycling lower in Athlone. Carbon emissions resulting from electricity consumption is higher as most households do not use gas as fuel. Few are involved in community activities, but fewer are connected to the internet. Drinking water quality is satisfactory but green open spaces are scarce. Service provision is clearly better than for Annacotty, but average income is lower. Journeys to work are considerably shorter than in Annacotty, but traffic congestion is a serious problem. Once again, this brief analysis points up possible targets for policy interventions designed to enhance the sustainability of Athlone.



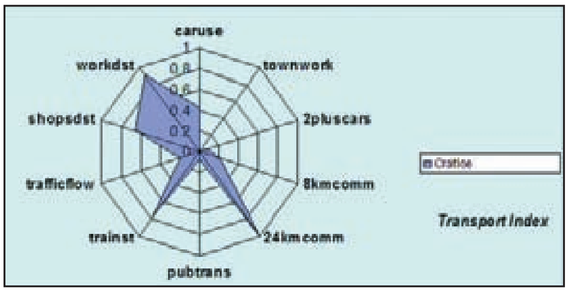
Environment Index = 5.08



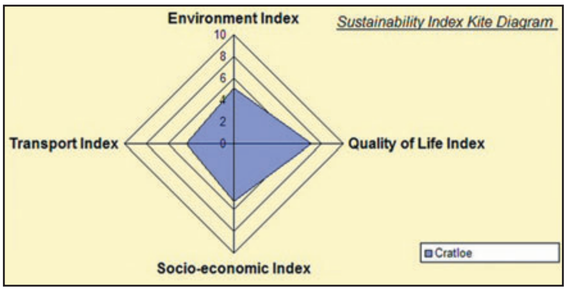
Quality of Life Index = 7.09



Socio-Economic Index = 5.27



Transport Index = 4.33

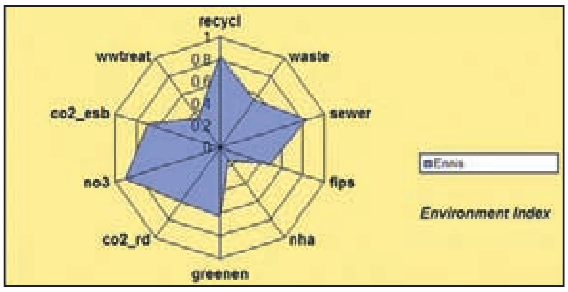


Sustainable Development Index = 54.43

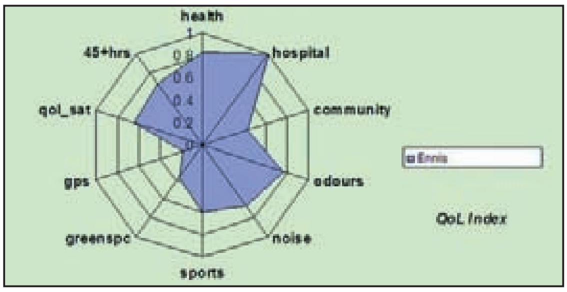
Figure 5. Cratloe: Graphical representation of indices for environment, quality of Life, socio-economics and transport, and Sustainable Development Index.

Figure 5 may be interpreted as follows. Cratloe is a small settlement close to Limerick, without wastewater treatment, with little public transport provision, with traffic congestion and with an overall very low Environment Index score. Services are lacking, so that number of journeys is increased and commuter traffic congestion is a problem. The overall Sustainable Development Index is relatively low.

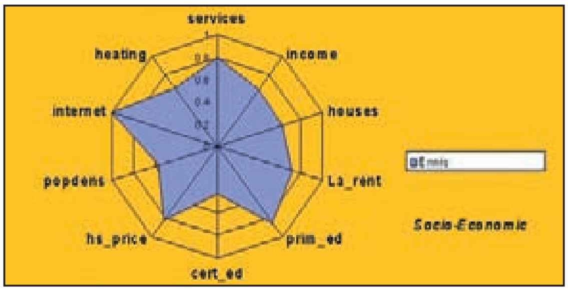
While the Socio-Economic Index scores are relatively low, the quality of life score is markedly high: residents of a clearly less sustainable settlement appear in general to be happy with their lives. This points up the difficulties in communicating the need to change individual attitudes and behaviours so as to achieve greater sustainability at regional and national levels.



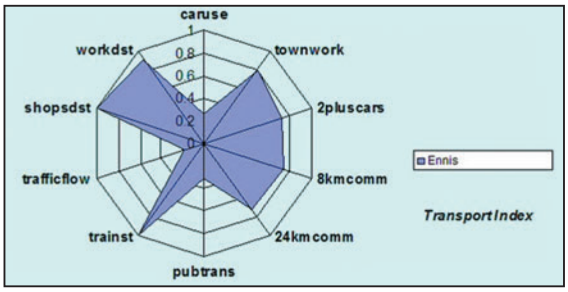
Environment Index = 5.94



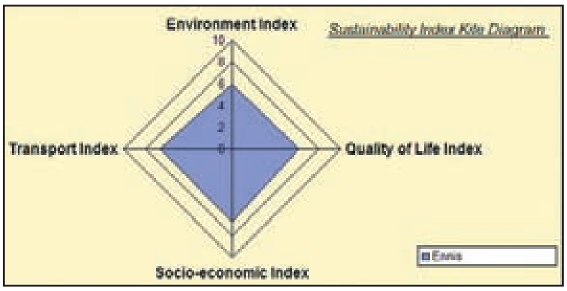
Quality of Life Index = 6.13



Socio-Economic Index = 6.74



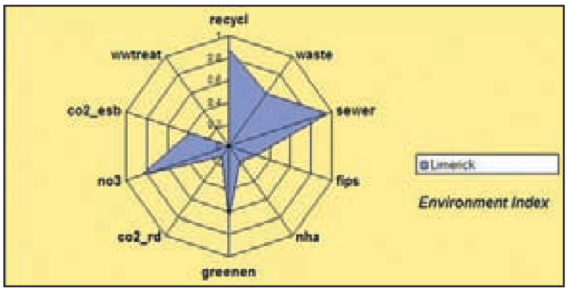
Transport Index = 6.66



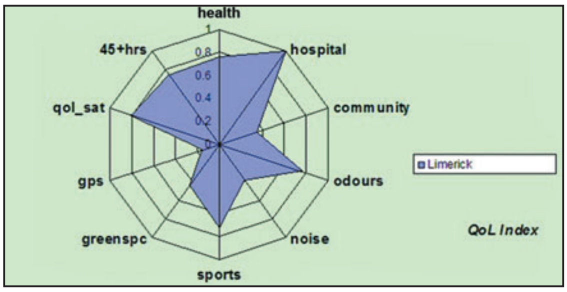
Sustainable Development Index = 63.67

Figure 6. Ennis: Graphical representation of indices for environment, quality of Life, socio-economics and transport, and Sustainable Development Index.

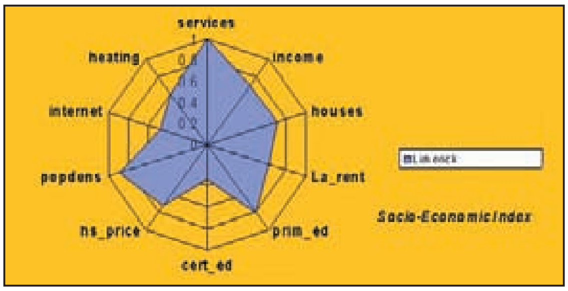
Figure 6 may be interpreted as follows. Ennis provides a much fuller set of services, but dependence on car transport is still high, resulting in traffic congestion. Recycling rates are relatively high, and waste production therefore reduced. Wastewater treatment scores poorly but most houses are connected to mains sewerage. Journeys to shops and work are relatively short. Overall, Ennis is a relatively sustainable settlement.



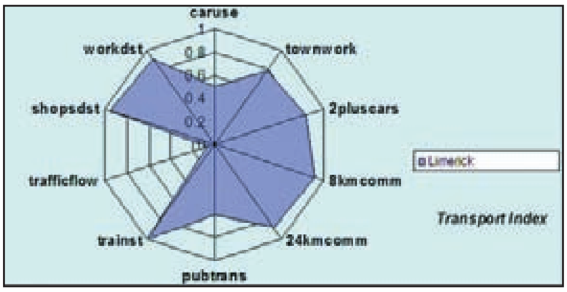
Environment Index = 4.85



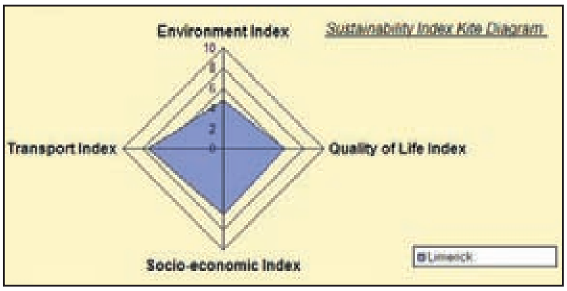
Quality of Life Index = 6.11



Socio-Economic Index = 6.56



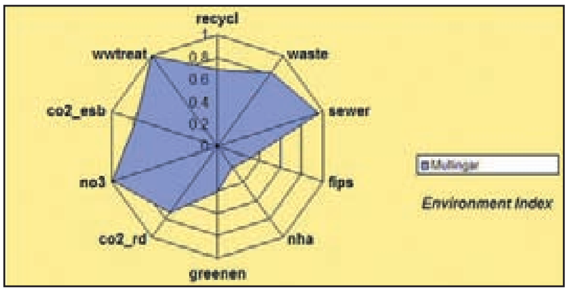
Transport Index = 7.48



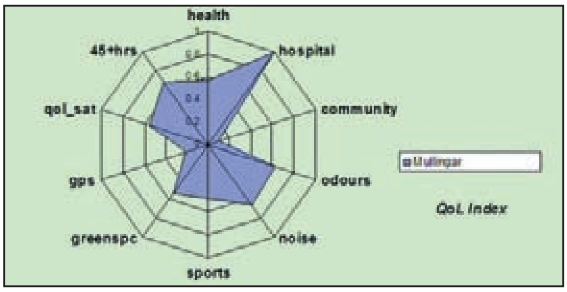
Sustainable Development Index = 62.52

Figure 7. Limerick: Graphical representation of indices for environment, quality of Life, socio-economics and transport, and Sustainable Development Index.

