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Modelling for sustainable futures: problems and opportunities

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Abstract

Sustainable development is a high priority for the 21st Century but the complexity of development issues and the need to take a holistic approach makes it a major challenge for policy makers. In view of this, there is a need for a new generation of decision-support tools which can provide necessary intelligence whilst also providing a platform for communicating differing perspectives on both the problems and also the alternative pathways to potential solutions within a locality.

This paper discusses the development of a regional interactive sustainability atlas (*Atlas*^{NW}), which aims to be a prototype sustainability 'toolkit' for the North West region of England. The project attempts to draw together thinking on the current nature of urban and regional developmental processes and use these as the basis for exploring potential future scenarios and their environmental, social and economic impacts. It is directed at two principal audiences, firstly regional policy makers through providing the facility to investigate and assess different policy options and secondly the general public through providing a user-friendly awareness-raising tool.

The software uses an extensive GIS-based database of spatial information about the North West which is also used to produce a series of 3D visualisations of regional and sub-regional data layers and animations of related development processes. Although the study uses the North West region as the initial testbed for the work, it is intended that the framework will be applicable to different spatial scales of investigation as well as directly to other UK regions.

Introduction

Although a high priority for the 21st Century, there are many views on what constitutes 'sustainable development'. The UK Sustainable Development Strategy, for example, aims to achieve high and stable levels of economic growth whilst ensuring: the prudent use of natural resources; social progress that recognises the needs of everyone; and the effective protection of the environment (DETR, 1999). To be successful, the Strategy recognises the critical role of integrated policies and 'joined-up' government for both policy formulation and its delivery. However, finding a more sustainable path to future development patterns is a significant challenge requiring:

- consideration of multiple actors and conflicting policy goals
- successful incorporation of legitimate goals into a single, achievable vision and translated into a workable blueprint at different scales of government, and
- that both public and private sectors, as well as citizens at large, feel ownership of the vision and are willing and able to participate in its realisation.

In practical terms, it could be argued that the structure and nature of government in the UK presents a first constraint in the formulation of an effective strategic response. Whilst Local Agenda 21 initiatives have made an important 'bottom-up' contribution it is now recognised that this activity needs to be placed within

an overarching policy framework that can ensure that wider issues can be fully incorporated. For this reason the Government also sees an important role for regional government and associated agencies in providing the cornerstone of the Strategy's delivery.

In response, the work described here takes a regional approach to the issue of planning for sustainable future development patterns by providing the building blocks of a fully holistic, multi-disciplinary decision-support mechanism for policy makers. It concentrates on exploring the linkages between sectors through an examination of the potential repercussions of individual policies and policy packages in a range of different sectors. It also provides a mechanism for dialogue with the general public through data and scenario visualisations and the capability to interactively design user-generated scenarios that illustrate the consequences of different visions of the future, thereby improving understanding and encouraging support for the route that is eventually chosen.

The study uses the North West region as the initial testbed for the work but the framework developed will be directly applicable to other UK regions. The North West is a useful and interesting case study from a number of perspectives (Figure 1). Firstly both the North West Regional Assembly and the North West Development Agency place a strong emphasis on achieving sustainable growth for benefit all communities in the region (NWRA, 2000; NWDA, 2000). Secondly, the region also faces some of the greatest contrasts in the whole of the UK. It has a strong tradition of innovation and industrial development which, together with proximity to some of the UK's highest quality landscapes makes for wealth and a good quality of life for many of it's 6.9 million citizens (NWRA, 2000; NWDA, 2000). However, the deep divisions between the beneficiaries and those in communities with serious problems of unemployment, dereliction, and social exclusion make the need for a sustainable vision for all particularly crucial and a significant practical challenge. All regional Strategies recognise that while immediate action is necessary to halt negative patterns of change, successful solutions to reversing such patterns can only be implemented over the long term. The ability to examine scenarios in an interactive and flexible manner over the long term is therefore also a highly desirable aspect of any decision-support tool used.

In contrast to the requirements of a 'sustainability model', traditional modelling activities for supporting strategic planning and management activities have tended to focus on discipline-specific predictive modelling activities (Klosterman, 1997). These are limited in terms of an essential consideration of multiple and conflicting actors, sectors and objectives (Nijkamp and van de Bergh. 1997) and in their treatment of spatial components (Landis and Zhang, 2000). They are furthermore not generally regarded as suitable communication platforms between policy-makers and the wider public.

