



Deposited via The University of Leeds.

White Rose Research Online URL for this paper:

<https://eprints.whiterose.ac.uk/id/eprint/2092/>

Monograph:

Kupiszewska, D. (1997) Computer implementation of the Quantifiable City Decision Support System (QCDSS). Working Paper. Institute of Transport Studies, University of Leeds , Leeds, UK.

Working Paper 519

Reuse

See Attached

Takedown

If you consider content in White Rose Research Online to be in breach of UK law, please notify us by emailing eprints@whiterose.ac.uk including the URL of the record and the reason for the withdrawal request.



White Rose Research Online

<http://eprints.whiterose.ac.uk/>



[Institute of Transport Studies](#)

University of Leeds

This is an ITS Working Paper produced and published by the University of Leeds. ITS Working Papers are intended to provide information and encourage discussion on a topic in advance of formal publication. They represent only the views of the authors, and do not necessarily reflect the views or approval of the sponsors.

White Rose Repository URL for this paper:
<http://eprints.whiterose.ac.uk/2092>

Published paper

Dorota Kupiszewska (1997) *Computer implementation of the Quantifiable City Decision Support System (QCDSS)*. Institute of Transport Studies, University of Leeds, Working Paper 519

Working Paper 519

November 1997

**Computer implementation of the
Quantifiable City
Decision Support System (QCDSS)**

Dorota Kupiszewska

ITS Working Papers are intended to provide information and encourage discussion on a topic in advance of formal publication. They represent only the views of the authors, and do not necessarily reflect the views or approval of the sponsors.

UNIVERSITY OF LEEDS
Institute for Transport Studies

ITS Working Paper 519

November 1997

**Computer implementation of the Quantifiable City
Decision Support System (QCDSS)**

Dorota Kupiszewska

This report is the first one in the series of four reports prepared by the author within the Sustainable/Quantifiable City project conducted in 1994-1996 at the Environment Centre. The author wishes to thank the grantholders: Prof. David Kay (Environment Centre), Prof. Tony May (Institute for Transport Studies) and Prof. Mike Pilling (School of Chemistry), as well as Dr Gordon Mitchell (co-researcher, Environment Centre) and Prof. Adrian McDonald (School of Geography) for their support.

A colour version of this report is available on request from the publications secretary at the Institute for Transport Studies, Leeds University.

Other reports in the series are:

Working Paper 520

“Modelling for sustainable cities: Conceptual approach and an audit of existing sectoral models for transport, air pollution, land use, and population modelling”.

Working Paper 521

“Modelling for sustainable cities: the transportation sector”, and

Working Paper 522

“MUPPETS: A computer tool for modelling and mapping emissions from urban transport and stationary sources”.

A colour version of this report is also available on request from the publications secretary at the Institute for Transport Studies, Leeds University.

Contents

A. Introduction	1
B. Computer framework for the QCDSS	3
B.1 Database design	5
B.1.1 Common file structure	5
B.1.2 Format of spatially referenced data	6
B.1.3 Basic zoning systems	7
B.1.4 Road network link-based data	13
B.2 Graphical User Interface	14
B.2.1 Characteristics of Visual Basic	14
B.2.2 Components of the QCDSS GUI	18
B.2.3 Technical details of the QCDSS GUI	32
B.3 Sectoral models and the GIS	33
C. Description of the exemplar model	35
D. Bibliography	38

A. Introduction

Design and development of a computer model that would allow to monitor urban sustainability trends, to identify major urban processes contributing to unsustainability, and to predict the impacts of policies on city sustainability involves two major tasks: (i) Specification of the scientific contents of the model; (ii) Design and development of the computing framework that will enable an effective implementation of functionality specified under (i). This report addresses mainly the second task. Part B describes the general structure of the computer system (called the Quantifiable City Decision Support System, QCDSS in short). Part C introduces an exemplar model that has been used to demonstrate the process of the transition from a conceptual to an operational computer model. A detailed description of the computer implementation of the exemplar model, which focuses on urban air pollution, including sources and impacts, is presented in [Kupiszewska 1996a].

In order to specify the computing requirements of the modelling system and the characteristics of the computer architecture, one has to first define, at least in general terms, the required functionality of the model. Here, a conceptual model of city sustainability covers a wide range of urban activities and processes: changes in land use patterns; economic development; demographic changes; transport demand and supply, consumption of energy and other resources; water supply, demand and quality; atmospheric pollution; land contamination; waste generation and processing; and impacts of all the above on the quality of life. A set of indicators is needed to measure urban sustainability, with several indicators usually required to assess trends and policies in each particular sector. One combined index of city performance would not be useful for city planners and researchers who have to address specific problems in sectors they represent.