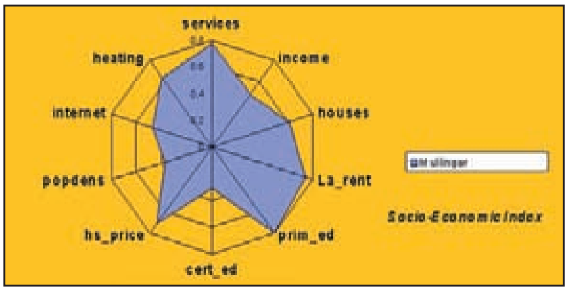
Figure 7 may be interpreted as follows. The Environment Index score for Limerick is very low, resulting in part from a lack of wastewater treatment. Since the time of data collection, this problem has been rectified. Most households are connected to mains sewerage, so it may be expected that the new treatment plant has significantly reduced Limerick's impacts on the environment. For many people, poor access to green open spaces further reduces the Environment Index: this points up a trade-off between population density and open space availability. Recycling rates are relatively high and waste produced therefore reduced. As a city, Limerick offers a fuller range of services, though numbers of doctors appears low. Limerick is large enough to sustain an urban public transport system, so car dependency is lower and the Transport Index score correspondingly higher. However, car use and traffic congestion are clearly seen as the problem areas in relation to the Transport Index. Limerick residents' average income is lower than that for satellites such as Annacotty, but Quality of Life indices are similar.



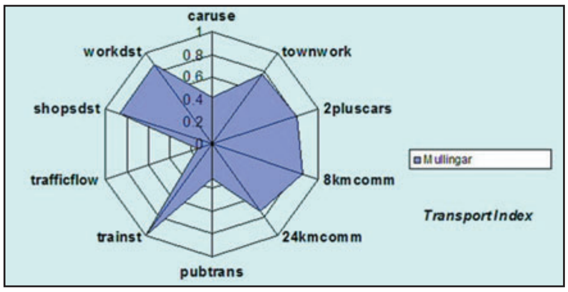
Environment Index = 6.92



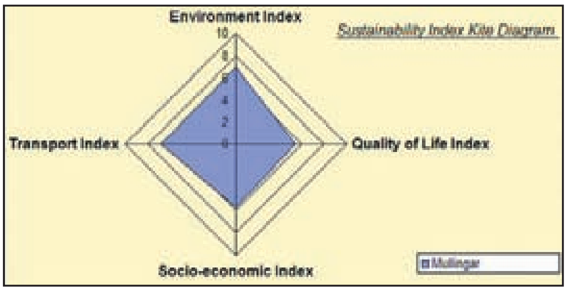
Quality of Life Index = 5.41



Socio-Economic Index = 5.70



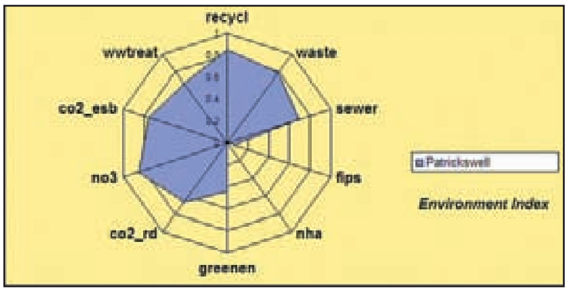
Transport Index = 6.77



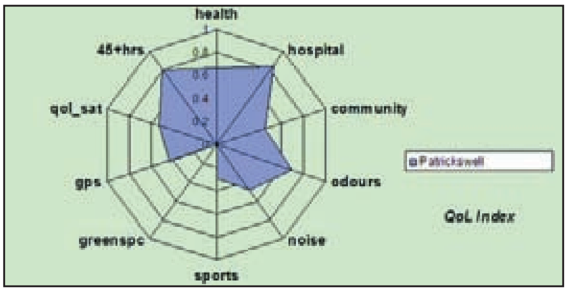
Sustainable Development Index = 62.00

Figure 8. Mullingar: Graphical representation of indices for environment, quality of Life, socio-economics and transport, and Sustainable Development Index.

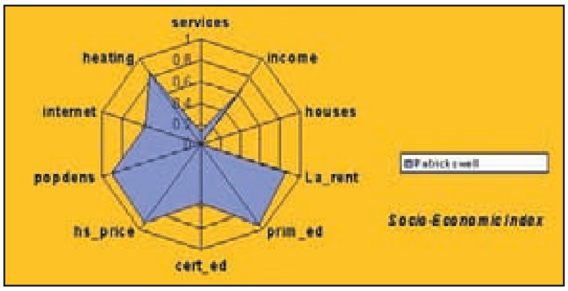
Figure 8 may be interpreted as follows. Athlone (Figure 4) and Mullingar (Figure 8) are similar in size and location and, for both, overall Sustainable Development Index scores are relatively high. Between 1996 and 2002, the population of Mullingar rose by about 25%, while that of Athlone rose by about 3%. In Mullingar, carbon emissions arising from consumption of electricity are lower (probably because a greater proportion of residents live in newer and therefore more energy efficient houses), but car dependency is higher (associated with lower modern housing densities). However, traffic congestion is a problem in both towns. Indicators suggest that residents in Athlone are happier with their quality of life: provision of infrastructure in Mullingar appears to have lagged behind rapid growth and community involvement is lower.



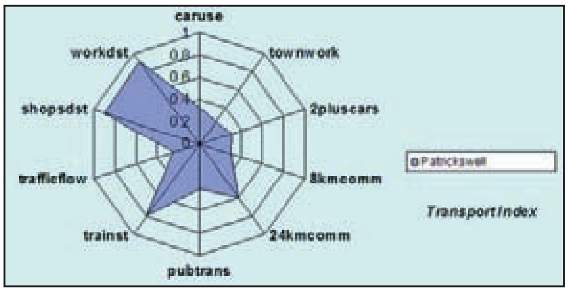
Environment Index = 5.78



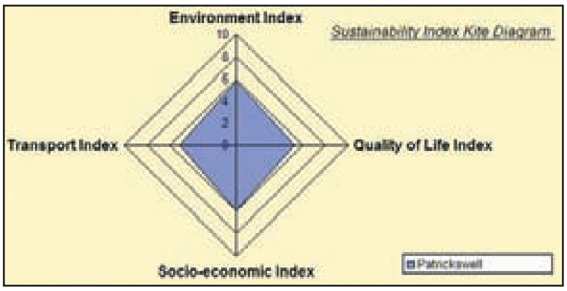
Quality of Life Index = 5.19



Socio-Economic Index = 5.96



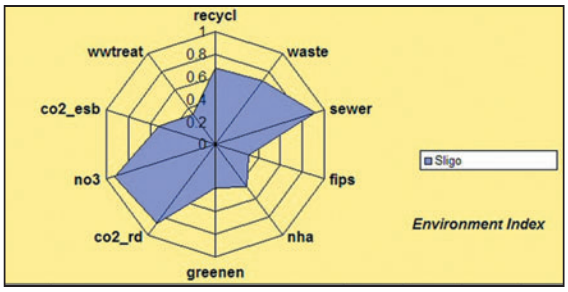
Transport Index = 5.06



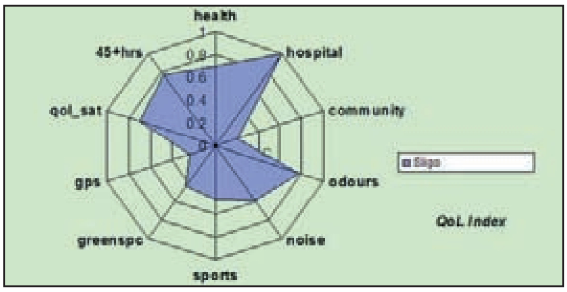
Sustainable Development Index = 54.99

Figure 9: Patrickswell: Graphical representation of indices for environment, quality of Life, socio-economics and transport, and Sustainable Development Index.

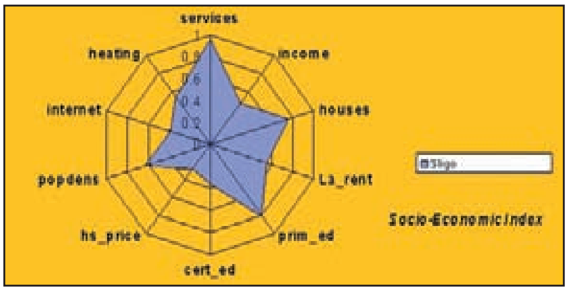
Patrickswell (Figure 9) is a small settlement close to Limerick city and functions as a satellite. As with most settlements in this category, Patrickswell has a relatively low Sustainable Development Index score. Compared to larger settlements and recently built satellites, Patrickswell has a relatively small proportion of houses connected to mains sewerage. Quality of life indicators suggest a problem: reasons for this were poor access to green spaces and sporting facilities.



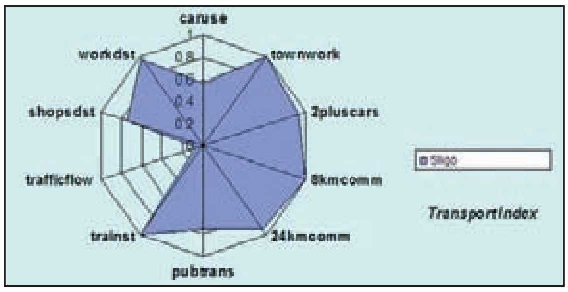
Environment Index = 6.12



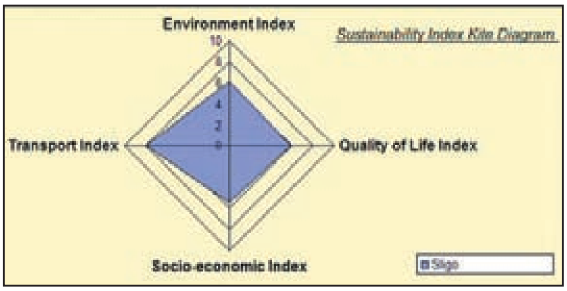
Quality of Life Index = 5.88



Socio-Economic Index = 5.47



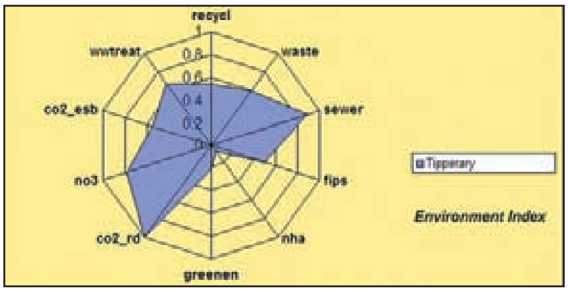
Transport Index = 7.94



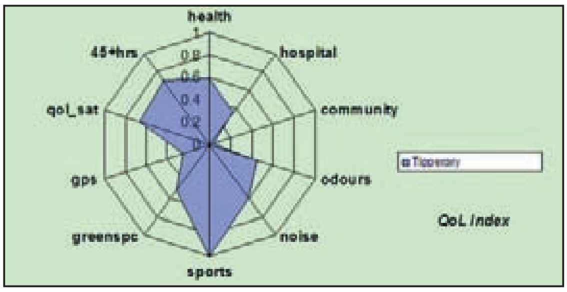
Sustainable Development Index = 63.50

Figure 10. Sligo: Graphical representation of indices for environment, quality of Life, socio-economics and transport, and Sustainable Development Index.