In response to the limitations of a traditional modelling approach, an alternative has been developed rejecting the principle of attempting to produce a single absolute prediction of the future in favour of the idea of creating numerous alternative visions and identifying what would happen in each case if the underlying assumptions were proved correct (Robinson, 1990; Ravetz, 1998; Klosterman 1999). In contrast to traditional modelling the scenario approach:

- Considers qualitative as well as quantitative aspects of processes and variables;
- Emphasises global trends over detailed, very accurate representations;
- Promotes flexible, creative thinking over deterministic analysis;
- Enables the examination of new policies over an analysis of past experiences; and
- Generates results based on future visions rather than based on the status quo.

(After Nijkamp and van de Bergh, 1997)

Applied within an information systems environment, scenario-based models can make good use of aspects of GIS, multi-media and the Internet and have the further advantage of being attractive, user friendly and more accessible to the user, whether the policy maker or a member of the wider public (Wegener and Fotheringham, 2000; Prastacos and Diamandakis, 2000). This is in tune with the Government's current approach to forward planning in which 'plan-monitor and manage' replaces the past notion of 'predict and provide'.

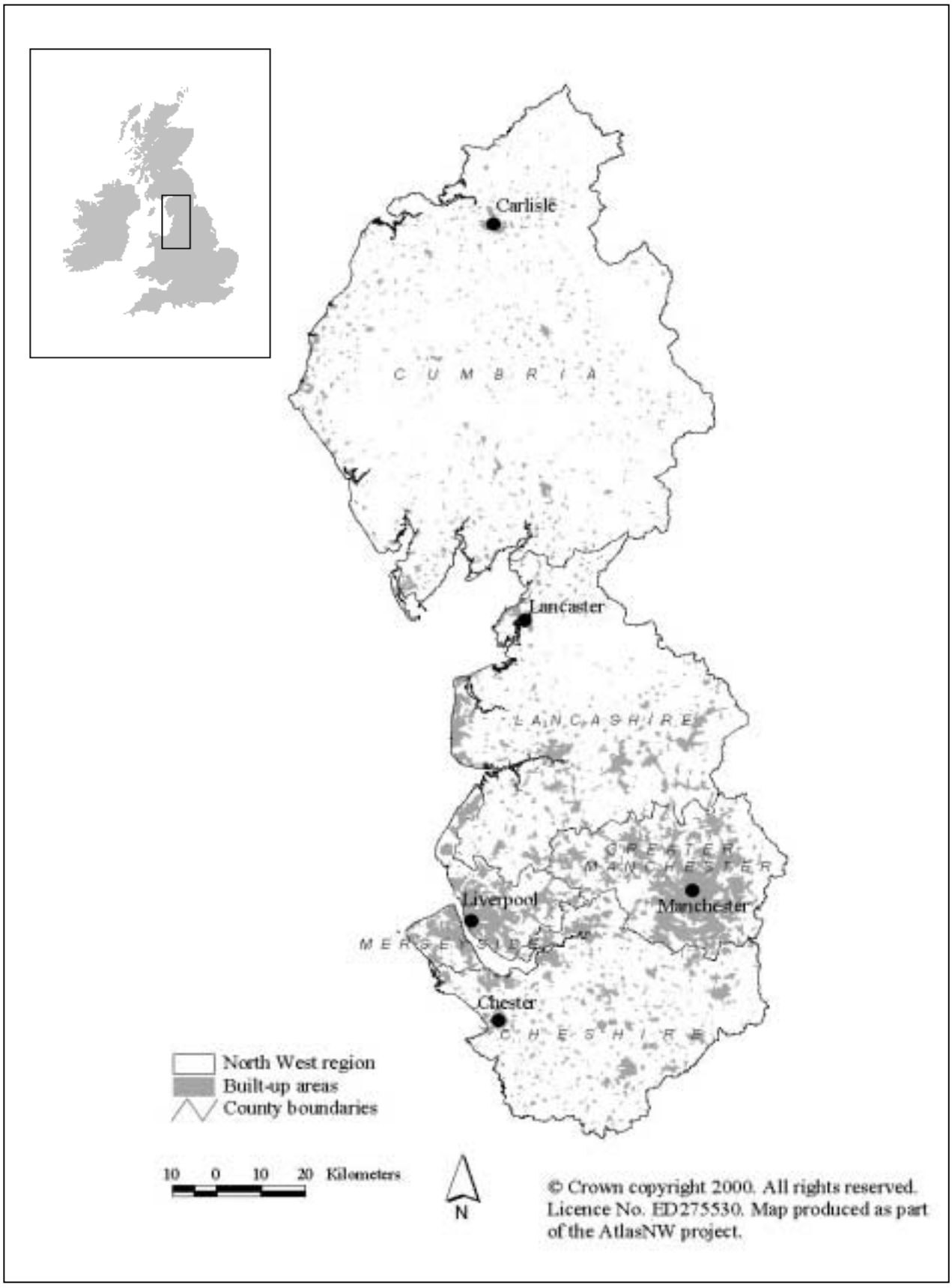


Figure 1: Study area – aspects of the NW region of England.