What distinguishes an integrated sustainability model from standard sector or process models is the emphasis on the interactions between various processes and on the impacts of activities and policies in one sector on sustainability trends in the others.

Given the above specified set of processes to model, it is clear that a strong integration of all processes within a single, necessarily huge, model is not feasible. First, it would require too many simplifying assumption. Second, it would require a large team of experts dedicated for a long time to the project.

Instead, we have proposed to develop a Quantifiable City Decision Support System (QCDSS) in a modular form, described in detail in the next section. The core part of the QCDSS is a system of loosely inter-connected sectoral models communicating with each other through their input and output data. Some of the models to be used in the QCDSS have been used extensively by researchers and planners in the past. Integrating these models in a single framework will bring new information about interactions between various sectors and about the overall impact on city sustainability. Future research will concentrate on filling modelling gaps or on the improvement of existing models, especially in the priority areas.

B. Computer framework for the QCDSS

Quantifiable City Decision Support System is a multi-platform, multi-model computer system for analysing sustainability trends, and for testing scenarios and policies. The structure of the QCDSS is presented at Figure 1. The main elements of the system are:

- Database;
- Sector models;
- Geographic Information System;
- Graphical User Interface.

Sector models interact with each other through the Database, where all data is kept in a common format (see Section B.1). By changing values of controllable variables in sector models one can test consequences of various policies and scenarios. It is anticipated that many models will be acquired in a compiled form, with the input and output file formats pre-defined by model authors and differing from the Database format. Therefore, interfaces are needed to allow for a transfer of data between the Database and models. In the QCDSS for Leeds the interfaces have been written in C++, but different programming languages might be used in other implementations.

In addition to model inputs and outputs, the database contains information on non-modelled indicators, e.g. socio-economic data or environmental indicators obtained from monitoring. While models are mainly important for forecasting purposes, the monitored data are used to analyse the observed sustainability trends. Monitored data and outputs from the models are displayed in the form of graphs, tables or maps. Sector models produce two types of outputs: (i) intermediate results to be used as an input to other sector models; (ii) reference or/and sustainability indicators. Data transformation modules might be programmed to calculate sustainability indicators from reference indicators and additional data from the database, e.g. census data or data on carrying capacities.

The GIS system is used both for mapping purposes and as a modelling tool. In particular, it is used for transforming spatial data into different zoning system, e.g. for recalculating