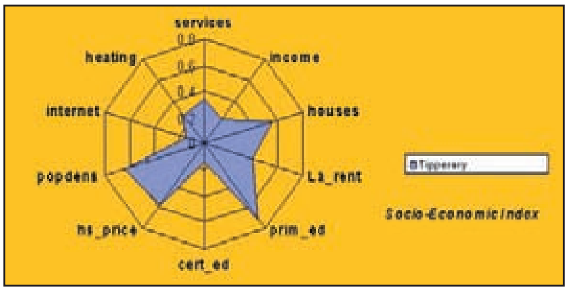
As a larger settlement, Sligo (Figure 10) offers a wider range of services. Public transport use is relatively high and, in general, transport indicators scores are high, but traffic congestion is an exception to this. Sligo has modest recycling rates and lacks open spaces. As with most settlements, numbers of doctors and community involvement indicator scores are low. The socio-economic and quality of life indices scores are somewhat lower than for Limerick. There emerges a clearly identifiable agenda of policy interventions which would enhance Sligo's sustainability.



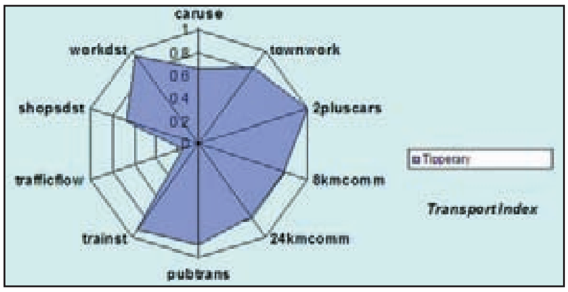
Environment Index = 5.79



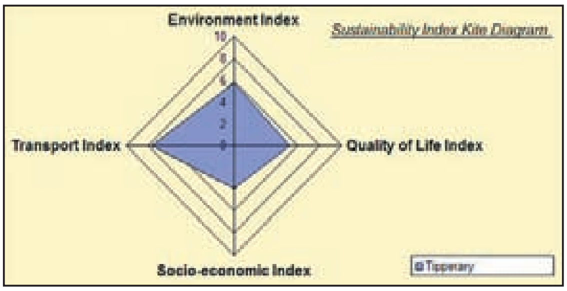
Quality of Life Index = 5.17



Socio-Economic Index = 3.87



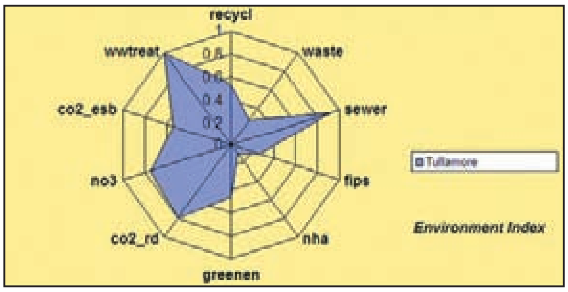
Transport Index = 7.65



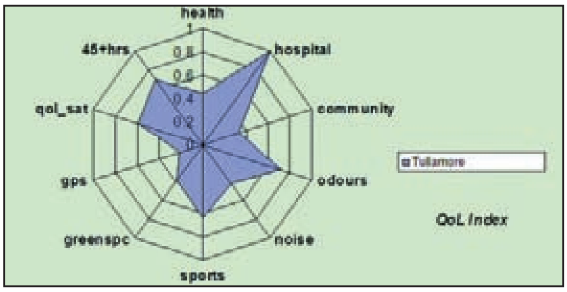
Sustainable Development Index = 56.20

Figure 11. Tipperary: Graphical representation of indices for environment, quality of Life, socio-economics and transport, and Sustainable Development Index.

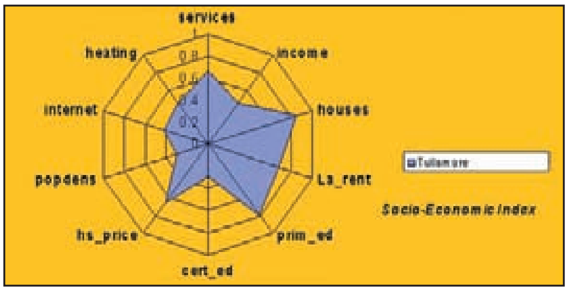
Figure 11 can be interpreted as follows. The Sustainable Development Index score for Tipperary is relatively low. The Transport Index is similar to that for many other settlements, with traffic congestion as the outstanding problem. The low Environment Index score relates particularly to the fact that not all houses are connected to mains sewerage. Green area indicators scores are low, recycling rates are low and relatively few residents showed an interest in purchasing green energy. Satisfaction with quality of life is relatively low: while sports facilities are good, community involvement appears very low. Access to health services appears relatively low. Perhaps most striking is the low Socio-Economic Index score, which arises because of low scores for many indicators. The policy implications are clear: to become more sustainable, Tipperary requires an improvement in its economic base, better social infrastructure, enhanced social inclusion, more services and improved waste management.



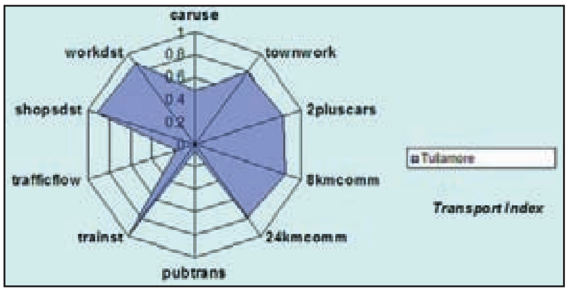
Environment Index = 5.64



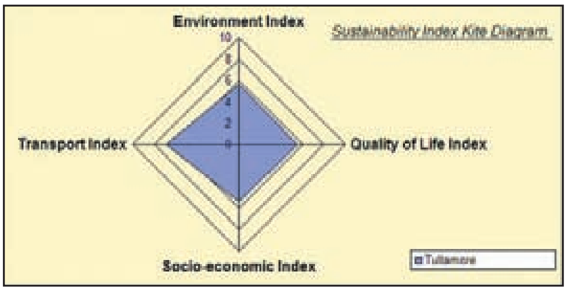
Quality of Life Index = 5.44



Socio-Economic Index = 5.40



Transport Index = 6.80



Sustainable Development Index = 58.19

Figure 12. Tullamore: Graphical representation of indices for environment, quality of Life, socio-economics and transport, and Sustainable Development Index.

Figure 12 can be interpreted as follows. The Sustainable Development Index for Tullamore is somewhat low. Public transport use is low, and car dependency therefore high. Traffic congestion further reduces the Transport Index score. Tullamore is not connected to the natural gas network, recycling rates are low and waste production relatively high. Open areas indicator scores are low. Tullamore does have a wastewater treatment plant and most houses are connected to mains sewerage. Quality of life indicators suggest that while Tullamore has a hospital, in general access to health facilities and doctors is not seen as satisfactory. Community involvement is relatively low. The socio-economic indicators suggest that Tullamore would benefit greatly from a broader economic base.

4.3 The Sustainability of Irish Settlements

Results from the application of the two methods are presented separately. While results from the two methods were in general very similar, they contain some differences which are informative and interesting. One important difference relates to the time of data collection: data sourcing for the metabolism modelling method occurred after the commissioning of the Limerick wastewater treatment plant, whereas data sourcing for the indicator and indices modelling method occurred before its commissioning.

A final section describes the results of an analysis in which the two methods were combined into one.

4.3.1 Selected Results of Metabolism Modelling

4.3.1.1 Settlement Population Size and Class Related to the Overall Ecological Footprint

Settlements were grouped according to population size, and the average EF for settlements forming each size category was calculated (see Figure 13). The smaller the footprint, the more sustainable is the settlement. Limerick clearly has the smallest footprint. In all other population categories, with the exception of the smallest settlements, the EF varied greatly amongst the settlements, so no clear pattern could be detected. When the same exercise was repeated, this time dividing settlements into classes, a broadly similar pattern emerged. Once again, Limerick had the smallest footprint (see Figure 14). One important difference did emerge: Class 4 settlements had relatively small footprints compared to those of Class 5 settlements, which had similar sized populations

In Figures 13–25 (with the exception of the map in Figure 23), settlements were grouped either by population size or class, and the ranges in population size or class number for each group are indicated on the horizontal axis. On the horizontal axis, N is the number of settlements studied in each population size range or class. On the vertical axis the square points on the graph represent the average (mean) EF score for settlements in a group. These scores are called 'fractional' because they are all related to the settlement with the biggest per capita footprint. Thus, for example, the per capita EF for Limerick is about 0.38 or 38% of the size of the settlement with the biggest per capita footprint. SE is an abbreviation for standard error, which is a measure of the extent to which the settlements in a group varied in their EF scores. The size of this variation is indicated by the height of the vertical bar passing through each point.

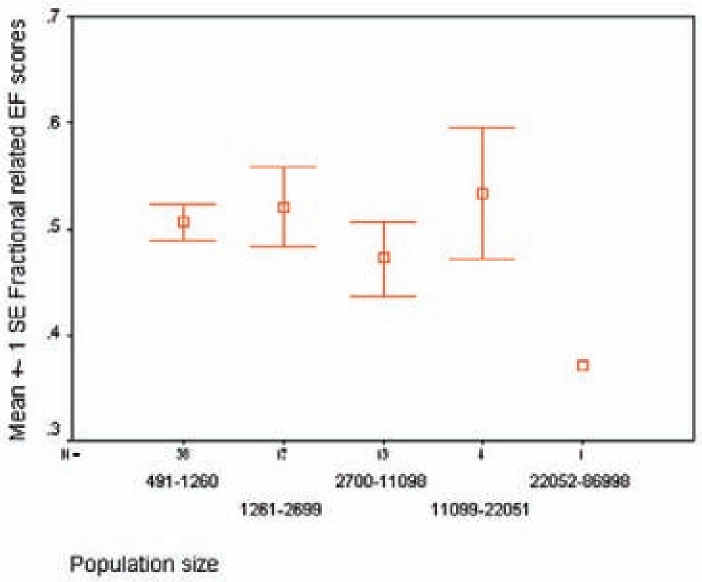


Figure 13. The relationship between overall EF per-capita scores and population size. The smaller the footprint, the greater the level of sustainability achieved. N on the horizontal axis gives the number of settlements in each category.