Such developments can then also be seen to embrace developments in UK Information Policy through the Government's 'e-government strategy'. Launched in 2000, the Strategy contains an ambitious agenda to achieve the Prime Minister's vision of modernised, efficient government, which is alive to the latest developments in technology and to meeting the needs of both citizens and businesses. It fulfills the commitment in the 'Modernising Government' white paper to publish a strategy for the Information Age and has for guiding principles:

- Building services around citizen's choices (people should be able to interact with the Government on their terms);
- Making government and its services more accessible (all services which can be electronically delivered should be);
- Social inclusion (including a commitment to make it easier for all people to get access to the Internet, whether individually or through community facilities); and
- Using information better (recognising that the Governments knowledge and information are valuable resources).

(Cabinet Office, 2000)

Components of the *Atlas*^{NW} toolbox

The *Atlas*^{NW} project applies the scenario approach to the practical task of creating a multi-disciplinary systems modelling and visualisation tool for the North West region. The full toolbox (Figure 2) comprises a variety of components and these are summarised below.

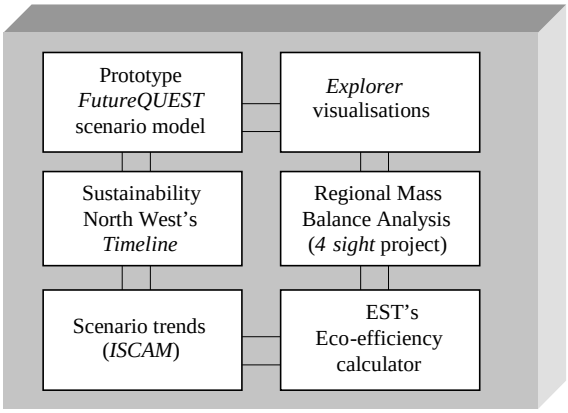


Figure 2: Components of Atlas^{NW}

- FutureQUEST: A future scenario tool developed from the Canadian *QUEST* model and applied to the UK. *QUEST* was originally developed at the Sustainable Development Research Institute (SDRI) of the University of British Columbia and which is now being advanced by Envision Sustainability Tools (EST) together with a global network of research partners. The original *QUEST* model provides a holistic framework for investigating personalised visions of the future by integrating sub-modules associated with land-use, economics, natural habitat, housing, water, transportation, air quality and energy together with aspects of governance and social attitudes (EST, 2000).
- GISExplorer: A web-based visualisation tool which takes key characteristics, such as those associated with land-use, planning designations, social and economic patterns and the state of the environment of the North West region and allows users to view 2D and 3D maps from different regional perspectives.
- *Integrated Sustainable Cities Assessment Method (ISCAM)* model facilitating an assessment of regional trends and accounts (Ravetz, 2000b)

- Sustainability North West's *Timeline* allowing the user to call up a databank of scenario-linked semi-hypothetical news & features from the 21st century (SNW, 2000).
- *4-sight* – integration of data from a sister project focussing on the nature and sustainability of resource flows within the region (Ravetz, 2000a).

The remainder of the paper investigates two of the principal components, *FutureQUEST* and *GISExplorer*, as tools which particularly emphasise the use of scenario modelling and visualisation techniques in decision-support and which therefore also address the demands of current UK policy in terms of the Information and Sustainable Development strategies. The toolbox is to be brought together by a further website development which uses aspects of each module to produce a 'time and space machine' and which acts as a gateway to the final products in each area. On completion a link to this gateway will be found on the CURE website (http://www.art.man.ac.uk/planning/cure).

FutureQUEST

The *FutureQUEST* scenario model is a strongly user-centred model which enables users to explore different futures from the base year of 1995 through to 2035. An overview of the stages in developing a scenario is shown in Figure 3.