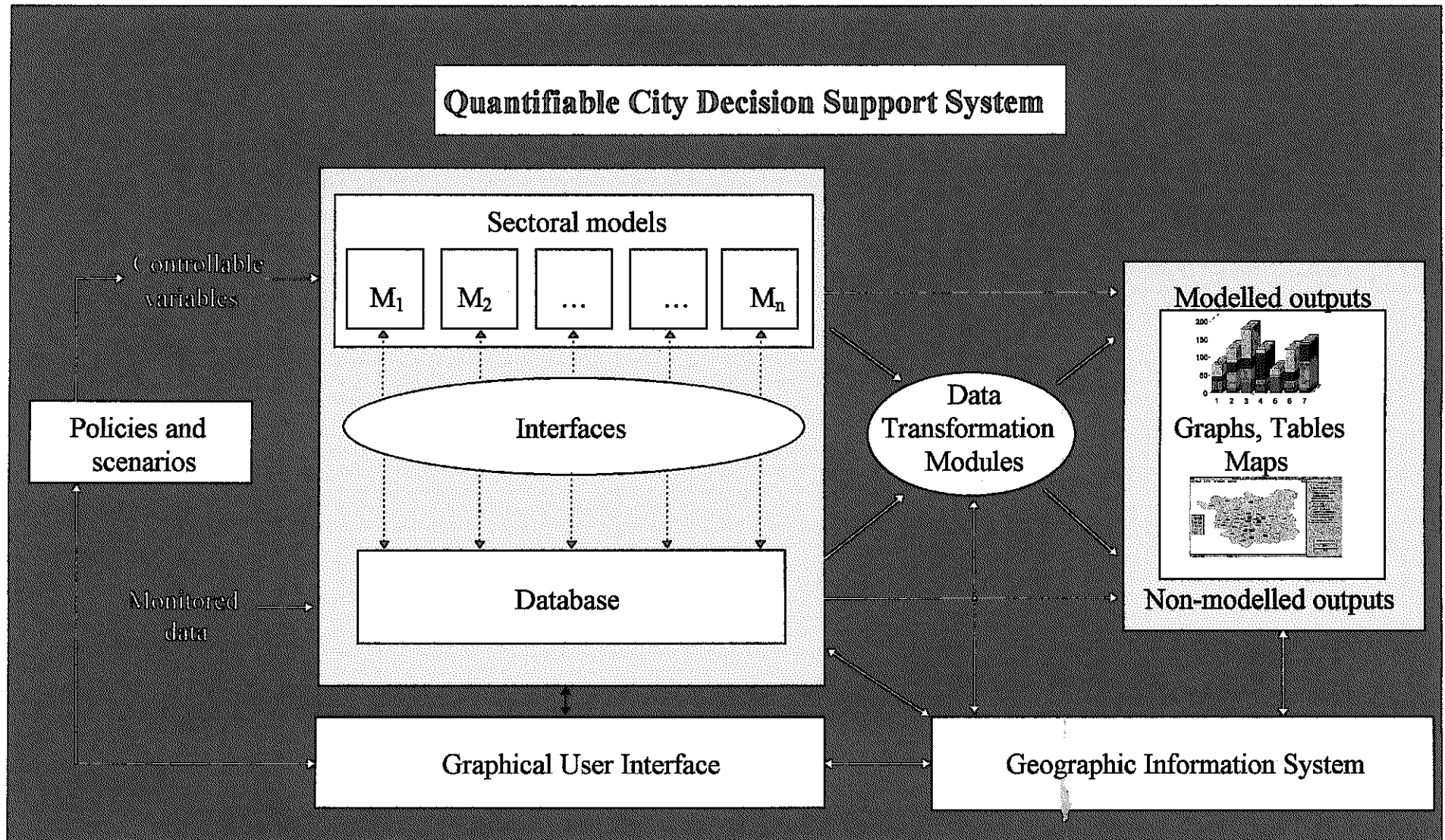


Figure 1. Structure of the Quantifiable City Decision Support System.

administrative division-based data into grid-based data. An important part of the QCDSS is the user-friendly graphical user interface that allows for an easy access to models and data.

The QCDSS has been mainly developed on a PC platform (a Pentium 90), as this is a platform available to the largest number of users. Although an increasing number of sector models has been developed to run on PCs, there is a number of models that have higher memory or speed requirements. Also, some local authorities might already use workstations. For these reasons the exemplar model introduced in Section C and described in [Kupiszewska 1996a] has been developed partially on the Pentium PC and partially on the Sun workstation.

B.1 Database design

B.1.1 Common file structure

Data are kept in space delimited text files, which facilitates transfer of files between various platforms and operating systems. When a file is required as comma delimited text (for example as an input to MapInfo or ARC/INFO), the easiest way is to open a file in Excel spreadsheet and use Save As, selecting comma delimited (.csv) option.

Each file in the database has the following structure:

Line 1: Data set *number*

Line 2: File name "*filename.ext*"

Line 3: *Description of the file contents*

Line 4: *List of variables*

Line 5: Blank

Line 6 and subsequent: *data*

In the above description italics indicate placeholders for the information referring to a specific data set.

A data set *number* identifies a file in a unique way and helps to find the detailed specification of the data set (including the description of all the variables and the source of the data) in the “Database description” document.

Names of the files must follow the DOS file naming rules, so that the same name could be used on UNIX and DOS/MS Windows platforms. A file name *filename* can be up to eight characters long. In addition, an extension *ext* up to three characters long may be included. The following characters are acceptable: the letters A through Z, the numbers 0 through 9, and the following special characters: ` , ! , \$, % , ^ , & , (,) , _ , - , { , } , @ , ' , ~ , and #.

A *description of the file contents* gives a brief indication of data kept in the file, including the information on the zoning system, if relevant.

A *list of variables* gives names of variables in the order in which they appear in the *data* lines. There is no restriction on the length of names, because here they are used only for descriptive purposes. Usually, the corresponding names used in the computer codes of the models will be different, and then they might be subject to various restrictions. For example in FORTRAN 77 names of variables are strings composed of up to six characters (letters or numbers), and beginning with a letter.

The exact format of *data* lines is specific to each data set. A special format have been designed for spatially referenced data, in particular for the basic zoning systems used in the Quantifiable City model and for the road network link-based data.

B.1.2 Format of spatially referenced data

B.1.2.1 Geographic files

Geographic files (digital boundaries, point and line objects) are kept in the DXF format, and in MapInfo or ARC/INFO format when appropriate. Co-ordinates of point and line objects may be also stored in attribute ASCII files, if they are used for modelling rather than mapping purposes.

B.1.2.2 Spatial co-ordinates unites

Co-ordinates of all objects represented in geographic files and attribute files are given using the British National Grid system described below. Within a GIS, data can be represented in other co-ordinate systems (e.g. latitude/longitude).