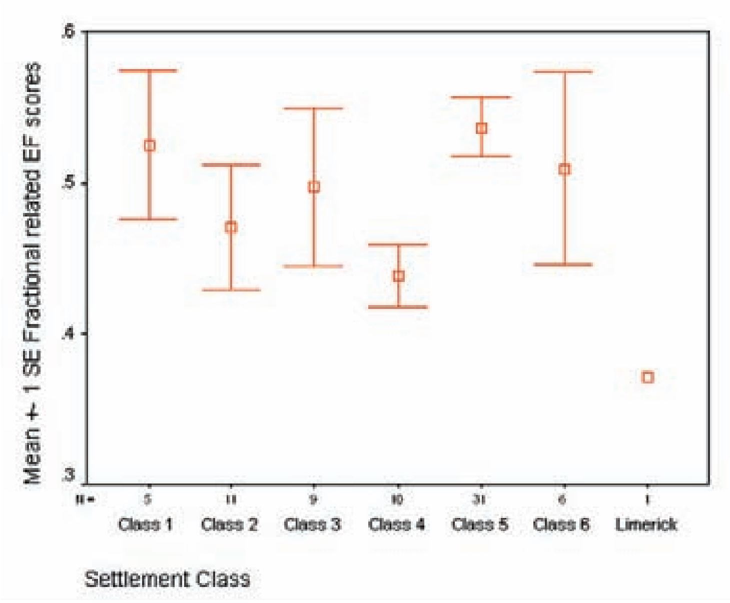


Figure 14. The relationship between overall EF per-capita scores and settlement class. The smaller the footprint, the greater the level of sustainability achieved. N on the horizontal axis gives the number of settlements in each category.

In Figure 13, SE bars overlap for all settlement size groups except Limerick, so it is not possible to point to any significant differences in overall EF scores amongst the settlements other than Limerick. In Figure 14, SE bars for Classes 1, 2, 3 and 6 overlap, so that it is not possible to point to any significant differences in overall EF scores amongst these Classes. The overall EF for Limerick is relatively small, and the differences between EFs for Classes 4 and 5 are important.

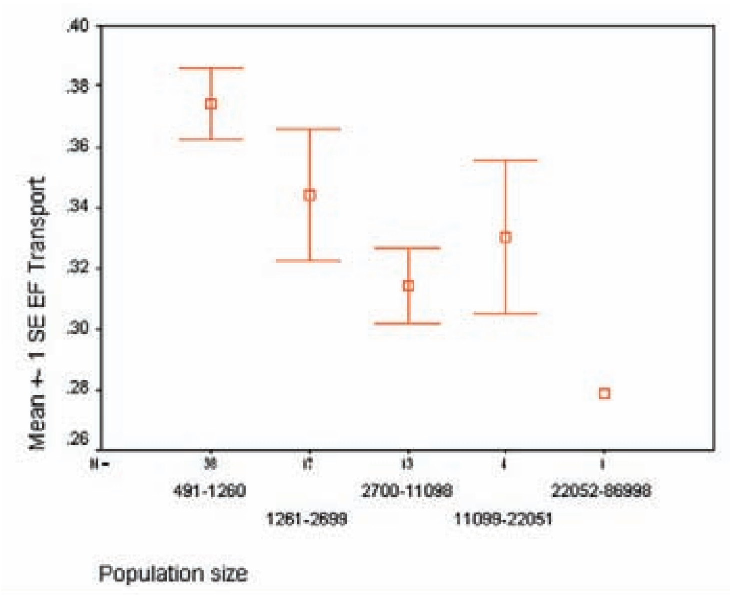


Figure 15. The relationship between the per-capita transport footprint and population size. N on the horizontal axis gives the number of settlements in each category.

4.3.1.2 Settlement Population Size and Class Related to the Transport Component Ecological Footprint

Limerick city had the lowest per-capita EF for transport (Figure 15). While the standard error bars indicate that there is considerable variation amongst the scores for individual settlements forming some size categories. In general, settlements with larger populations have smaller EFs associated with transport. However, some settlements in the population range 11,098 to 22,051 (e.g. Athlone, Sligo and Ennis) with high Service Index scores but limited public transport provision, attract many inward car journeys by residents of surrounding areas, leading to relatively large transport EFs for these settlements.

The per-capita transport-related EF varied greatly amongst settlement classes (Figure 16). The very small EFs associated with Class 4 settlements are noteworthy. Most Class 4 settlements showed little population growth, and some had a reduced population in recent times, and this was associated with relatively poor economic performance resulting in low transport-related environmental impacts. Classes 3 and 5 include more rapidly growing satellite settlements with much greater transport-related environmental impacts, resulting in relatively large per-capita footprints. In a separate study, a very detailed examination was undertaken of the sustainability of a single satellite settlement, Freshford in Co Kilkenny, and results of this study confirmed those reported here. Full details of the Freshford study are provided in Ryan (2006). With the exception of Class 4, the classes containing the largest settlements, Class 6 and Limerick, have the smallest transport impacts. There are therefore two distinct explanations for the low transport-related EFs: for some settlements, efficiencies related to their size result in low EFs, while for others low EFs are associated with poor economic performance.

4.3.1.3 Settlement Population Size, Class And Location and the Energy Component Ecological Footprint

Limerick very clearly has the smallest energy-related footprint (Figure 17). Little difference is evident amongst other settlement size categories. Settlements in the population size range 2,700–11,098 have markedly larger energy-related EFs: these settlements are not connected to the natural gas network, and some evidence suggests that they rely more heavily on solid fuel, use of which impacts more heavily on the environment. When the analysis was repeated, this time dividing settlements into their classes,

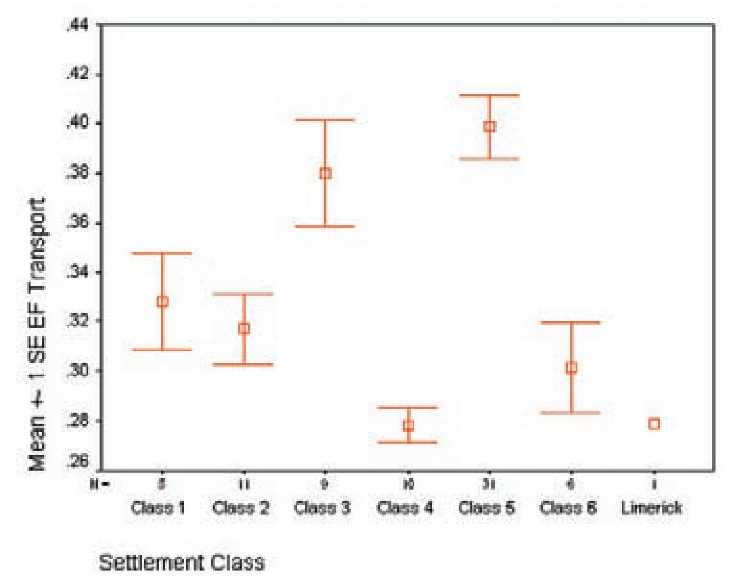


Figure 16. The relationship between the per-capita transport footprint and settlement class. N on the horizontal axis gives the number of settlements in each category.

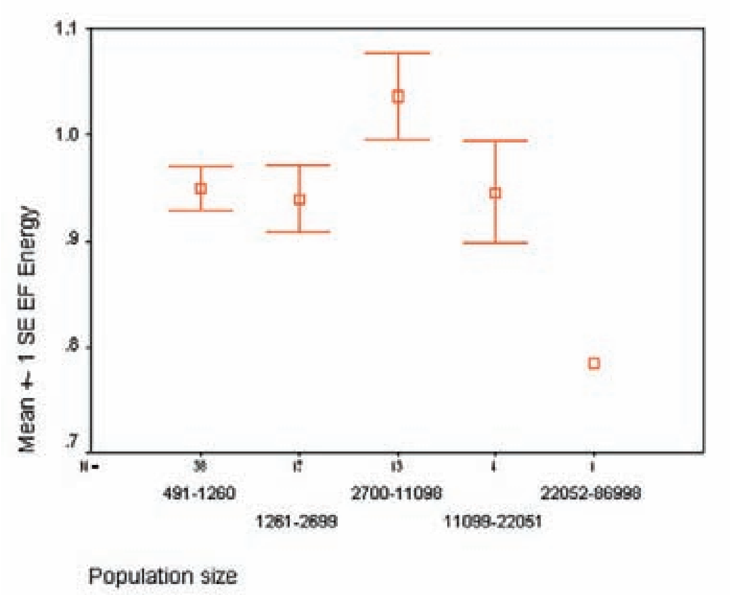


Figure 17. The relationship between the per-capita energy footprint and population size.

a similar pattern emerged (Figure 18). Limerick, with a natural gas supply, again has the smallest footprint, and again the footprint of classes relates to whether or not constituent settlements have a connection to the natural gas grid and on what fuel mix is used. The energy EFs for settlements forming the three clusters (around Limerick, around Sligo and around Athlone/Mullingar) were compared (Figure 19). Most settlements in the Limerick cluster were connected to the natural gas network. Most Midlands settlements were not connected to a gas supply and relied more heavily on solid fuel, including peat. Settlements in the Sligo cluster used a similar fuel mix as those forming the Midlands cluster, and most were not connected to a gas supply. Availability of natural gas supply emerges as the most important factor causing variation amongst settlements in the energy-related EF scores.

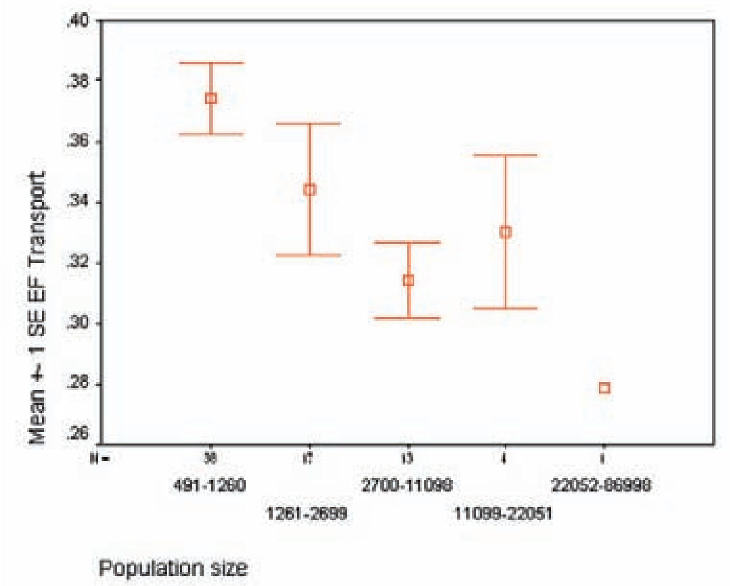


Figure 18. The relationship between the per-capita energy footprint and settlement class. N on the horizontal axis gives the number of settlements in each category.