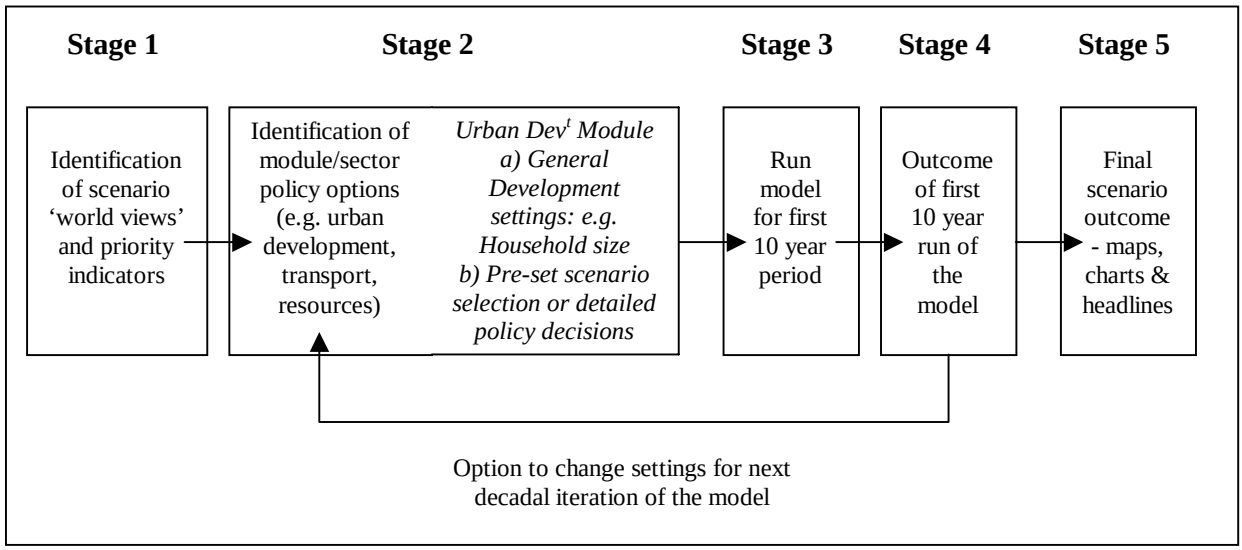
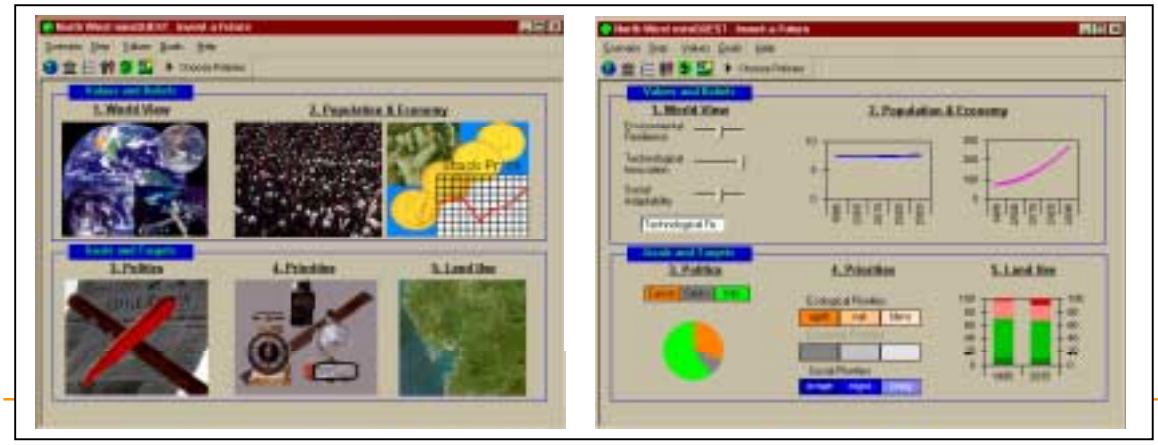


Figure 3: Stages in the development of a future development scenario in Atlas[NW]*'s* FutureQUEST.

Stage 1 – The user specifies a series of 'values and beliefs' for the particular scenario being developed which will be used to identify broad environmental, social and economic characteristics to be applied throughout the 40 year modelling period (Figure 4). The user is also asked to specify a series of goals/targets which become the indicators against which the scenario results can be judged.

Figure 4: Interface for setting the values/beliefs and goals/priorities of a FutureQUEST *scenario*

Before making choices *After making choices*



Stage 2 – Specific choices are made in relation to each of the interlinked modules which represent the main aspects of activity in a locality. Whilst the model does not, and indeed cannot, make absolute predictions of the impact of particular activities on all spheres of development, it takes a global trend approach to allow users to explore what may occur in different sectors given a particular set of circumstances and this will then provide a guide for more rigorous testing of the specific nature of the possible outcomes. There are currently two levels of interface, a detailed interface which will allow modification of the individual settings for each parameter and a more basic interface that groups parameter settings within pre-set scenarios. The latter is particularly useful in engaging the wider public and encouraging exploration of a range of potential policy options.