The National Grid [Hartley 1975] is formed by a set of lines drawn parallel and perpendicular to the central meridian of a Transverse Mercator projection used for the maps of Great Britain by the Ordnance Survey. The National Grid rectangular co-ordinates are a set of two numbers, which give the position of a point in terms of its distance east (Easting) and north (Northing) from an origin. The true origin of the projection is at Latitude 49° North, Longitude 2° West of Greenwich, but the National Grid co-ordinates are given relative to the false origin, which is located 400 km west and 100 km north from the true origin (so at Lat. 49°46'N; Long. 7°33'W of Greenwich). In this way the co-ordinates of all the locations within Great Britain are positive and smaller than 1000 km. Eastings and Northings are given as six digit numbers, expressing the distance from the false origin in meters.

B.1.2.3 Attribute files

Attribute files contain variables characterising geographical objects (zones, wards, road network links etc.). Many attribute files may be created for a given set of objects. Line 4 of an attribute file has the form

Object_Code VariableName1 VariableName2 ...

Each *data* line (in Lines 6 - EOF) begins with the value of an object code (identifier).

B.1.3 Basic zoning systems

The following basic zoning systems are used in the Quantifiable City model:

- Wards (Figure 2)
- Census Enumeration Districts (EDs)

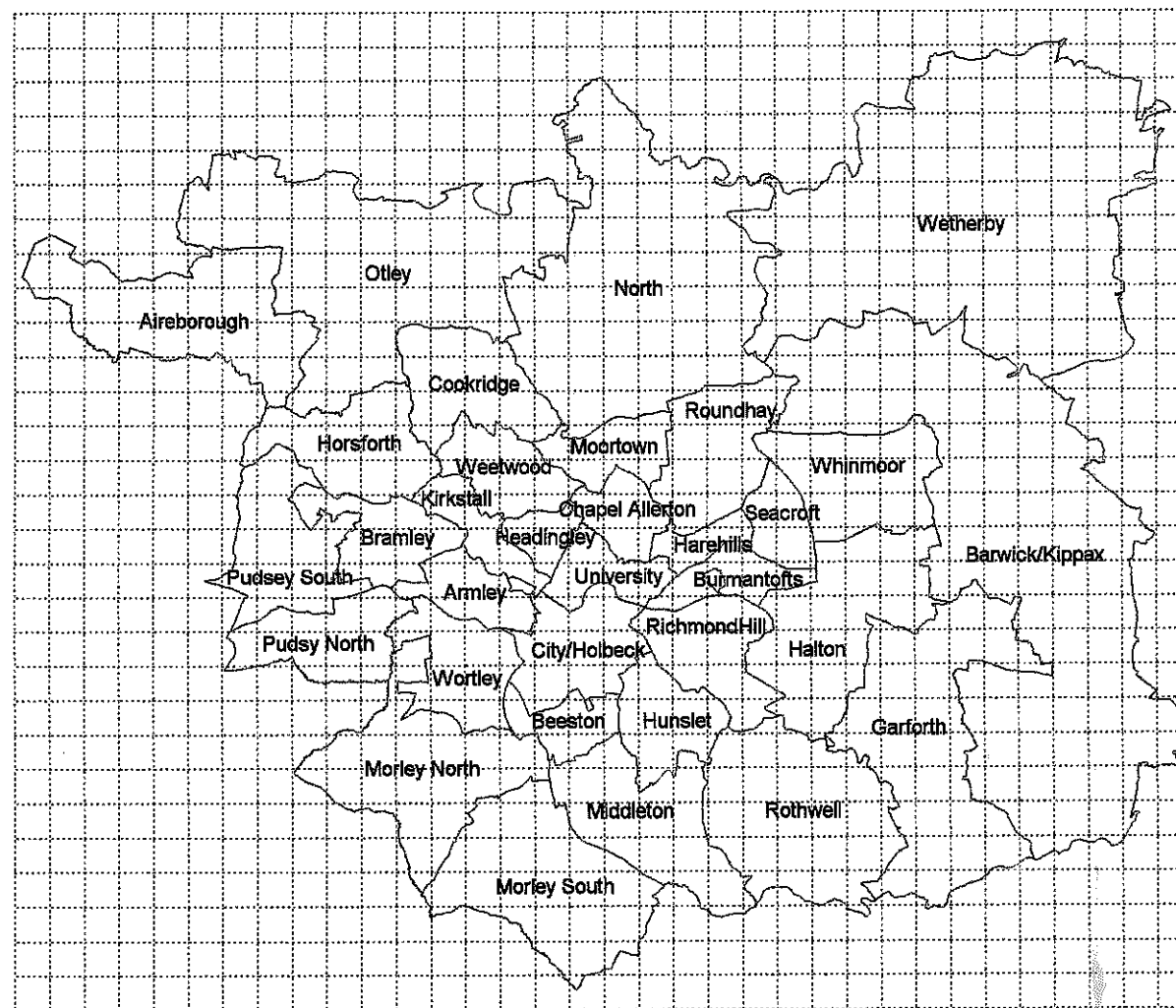


Figure 2. Leeds wards boundaries and the 1km x 1km grid.