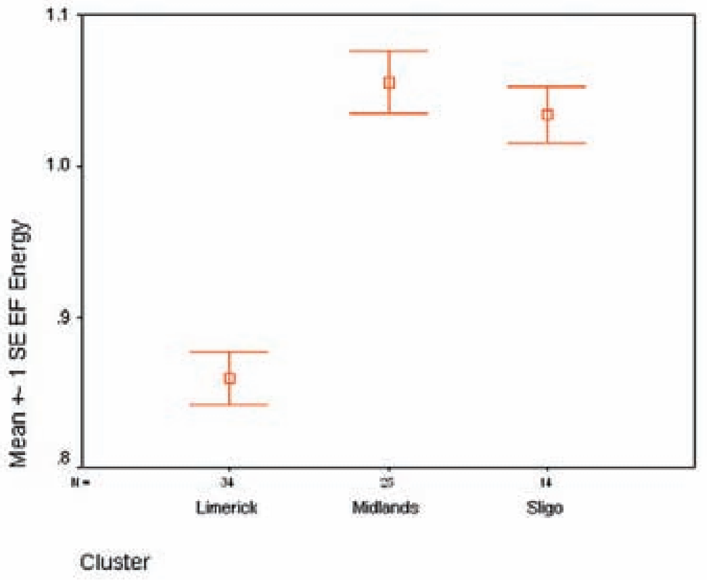


Figure 19. The relationship between per-capita energy-related footprints and the location of settlements in the three clusters (Limerick, Midlands and Sligo). N on the horizontal axis gives the number of settlements in each category.

4.3.1.4 Settlement Population Size and Class Related to the Food Component Ecological Footprint

The food-related EFs were highest for residents of larger settlements (Figure 20). As expenditure on food is related to income, and residents of larger settlements tend to have higher average incomes, this is perhaps to be expected. The environmental impacts associated with dining in restaurants are known to be especially significant: it may be that residents in larger settlements have a greater range of restaurants to select from. A similar pattern emerged when the analysis was repeated, this time for settlements grouped by class (Figure 21). Policy makers could improve this aspect of sustainability by promoting local produce markets for example.

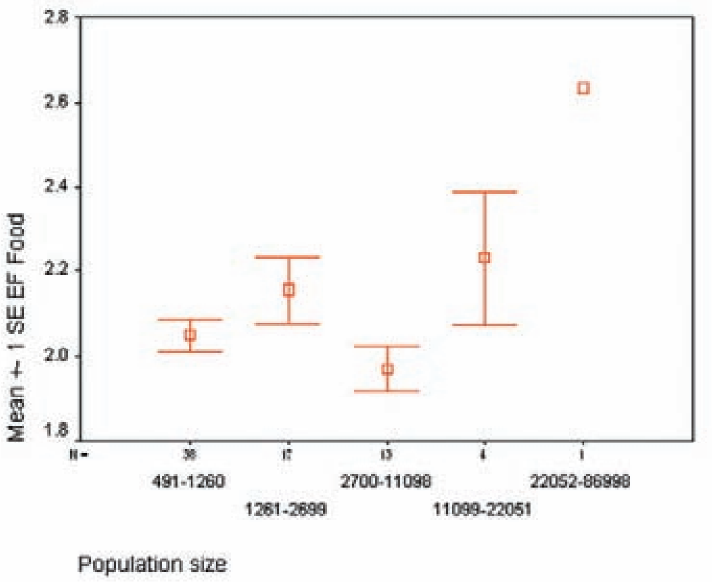


Figure 20. The relationship between the per-capita food footprint and population size. N on the horizontal axis gives the number of settlements in each category.

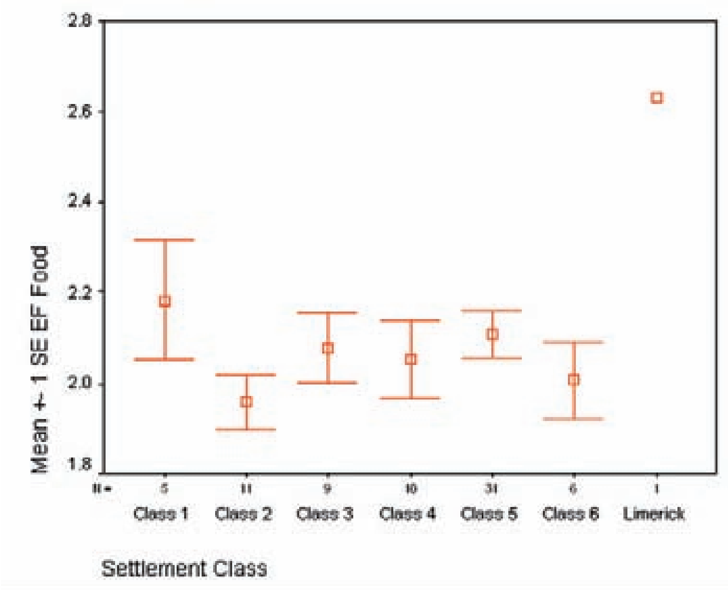


Figure 21. The relationship between the per-capita food footprint and settlement class. N on the horizontal axis gives the number of settlements in each category.

4.3.1.5 Settlement Population Size and Class Related to the Waste Component Ecological Footprint

The very large standard errors indicate great variation in scores amongst settlements of similar population size, and no clear pattern was evident linking the waste EFs to settlement size. (Figure 22.) The waste-related EF scores for settlements were plotted on a map (Figure 23): it is clear that settlements with similar scores tend to be clustered together. This is because waste management is organised on a regional basis, rather than on an individual settlement basis. The score for a settlement is therefore related more strongly to its geographical location. Thus, the method by which the waste-related footprints of settlements may be reduced in size is to increase the efficiency of regional waste management systems.

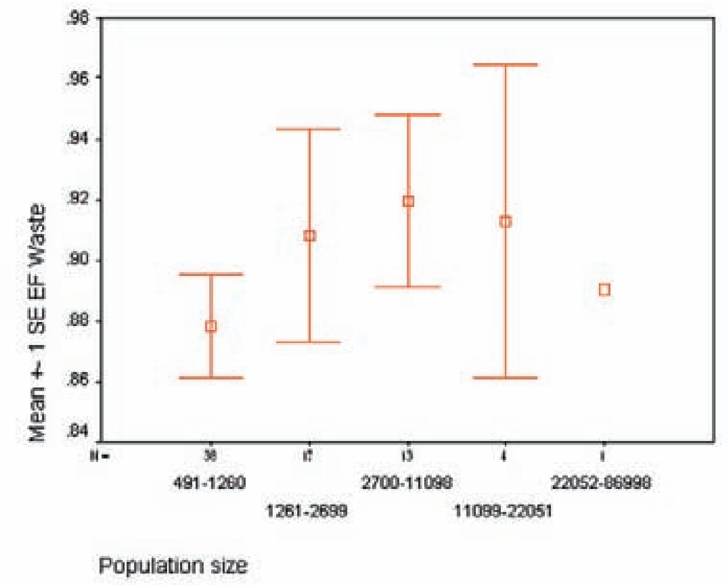


Figure 22. The relationship between the per-capita waste footprint and population size. N on the horizontal axis gives the number of settlements in each category.

Each dot on the map in Figure 23 represents a settlement and the size of the dot is related to the size of the footprint measured in global hectares (GHA). Note that in some areas most settlements have smaller footprints, while in other areas most settlements have larger footprints.

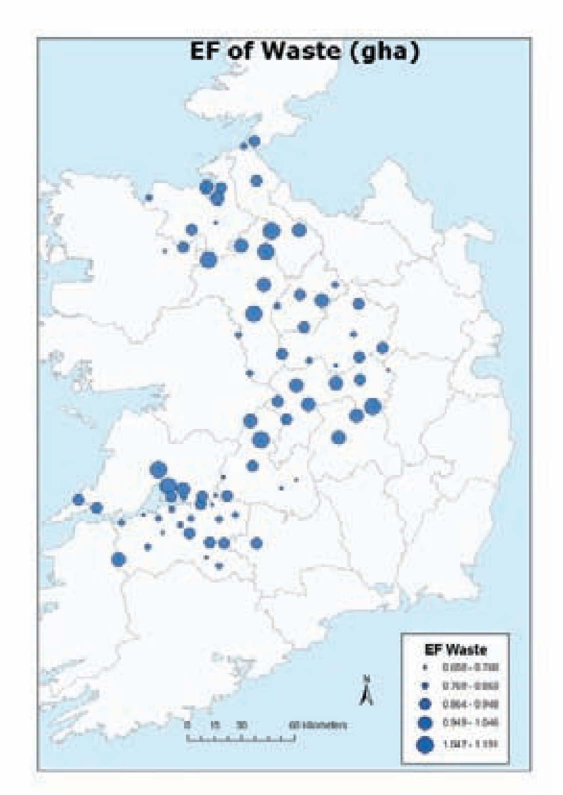


Figure 23. Map showing the size of waste-related footprints for settlements. Each dot represents a settlement and the size of the dot is related to the size of the footprint. Note that in some areas most settlements have smaller footprints while in other areas most settlements have larger footprints.

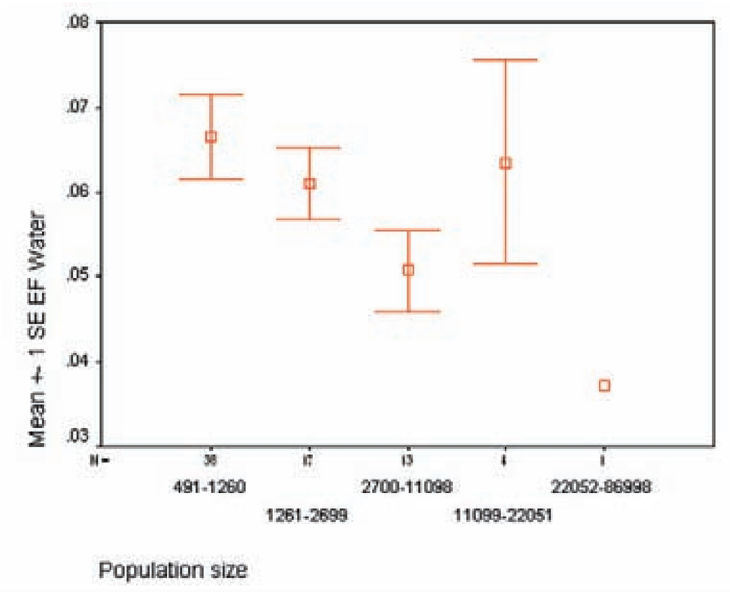


Figure 24. The relationship between the per-capita water footprint and population size. N on the horizontal axis gives the number of settlements in each category.

4.3.1.6 Settlement Population Size and Class Related to the Water Component Ecological Footprint

When the scores for footprints associated with water consumption and wastewater treatment are compared to settlement population size, a clear pattern is evident: the per-capita footprint is smaller in larger settlements and is smallest for Limerick, the largest settlement (Figure 24). Septic tanks and other on-site water treatment require large areas to work effectively, so that smaller settlements without mains sewerage and water treatment plants have larger water-related footprints. The exception to the trend was the settlement size category formed of settlements with populations in the range 11,099–22,051, which includes Sligo. At the time of data collection for the EF analysis reported here, the new wastewater treatment plant in Limerick was operational, but the Sligo plant was not. As Sligo discharged wastewater directly to the sea and relied more heavily on on-site wastewater treatment, its water-related footprint was relatively large, and this increased the average footprint for this population category.