Stage 3 – The model is run for the first ten-year period.

Stage 4 – At end of the first iteration of the scenario, the degree to which the user's goal has been achieved is reported back through a virtual 'newspaper' featuring headlines and supporting information in the form of charts and summary statistics. At this point the user can chose to either continue with the same set of policies or make further modifications with every iteration of the model until the current scenario end-date of 2035.

Stage 5 – The final scenario results are shown, together with a tool to compare trends over time.

The core driver for the model has been taken as urban development, specifically residential choice behaviour, which then affects changes in other sectors such as transport and resource use. There are certain advantages in using residential change over other potential drivers such as the economy. This is because it is a process that is:

- inherently spatial and visual in nature;
- readily identifiable to many users and therefore perhaps less exclusionary than many other approaches; and
- essentially holistic in that it encompasses aspects of lifestyle and values together with recognisable economic issues such as employment.

Changes between the start and end of the each decade are generated through the user's interactive assessment of the importance of individual aspects of the development process for the scenario being developed. To do this, a basic push/pull scheme has been developed. Development processes have been generalised either as push factors that act to displace people from an existing location or as pull factors that act to attract population to a new location. Each factor has a set of alternative algorithms selected through the user's response to a particular question on the model interface and these determine either the direction or the strength of a particular process. The settings are then used to generate composite indices of 'attractiveness' and 'unattractiveness' which determine the cells to lose or gain population in any decade. The model also considers the influence of processes operating on the region as a whole such as demographic and migration trends and, where the user specifies accordingly, account is also taken of factors such as the location of green belt and other land-use protection policies in determining the final distribution of population at the end of any iteration of the model.

Data used in the model have been collated from a wide range of local, regional and national data providers and stored within an extensive GIS-based Access database. Where necessary, the input data have then been manipulated and analysed within GIS (Arcview and/or ArcInfo) in order to create the necessary layers of information that are spatially resolved to a grid of 500m x 500m. This resolution offers sufficient detail to create meaningful representations of the region's characteristics whilst still allowing the model to process data in real-time in response to the wide variety of possible policy packages specified by the user. It is important to emphasise that the data layers are intended to provide a guide to the characteristics of the region rather than a snapshot of reality.

There are currently some 30 data layers in the urban development module alone which describe different social, economic and environmental parameters which influence patterns of urban development at the regional scale including: population density & land-use, landscape character, social deprivation, employment, proximity to road and rail transport, proximity to schools, crime risk, land-use designations, derelict land densities, council tax and house prices.

The final prototype for this stage of the work includes a sub-set of the full range of potential modules, exemplified by those included in the original *QUEST* model (EST, 2000). This subset includes modules that deal with issues associated with urban development, economics, resources, transport demand and end-user air emissions each with their own input screens representing sector specific policy choices.

GISExplorer

Graphical representations of large volumes of data, such as 2D and 3D maps together with associated charts, graphs, tables and images, have been found to be beneficial to human cognitive performance through making data accessible, manageable and comprehensible (Medyckyj-Scott, 1994). The use of GIS–based visualisations to communicate information about the North West region therefore represents an extremely valuable element of the *Atlas*^{NW} work. In addition to using GIS in the creation of the input database for the *FutureQUEST* model, it has also been used as the basis for a present-day digital atlas of the region which can, through ongoing development, be linked more closely with the model outputs and eventually with the modelling process itself. Visualisations have been produced in Mapinfo using add-on tools and in ArcView using 3D Analyst.

The *GISExplorer* component of the *Atlas*^{NW} has a web-based navigation tool which provides a gateway whereby users can view themed visualisations describing the salient characteristics of the North West region in the base year of the model. The homepage directs the user to select whether to view data by county or through a full regional representation. The user then selects the particular theme to view by means of a drop-down menu. These can include the data layers referred to in the *FutureQUEST* scenario model, such as areas of social deprivation, protected areas and areas of flood risk or they could be representations of the original input data provided by the data providers. The categories presently available include:

- Countryside Designations – including national parks and Areas of Outstanding Natural Beauty
- Population density
- Land Cover – including forestry and moorland
- Greenbelt designations
- Traffic flows on the region's road networks
- Areas of Social Deprivation
- Industrial sites – Environment Agency registered Part A industrial processes
- Mineral extraction sites
- Atmospheric Emissions

Each layer can be viewed either in a conventional 2D format or as a 3D representation. The 3D visualisations comprise thematic drapes over a topographical surface or extruded attribute data. In 3D mode the user can opt to view the region from a number of different angles in order to provide differing perspectives on the same base dataset. Thematic drapes showing the location of industrial processes are illustrated in Figures 5. Figure 6 shows the different perspectives of the population surface of the region – contrasting the 'usual' view of the region from the SE with that from the viewpoint of a resident in Carlisle. Taking these different perspectives on regional issues is of critical importance if development is to take a more sustainable form that recognises the needs of everyone.