- Postcode Districts
- Postcode Sectors (Figure 3)
- Postcode Units
- Potable Water Zones
- Grid_1000: 1km by 1km grid
- Grid_100: 100m by 100m grid

Grids based on squares of different size are created when necessary (e.g. Grid_200 with 200m by 200m grid squares). All grids are compatible with the British National Grid.

Each *data* line (in Lines 6 - End-of-file) begins with the value of a zone code. Rules for creating zone codes are given below.

B.1.3.1 Grid-based data

The code of a grid square is built using the National Grid rectangular co-ordinates of the south-west corner of the square. In the case of the Grid_1000 (1 km by 1 km), co-ordinates are expressed in 1km units and the code is defined as a six characters string composed of a three digit easting and a three digit northing. For example for the Leeds Metropolitan District grid square codes are in the range 413422 to 446450.

For the Grid_100, codes are defined similarly, but they are 8 characters long (e.g. 41304220) and are composed of four digits eastings and four digits northings giving the co-ordinates of the south-west corner of a square in 100m units. Codes for the Grid_200 and Grid_500 have the same form as for the Grid_100 (8 characters). There is no danger of confusing grid squares with the same code but from different grids (e.g. the square xxx0xxx0 from Grid_100 with that from Grid_200) because data for various grids are kept in separate files and in separate GIS layers). Table 1 gives an example of a grid-based data file.

Table 1. Beginning of the file containing grid-based data on emissions of pollutants.

Dataset 1

File name "em1.txt"

Data on emissions of VOC and NOx, based on the 1 km by 1 km grid

Square_Code NOx Total_VOC Anthropogenic_VOC Biogenic_VOC Benzene Toluene

413443 0 0 0 0 0 0

413444 0 0 0 0 0 0

413445 0 0 0 0 0 0

414442 3 129 0 1 21 108

414443 10843 5892 308 644 5852 40

414444 2 25 0 1 12 13

B.1.3.2 Administrative and census units codes

The coding convention adopted by the OPCS (Office of Population Censuses and Surveys) [Dale and Marsh 1993] is used for administrative and census units. In England and Wales each enumeration district has an eight-character code composed of the following elements: a two character county code, a two character district code, a two character ward code and a two character Enumeration District code. County codes are two digit numbers in the range 01 to 55. For districts, two letter codes in the range AA to TT are used. District codes identify districts in a unique way, even without the county code. Within each district, two letter codes in the range FA-ZZ are assigned in sequence to alphabetically ordered wards. Within each ward, EDs are coded by two digit numbers starting from 01. Thus, a ward identifier 08DAFN01 would be decoded as follows:

08: the county of West Yorkshire

DA: Leeds district

FN: Headingly ward

01: enumeration district number 1 within the Headingly ward

In this project a focus is on the Leeds district, but data for neighbouring districts (Figure 4, Table 2) might also be needed.

Figure 4. Boundaries of Leeds and surrounding districts.

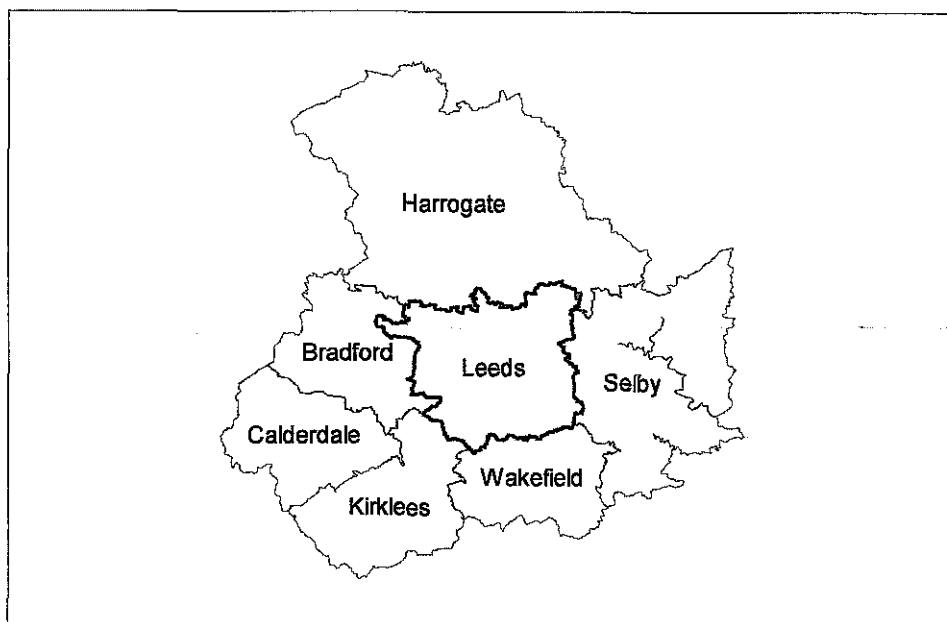


Table 2. OPCS codes for Leeds and neighbouring districts.