Classes 4 and 5, containing small settlements, had relatively large water-related footprints (Figure 25). This was because of high proportions of on-site treatment in these settlements. Limerick clearly showed the smallest water footprint. Provision of wastewater treatment plants, and the replacement of septic tanks and other on-site treatment methods by mains sewerage, are policy initiatives that will reduce the water footprints of smaller settlements.

4.3.2 Selected Results of Analysis of Indicators and Indices

4.3.2.1 Sustainable Development Index Scores Related to Settlement Population Size and Class

In the following figures, the higher the score, the greater the level of sustainability achieved.

In the even numbered figures, settlements are grouped by population size, and the ranges in population size for each group are indicated on the horizontal axis. On the vertical axis the round points represent the average (mean) Sustainable Development Index score for settlements in a size category. As noted above, SE is an abbreviation for standard error, which is a measure of the extent to which the settlements in a category varied in their EF scores. The size of this variation is indicated by the height of the vertical bar passing through each point.

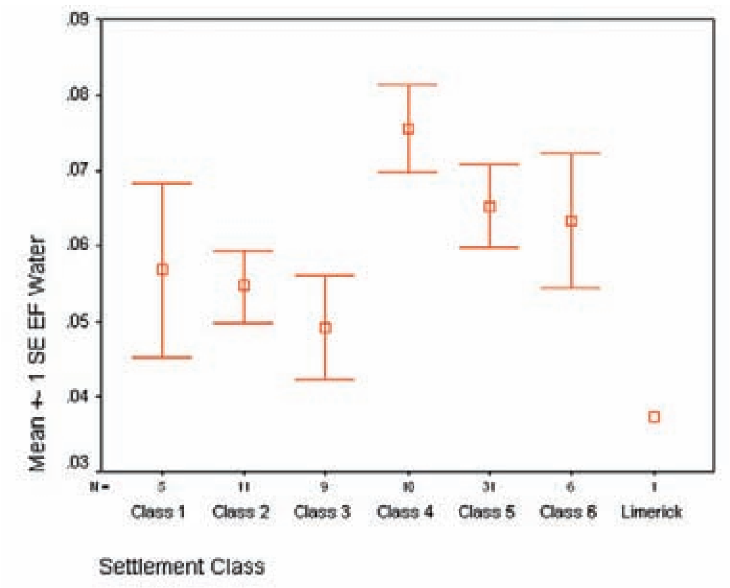


Figure 25. The relationship between the per-capita water footprint and settlement class. N on the horizontal axis gives the number of settlements in each category.

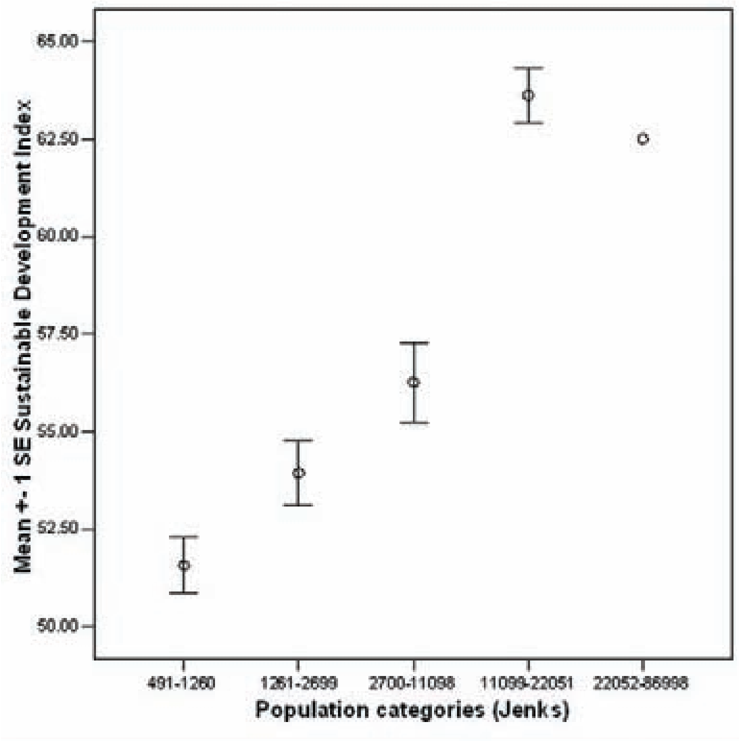


Figure 26. The relationship between Sustainable Development Index scores and population size.

In the odd numbered figures, settlements are grouped by class, and the classes are numbered on the horizontal axis (Limerick is named as it is the sole settlement in this class). On the vertical axis the round points represent the average (mean) index score for settlements in a class. Again SE is an abbreviation for standard error, which is a measure of the extent to which the settlements in a class varied in their index scores. The extent of this variation is indicated by the height of the vertical bar passing through each point.

The Sustainable Development Index scores showed a clear pattern in relation to the settlement size categories: they increased with population size (Figure 26), though the score for Limerick was slightly smaller than that for the second largest population category. Figure 27 shows the relationship between Sustainable Development Index scores and settlement class. Again, classes formed of larger settlements had relatively high scores but Limerick was not clearly more sustainable than Class 1 settlements. Classes 4 and 5 settlements were least sustainable. Note that the scores for many Class 6 settlements are relatively high: it is clearly possible for smaller settlements to achieve relatively high levels of sustainability.

To highlight important reasons why Sustainable Development Index scores differed amongst settlements, it is necessary to examine the component indices, and the Environment, Services, Socio-Economics and Transport indices.

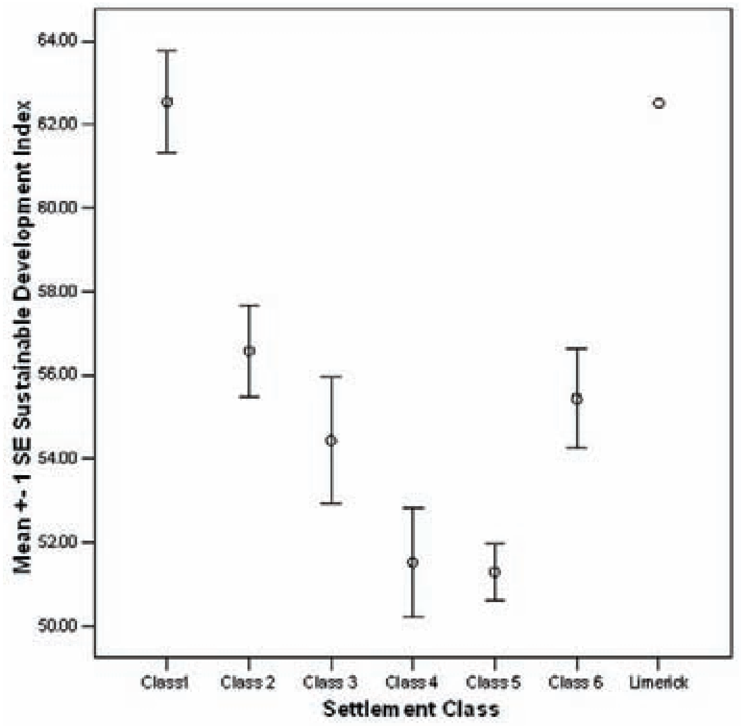


Figure 27. The relationship between Sustainable Development Index scores and settlement class.

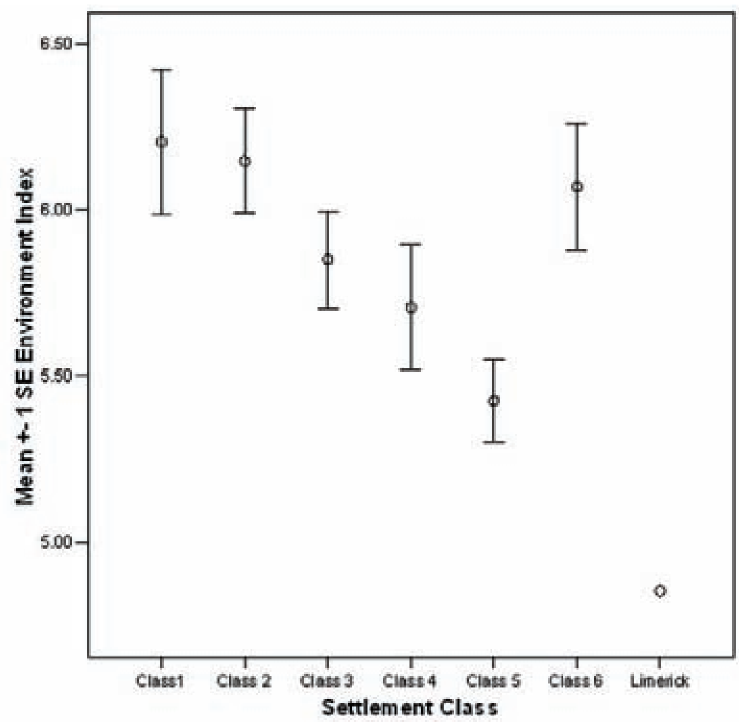


Figure 28. The relationship between Environment Index scores and settlement class.

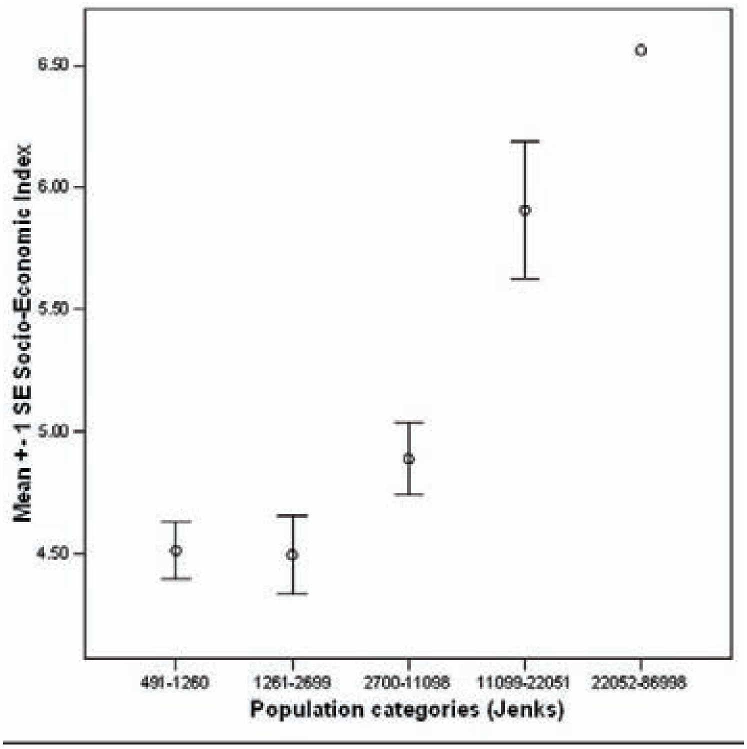


Figure 29. The relationship between Socio-Economic Index scores and population size.