Other tools available to assist the user in interpreting the data include a location finder and a satellite image viewer. The location finder includes a gazetteer of settlements in the region which can be accessed via an alphabetical list. When the user has selected their settlement of interest a 2D map is displayed with a reference to the area of interest.

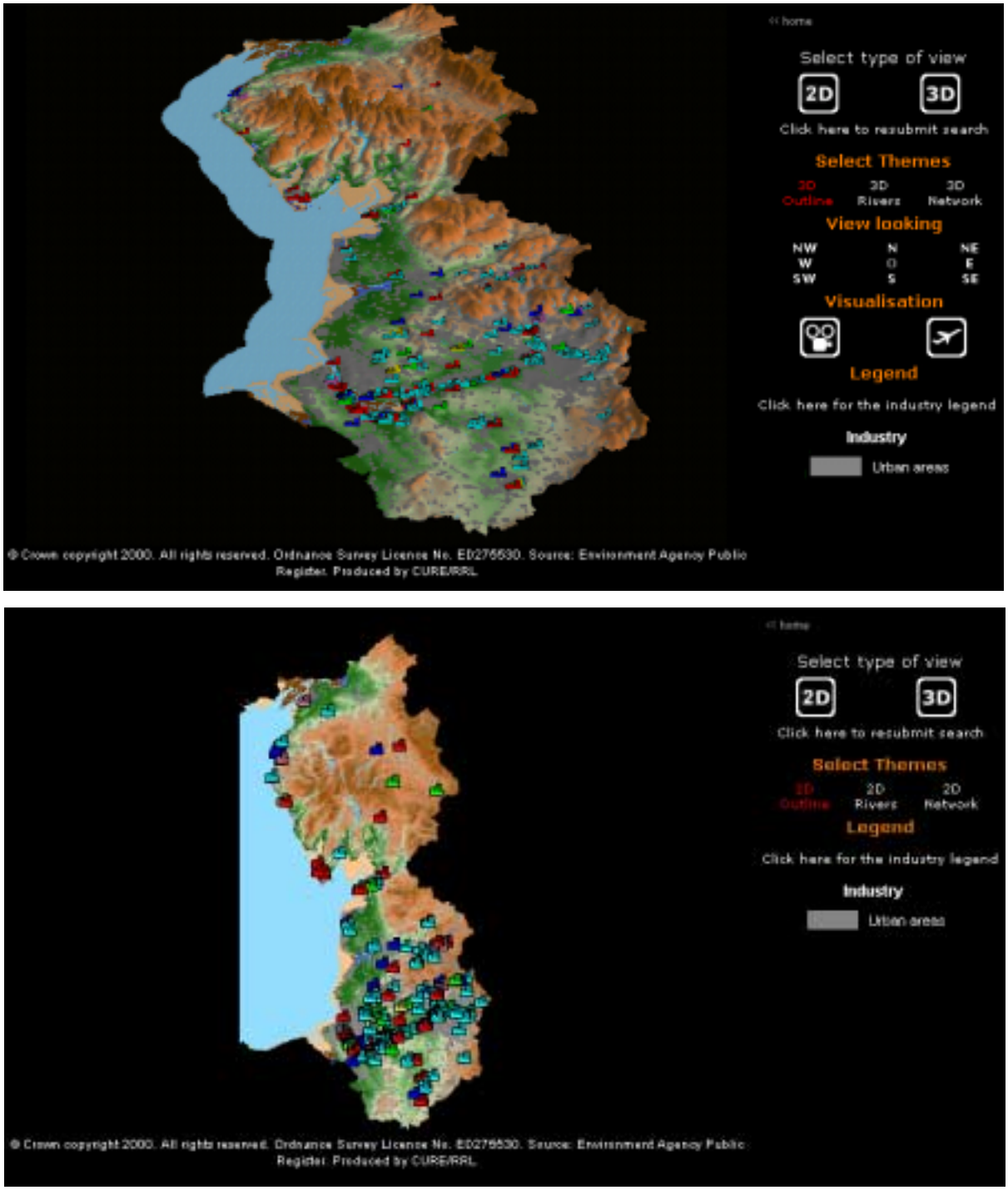
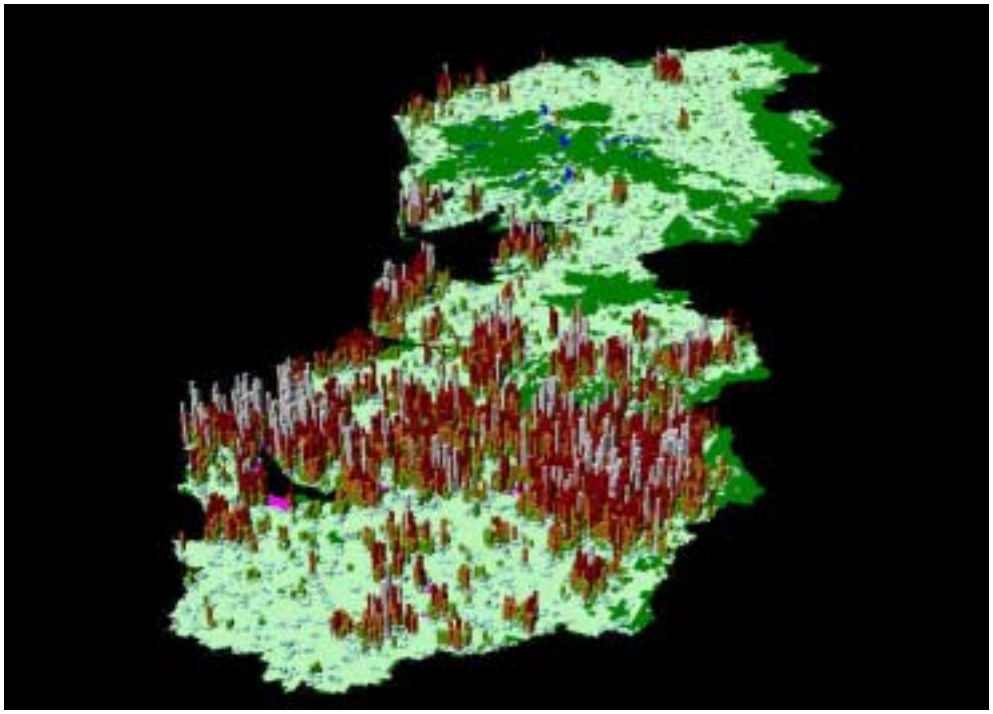
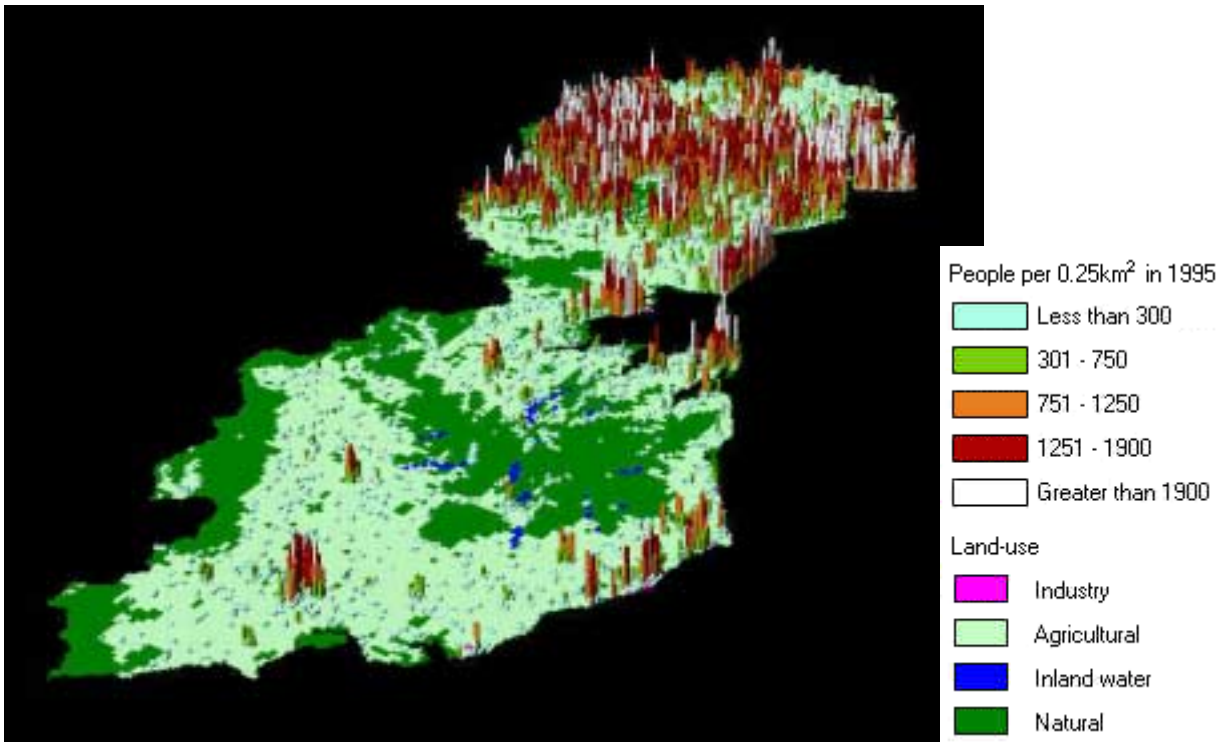


Figure 5: The location of industrial processes as 3D and 2D representations.