Counties		Districts		
Code	Name	Code	Name	Number of wards
08	West Yorkshire	DA	Leeds	33
		CX	Bradford	30
		CZ	Kirklees	24
		DB	Wakefield	21
37	North Yorkshire	PD	Selby	35
		NZ	Harrogate	33

In the QCDSS Database there are attribute files containing ward names. They have two columns containing respectively values of ward codes and corresponding names. Table 3 lists wards in Leeds (file Leeds.txt)

Table 3. OPCS codes for wards in Leeds

Code	Name	Code	Name
08DAFA	Airborough	08DAFT	Moortown
08DAFB	Armley	08DAFU	Morley North
08DAFC	Barwick	08DAFW	Morley South
08DAFD	Beeston	08DAFX	North
08DAFE	Bramley	08DAFY	Otley & Wharfedale
08DAFF	Burmantfts	08DAFZ	Pudsey North
08DAFG	Chapel Alerton	08DAGA	Pudsey South
08DAFH	City & Holbeck	08DAGB	Richmond Hill
08DAFJ	Cookridge	08DAGC	Rothwell
08DAFK	Garforth	08DAGD	Roundhay
08DAFL	Halton	08DAGE	Seacroft
08DAFM	Harehills	08DAGF	University
08DAFN	Headingley	08DAGG	Weetwood
08DAFP	Horsforth	08DAGH	Wetherby
08DAFQ	Hunslet	08DAGJ	Whinmoor
08DAFR	Kirkstall	08DAGK	Wortley
08DAFS	Middleton		

B.1.4 Road network link-based data

Two types of attribute data files are used to store road network link-based information: geographic attribute ASCII files with co-ordinates of link nodes, and other attribute files (e.g. data on a traffic flows, emissions of pollutants etc.). A number of geographic and corresponding attribute data files may be created for various possible networks and traffic conditions.

Line 4 of an attribute ASCII file has the following form:

Link_Code *VariableName1 VariableName2 ...*

Link codes must allow for the unique identification of a link within a given network, but might coincide with codes used in other networks.

For example, in the case of a geographic (ASCII) data file Line 4 has the form:

Link_Code X1 Y1 X2 Y2

According to this, the *data* lines contain the following information: a link identifier, x and y co-ordinates of the first node, x and y co-ordinate of the second node. Node co-ordinates are given as National Grid rectangular co-ordinates (described in the section on spatial co-ordinates unites)

B.2 Graphical User Interface

The main purpose of the Graphical User Interface (GUI) is to allow for access to the data and models to a non-specialists. Although the development of the full GUI was outside the objectives of Stage 1 of the project, it was decided that the design and development of a prototype of the GUI would be useful to demonstrate some features of such an interface.

Quantifiable City Decision Support System will include a large number of models and data. Therefore, a particular attention should be paid to the development of a user-friendly graphical interface (GUI). In doing so, one has to address the expectations of a contemporary user, who is usually looking for an interactive, graphical, Windows-based system. Such a system should allow for an interactive access to models and for visualisation of model inputs, outputs and monitored sustainability indicators. A prototype GUI for the QCDSS has been developed using Visual Basic, an application development tool described below.

B.2.1 Characteristics of Visual Basic

Until recently the design of a decision support system with a graphical user interface, like a design of any Windows-based application, was a lengthy job requiring extensive knowledge of programming in a relatively low level language like C or C++. One of tools which has radically changed this situation is Microsoft Visual Basic, first released five years ago and

now available in version VB 3.0 (Standard or Professional Edition) to run on Windows version 3.0 or later, and VB 4.0 to run on Windows NT and Windows 95. Visual Basic is a visually oriented "development platform that integrates graphical tools, a debugger, a compiler and the Basic language into a single environment" [Bourgeois 1994].

With Visual Basic the development of in-house applications interacting with databases becomes relatively quick even for a non-specialist. The first step of the design involves no programming at all. Instead of writing a code one just chooses elements of the graphical interface (so called controls) from the Toolbox (which contains icons of all controls such as a command button, a text box, a picture box) and drags them with the mouse onto the desired place on a form (a window). Then one specifies the properties of the controls (for example size, caption, colour, font) in the Properties window. Figure 5 shows how an application might look at the design stage. The controls often used are there: a Command button, a List box, a Check box, Option buttons, a Label, a Graph control, a Spin button, a Picture box (an object next to the Spin button) and a Data control.