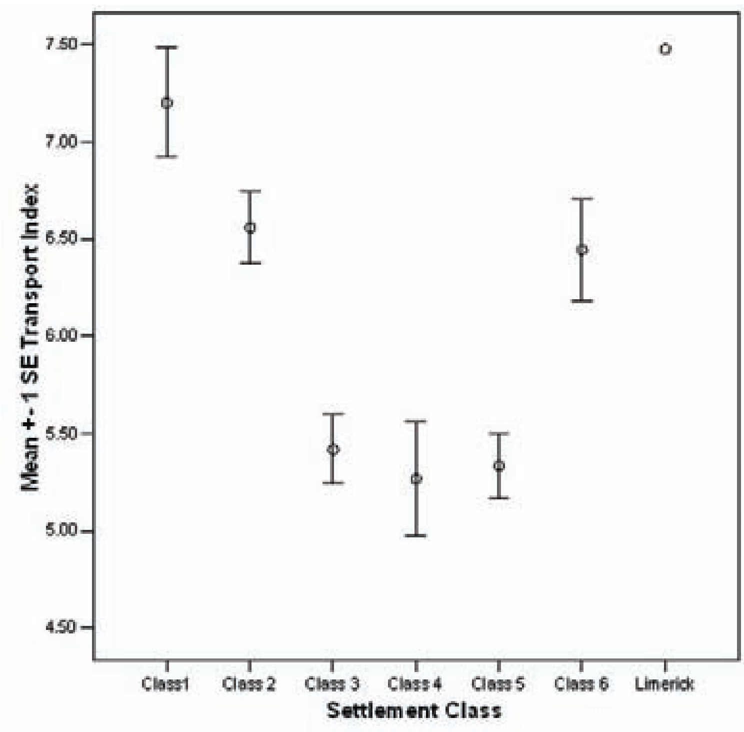


Figure 30. The relationship between Transport Index scores and settlement class.

The difference between Sustainable Development Index scores for Class 1 settlements and Limerick is noteworthy, as Class 1 settlements are second only to Limerick in population size. Limerick was the only city within the sample of settlements, and it is not known how typical Limerick is of Irish cities. It may be that as settlements grow to be greater in size than Class 1 settlements, they create significant environmental impacts. Poor wastewater management reduced Environmental Index scores for Class 4 and 5 settlements, which have the smallest populations (Figure 28). Services provided by these settlements were also very limited, necessitating car journeys to larger settlements, thus further reducing their Environment Index scores. Note that the scores for many Class 6 settlements are relatively very high: it is possible for some smaller settlements to achieve relatively high levels of sustainability.

Socio-Economic Index scores were most clearly related to settlement size, with larger settlements scoring highest (Figure 29). In direct contrast to Environment Index scores, Limerick scores highest on the Socio-Economic Index. There appears to exist therefore a trade-off between socio-economic status and environmental performance.

In relation to the Transport Index, Limerick and Classes 1 and 2 settlements scored highest (Figure 30). The difference in scores between Limerick and Class 1 settlements is not great: the larger size of Limerick resulted in many journeys being longer, and this counterbalanced the advantages gained through better public transport provision. Again, Class 6 settlements scored markedly higher than did Classes 3, 4 and 5 settlements. Transport Index scores are higher in larger settlements (Figure 31), but again the score for Limerick is not much greater than the average score for settlements in the population range 11,099–22,051, and some settlements in this size range score higher than Limerick.

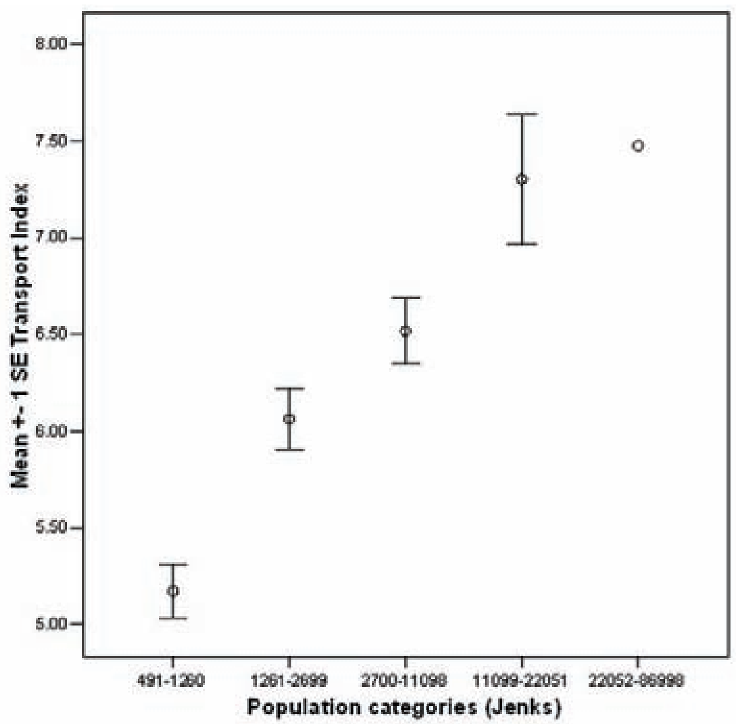


Figure 31. The relationship between Transport Index scores and population size.

4.4 The Combined Sustainable Development Index

As a final step, the Ecological Footprint scores for settlements (from the first method) were combined with Environment, Transport, Socio-Economic and Quality of Life indices scores (from the second method) to calculate a combined Sustainable Development Index score for each settlement. This was undertaken so as to bring together as much information as possible in the evaluation of the level of sustainability achieved by settlements. It has the effect of increasing the weighting of environmental factors in this evaluation.

Combined Sustainable Development Index scores are clearly related to population size, and are highest for the largest settlements (Figure 32). Index scores also differed significantly amongst settlement classes (Figure 33). Limerick scored highest, followed by Classes 1 and 2 settlements. Class 4 and especially Class 5 settlements achieved relatively low scores. Some Class 6 settlements achieved scores clearly higher than for most settlements of comparable population size.

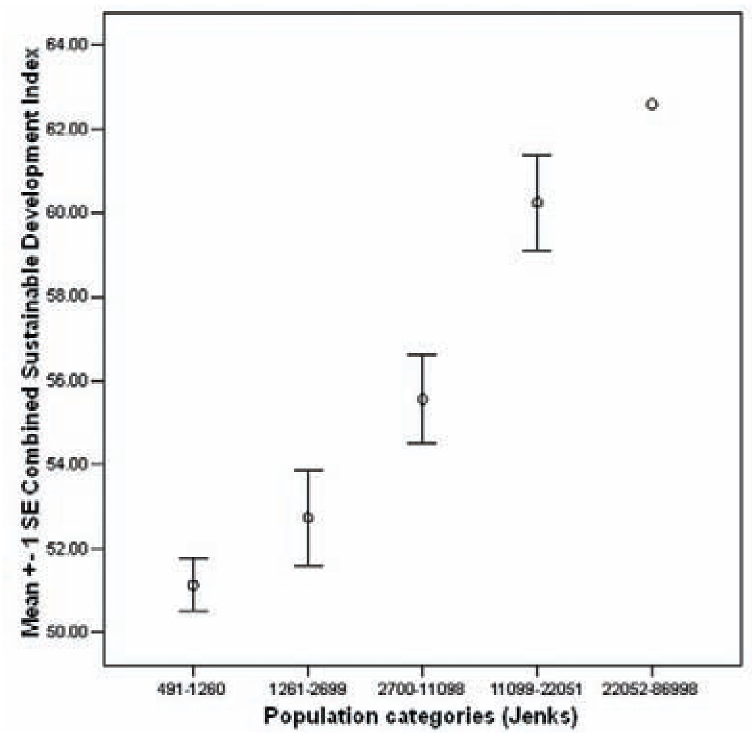


Figure 32. The relationship between combined Sustainable Development Index scores and population size.

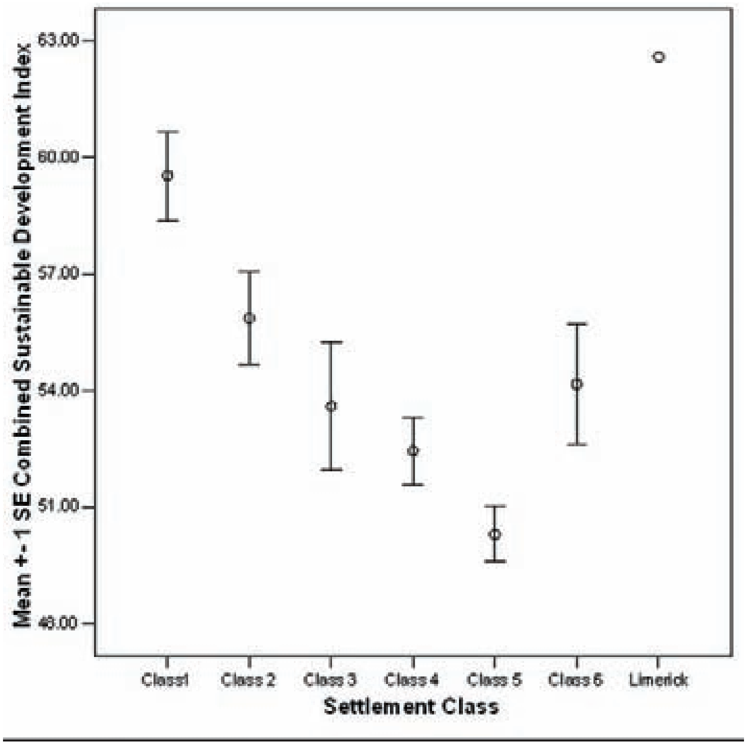


Figure 33. The relationship between combined Sustainable Development Index scores and settlement class.

5 Conclusions

5.1 Conclusions Related to the Methods

- The very considerable resources and time dedicated to data collation and collection proved crucial: on the basis of a much fuller factual base, analysis identified clear patterns linking settlement attributes to the level of sustainability achieved.
- The methods adopted worked well in practice. Of particular importance, while the methods were dissimilar in many ways, they provided similar results, thus enhancing confidence in both the methods and the results gained through each. At the same time, results gained through one method helped explain those gained through the second.
- Bringing the two methods together in a combined analysis was possible and provides a novel and robust measure for settlement sustainability.
- In certain respects, each settlement is unique. Results for individual settlements provided here and in the end-of-project report facilitate the selection of planning interventions which may effectively improve the level of sustainability achieved by individual settlements.
- The sample of 79 settlements was sufficiently large to allow identification of broad patterns in the relationships between settlement attributes and the level of household sustainability achieved, which may inform regional and national-scale planning, and has relevance at international scale.
- The fact that Limerick was the only city within the study limited the usefulness of results in selecting policy options for cities. The sustainability of cities requires additional research.
- The fact that only one settlement cluster in the study was polycentric meant that there was insufficient information to compare the relative sustainability of monocentric and polycentric settlement patterns. This requires additional research.
- To gain a full understanding of the level of household sustainability achieved within a settlement, it is necessary to consider both the overall score achieved, and also the components (such as energy and transport) that contribute to the overall score.
- As the population of many Irish settlements is changing rapidly, the sustainability scores for these settlements must be expected to change equally rapidly.