Finally, the interface provides a link to a series of semi-hypothetical animations of the potential future development patterns of selected processes within the region and various fly-throughs of the thematic datasets. For example, one animation traces the path of the M6 motorway across the region and the changing patterns of road flows are clearly illustrated. In this way it is intended that users can be guided into a greater appreciation of developmental issues facing the region.

The final version of the *GISExplorer* will also include a narrative describing the generation of the map, data layer or animation in question together with an indication of the level of certainty with which it should be treated. This is important in emphasising the inherent uncertainties associated with each visualisation which may not otherwise be obvious to either the lay or the expert viewer (Pickles, 1995; Monmonier, 1991) In doing this, *Explorer* will help make data more available, accessible and transparent to the public and further foster debate and user engagement in relation to the range of issues that affect the region both today and into the future.





Produced by the Centre for Urban & Regional Ecology (CURE), School of Planning & Landscape, University of Manchester, for Atlas[NW].

Based on: population density data generated from the UK Census of Population (1991) 'surpop' data (MIMAS) modified to 1995 using district level data (ONS); and land-use data from a variety of sources including the Countryside Information System.

Figure 6: Two views of the population distribution of the North West region in 1995
a) from the South East and b) from the North West

Concluding comments and future directions

The various components of the *Atlas*^{NW} project represent discrete but integrated tools, each dealing with different facets of planning, interaction and education for sustainable development at the regional scale. In linking these with current thinking on sustainable development policy, *Atlas*^{NW} shows considerable promise as an innovative and powerful system for exploring and disseminating information to a wide audience of policy-makers and the public. Nevertheless there are some important limitations to the model in its current form.

The first is that of the eternal quandary of how to best represent inherently complex and variable characteristics and processes. Clearly, the development of any model requires facing the challenge of representing complex patterns and processes with limited data and incomplete knowledge. In terms of an integrated model of this type this challenge becomes particularly acute as the development of model algorithms and associated base data must attempt to find a balance between the need to be representative and the need to generate results over acceptable timescales. In addition to the sheer number of parameters that are necessary to achieve an adequate picture of regional development processes, many are also inherently 'fuzzy' in nature and are particularly difficult to represent using current data analysis and manipulation tools, such as the interpretation of 'crime risk' for example.

The second relates to another fundamental modelling constraint, the need for a systems boundary. In this case the model region is that defined by the existing administrative framework and although a government defined region is useful in that it represents a coherent management and planning structure (albeit only in terms of one 'layer' of the full structure) it is unsatisfactorily restrictive in terms of a complete appreciation of the externalities of developmental processes which do not respect such artificial constraints. In practical terms, the case of the North West region is fortunate in that the government region also represents something of a 'natural' region being bounded by the Irish Sea to the West and the Pennines to the East but it is of course in no way a completely 'closed' system.

There are a number of planned future developments to the *Atlas*^{NW} including nested versions at different spatial scales, stronger linkages to GIS functionality and, ultimately the extension of the toolbox to a fully inter-linked Planning Support System (Harris and Batty 1993; Klosterman, 1997, 1999). Such developments will take a further step towards using the database to promote further analytical capabilities at the regional scale such as the monitoring and holistic assessment of sustainability indicators. When considered as a full 'toolbox' package, each of these discrete tools has added value and will produce a framework that goes some way to taking a genuinely holistic outlook to the challenging goal of achieving sustainable development. It also provides one of the many mechanisms by which the Government can help realise the ambitious goals of the UK Information Policy.

Finally, it is important to emphasise that there are a number of practical issues associated with the development of a tool of this nature including data availability, quality, and consistency and the not inconsiderable task of finding a means of presenting the information in a clear, unambiguous way. A preliminary assessment of the first prototype of the website by a group of 46 16-year olds revealed that only 33% considered that the information taught them anything new about their area and 37% felt that it helped them better appreciate the issues facing planners and managers in the region. Clearly, despite considerable promise there is still some way to go.

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