Programming comes only at the next stage of the design, when a functionality is added to all the elements. This is so called event-driven programming: for each element of the interface one may write a piece of code which will be executed as the result of an event (e.g. a mouse click, a double-click, a change. Figure 6 gives examples of simple codes for Click events of a Quit command button and an Option button. For visualisation of numerical data, VB 3.0 offers a very useful Graph control, which reduces the amount of programming. The graph type may be specified in the properties window (e.g. 2D or 3D Bar, Line, Pie, Scatter).

Apart from forms (*.frm files) certain parts of codes may go into separate modules (*.bas files). Forms, modules (and Custom controls *.vbx, if added) form a project (.mak file). A Visual Basic project and its functionality are easy to modify at a later stage, because new elements may be added at any time, properties of controls may be changed and new pieces of code added. In particular, Visual Basic is very convenient for developing modular applications, with modules developed by various authors.

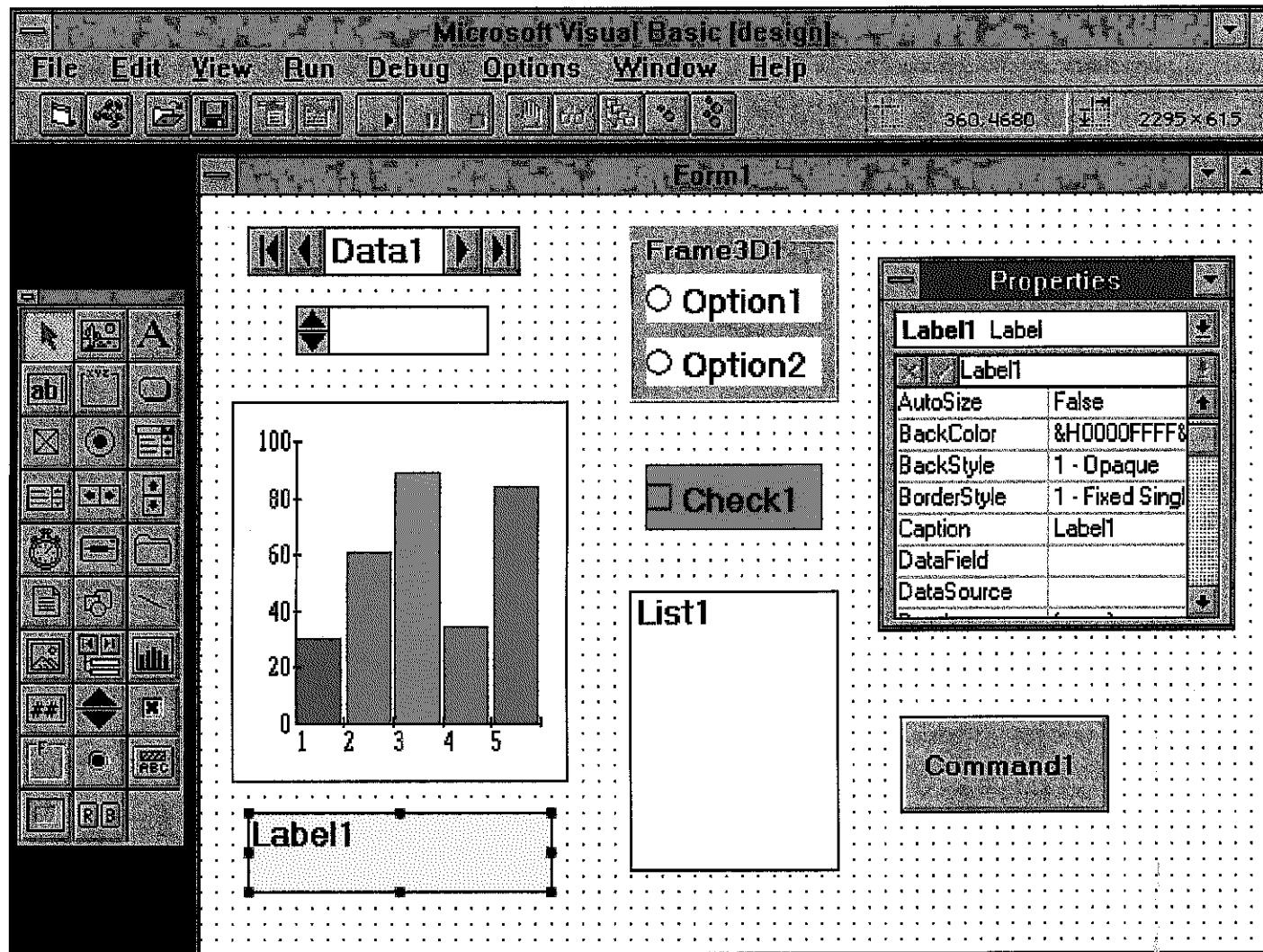


Figure 5. A Visual Basic application at a design stage.