5.2 General Conclusions Related to the Sustainability of Settlements

- Settlements varied significantly in the level of household sustainability achieved.
- With important exceptions, the larger the settlement, the higher the level of household sustainability achieved.
- If planned correctly, a smaller settlement as it grows in size will increase in household sustainability.
- It is possible for all settlements to enhance the level of household sustainability achieved without increasing in size.
- While the level of household sustainability achieved by a settlement was found in general to be related to population size, other factors were also important, such as rate of population growth, location, local economy, availability of services, connection to the natural gas network and distance to nearest larger settlement.
- Limerick households were not markedly more sustainable than Class 1 settlements in relation to transport, and Limerick scored lowest of all in relation to environment. Policy makers need to exploit the potential economies of scale offered by cities.
- Settlements which are relatively small in population size but located far from larger settlements were often more sustainable than similarly sized settlements closer to larger settlements.

- Settlements with rapid population growth create larger negative environmental impacts. Provision of services and public transport has not kept pace with additional housing, resulting in greater reliance on car transport, and longer journey lengths. However, socio-economic indicators suggest that inhabitants of satellites are relatively affluent.
- Many smaller settlements lack adequate economic activity to provide satisfactory employment for all inhabitants, resulting in low Socio-Economic Index scores. While such settlements often have small per-capita ecological footprints, overall household sustainability is low.
- Quality of Life Index scores did not vary significantly amongst settlement types and locations. This is perhaps counter-intuitive, and additional research is required to elucidate this finding.

6 Policy Implications

6.1 General Policy Implications

- Bigger settlements are most sustainable, and have the capacity to increase compactness further. Future development concentrated in the larger settlements (Limerick and Class 1) is most likely to prevent future decline in urban sustainability. Overall, no upper threshold population size was identified, above which diseconomies of scale might reduce sustainability. Results suggest that regional sustainability will be enhanced if some settlements grow to the population size of Limerick.
- To further enhance sustainability in larger settlements, policy should focus on increasing efficiency of infrastructure development and provision, and on integrating sectors such as housing, transport and availability of services, particularly in relation to transport. Special attention is needed to maintain higher environmental quality in the largest settlements, through, for example, biodiversity conservation and the maintenance of green spaces.
- In relation to their population sizes, settlements in Classes 2 and 6 offer a relatively wide range of transport and other services, and therefore offer opportunities for additional development without compromising existing levels of sustainability if population growth is matched by development of this infrastructure. If additional accessible jobs can be created, they may therefore represent more sustainable growth poles for regional development, additional to gateways.
- The relatively high sustainability levels achieved in some Class 6 settlements suggest that further research into the functioning of these settlements may provide a blueprint for making smaller Irish settlements more sustainable.
- For smaller settlements, specifically those in Classes 4 and 5, policy designed to improve their sustainability needs to focus on improving their economic bases, services and transport availability. Enhancing social cohesion and interaction may be necessary to facilitate communities focusing on longer-term sustainability goals, and in some cases reversing current patterns of decline. Special provision might be made for better public transport services and natural gas supplies. Municipal wastewater treatment is currently required only for settlements with populations greater than 2,000: population growth in smaller settlements without wastewater treatment plants may be expected to reduce their overall sustainability.
- Planning to enhance sustainability in individual small settlements may not be the optimal approach: such planning may be more effective if it focuses on groups of neighbouring settlements to achieve the critical mass necessary to solve problems inherent in smaller settlements.

Satellite settlements consistently scored poorly on services indices (the end-of-project report 2), necessitating travel from residences to most services. Public transport provision was found to be weak, with heavy reliance on private car mode, and distances travelled were relatively long. The ten settlements with the highest CO_2 emissions per capita associated with transport without exception were satellites. Moreover, satellites with fast-growing populations showed the very highest per-capita CO_2 emissions associated with transport (the end-of-project report 1, Section 3.7, point 5). Additional development in currently fast-growing satellite settlements with poor service provision has the greatest potential to reduce sustainability and increase Ireland's urban footprint. There is a need to plan for an integrated regional transport infrastructure; in particular the provision of effective public transport systems, and more generally to enhance sustainability in satellite settlements. Consideration might be given to restricting further growth in satellites to enable infrastructure and services to catch up with recent population growth.

- In relation to energy use, while natural gas is not a long-term sustainable option, in the medium term extending its distribution to settlements may be expected to lead to a significant reduction in CO_2 emissions. The more rapid exploitation of local-scale alternative technologies, such as combined heat and power, anaerobic digestion, and solar and wind energy generation, will minimise reliance on hydrocarbons and reduce CO_2 emissions.
- There was found to be no clear relationship between efficiency of waste management and settlement size. Groups of neighbouring settlements serviced by the same set of operators tended to show similar levels of waste management efficiency. Household sustainability of many settlements would be enhanced if all operators followed best practice.
- Sustainability needs to be improved in all settlements if Ireland is to meet international and national policy targets, for example in relation to water quality, waste management and carbon emissions. For each settlement, there are aspects of planning and management that are especially important in improving overall sustainability: these represent targets for policy and action interventions.
- People living in less sustainable settlements apparently were not experiencing a relatively low quality of life. This is counter-intuitive, and may be expected to reduce the likelihood of a general acceptance of a policy designed to enhance household sustainability. Additional research is required to explore the relationship between household sustainability and perceived quality of life, and perhaps to develop other indicators to evaluate quality of life.

6.2 Policy Implications in Relation to Policy Areas

- Waste management. Larger and more compact settlements reduce distances that waste is transported. Waste management efficiency varies from region to region: sustainability will be enhanced if all regions were as efficient as the best regions.
- Water. Under current regulations, wastewater treatment plants are required for settlements greater than 2,000 people. Lack of such treatment reduces sustainability. Unless this issue is addressed, additional population growth in the smallest settlements will tend to reduce future sustainability.
- Energy. Settlements connected to the natural gas network tend to have lower energy-related environmental impacts. While gas is a hydrocarbon fuel, its use as an energy source is preferable to the use of oil or solid fuel. In the longer term, to reduce energy-related impacts, greater reliance is required on renewable energy sources and local energy production.
- Transport. Inhabitants of the larger settlements travel shorter distances to shops and other services. Urban public transport is available only in larger settlements. However, larger settlements suffer greater traffic congestion, and if services are provided at settlement peripheries, then this increases journey length. Class 2 and 6 settlements may be planned to increase in size so as to enhance sustainability if transport and spatial planning is effective. Planning for enhanced sustainability for smaller settlements isolated from larger urban areas is problematic: enhanced accessibility through better transport provision may counteract by increasing car use. Population growth in satellite settlements near to larger urban areas, in which population growth is not matched by development of additional services, is especially unsustainable. Additional population growth in settlements with few services will exacerbate current low sustainability. Class 4 settlements show low environmental impacts associated with transport, but this is related to very low Socio-Economic Index scores. Ensuring the long-term viability of many such settlements may require an initial focus on enhancing their economic base.

- Environmental infrastructure. In the larger settlements, provision of an infrastructure to take advantage of economies of scale will enhance sustainability further. For Limerick, additional planning to enhance biodiversity conservation will enhance sustainability. For satellites, provision of an infrastructure needs to keep pace with population growth in relation to wastewater treatment, recycling facilities, and so on. For smaller settlements with little infrastructure, future growth should be delayed until plans are in place for enhanced infrastructure.
- Socio-economic welfare. Larger settlements are clearly at an advantage. Classes 2 and 6 settlements appear to be possible candidates for policy targeting to achieve socio-economic improvements in smaller settlements. Satellites benefit from close links to gateways. Better accessibility to larger settlements may represent the best way to enhance welfare in smaller, more isolated settlements. Economic growth is a priority in many Class 4 settlements.
- Additional housing. The more sustainable locations for additional housing are larger settlements, that is, Limerick and Classes 1, 2 and 6. Current rapid growth in satellites is reducing regional and national-scale sustainability especially because of increasing travel distances and reliance on private car transport. Class 4 and some Class 5 settlements require additional infrastructure and service provision if population growth is to maintain or enhance existing sustainability.

6.3 Key Policy Concerns in Settlement Types

- Limerick and Class 1 settlements. Policy should focus on maximising economies of scale through efficient provision of services and infrastructure, increasing housing density and reducing peripheral sprawl. The need to maintain or enhance the environment is crucial to future sustainability.
- Class 2 and 6 settlements. Investment in socio-economic welfare will encourage these settlements to become efficient locations for future growth.
- Satellites in Classes 3 and 5. These are both relatively unsustainable, and often now growing rapidly. Policies need to focus on enhancing services and accessible employment to reduce travel distances and on provision of transport alternatives to private cars.
- Smaller and more isolated settlements (Class 4 and some in Class 5) are currently less sustainable. Local economic are in general weak and priority needs to be given to enhancing the local economies of individual settlements or groups of settlements so as to reduce the need for relatively long journeys to work, education and services, and, for some settlements, to halt population decline.

7 Future Research

- It is important to monitor progress in settlement sustainability, given the currently rapidly changing Irish population and the increasing urbanisation of that population. To keep this work relevant, the database of information on settlements should be updated regularly (e.g. every five years). This project has identified the data sources, gaps and methods for data collection so that repeating this study will be relatively easy.
- Metrics of sustainability, indicators and footprints should be regularly calculated to provide a time series of information regarding the sustainability of settlements. This information will provide policy makers with local, regional and national perspectives on urban sustainability and, very importantly, will help identify the impacts of policies so that successful strategies can be repeated.
- More detailed research on Class 6 settlements is required to identify and better understand which of their characteristics makes them relatively more sustainable so that policy makers can learn lessons to enhance the sustainability of settlements of comparable population size.
- Similar research is needed in other Irish cities. This will help identify thresholds in sustainability where economies of scale become important.
- This work should also be repeated with a particular focus on coastal settlements, and east coast settlements influenced by Dublin.

Acronyms

EF	Ecological Footprint
ESRI	Economic and Social Research Institute
NDP	National Development Plan
NSS	National spatial strategy
CSO	Irish Central Statistics Office
SAPS	Small Area Population Statistics
SEI	Sustainable Energy Ireland

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