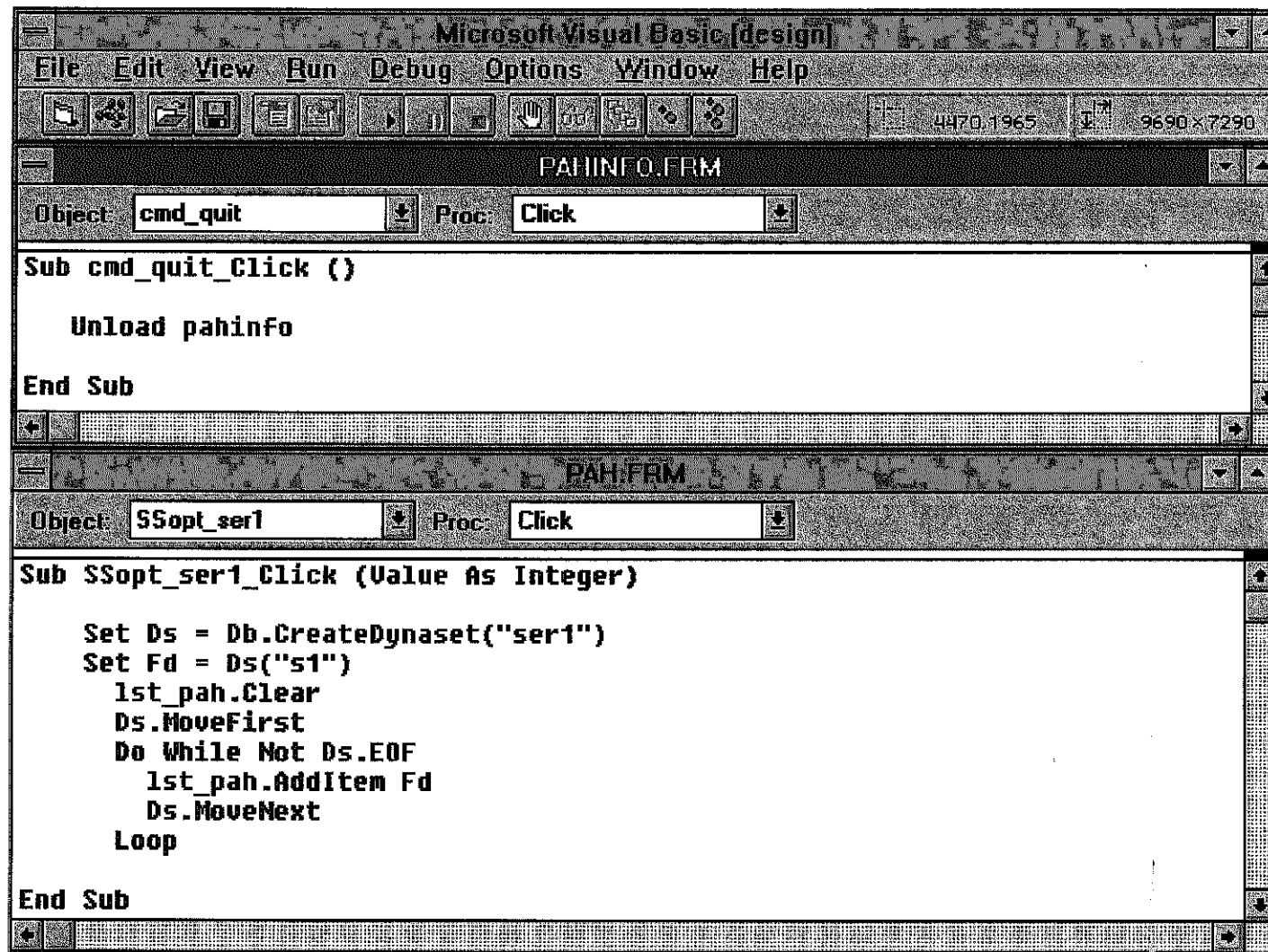


Figure 6. Examples of Basic codes for the event-driven programming.

An important part of many applications is the database. Visual Basic 3.0 has incorporated the same database engine as Access 1.1, which allows interaction with databases stored in common formats (Access, dBase, Paradox, FoxPro). With the use of the Data control one can easily link the required data with the application, by specifying the database name in the Properties window or in the code. If at the same time the database-related properties of a Text box or a picture control are defined, the required data will be automatically displayed on the screen. The Professional edition of Visual Basic 3.0 allows not only for using existing databases but also for creating and managing new databases.

Visual Basic does not have special features which would facilitate displaying maps. There are two possibilities to solve this problem. One is to buy a custom control from a third-party developer (e.g. Map Control available by GeoSoft). Second possibility, probably offering more functionality for manipulating geographic information, is to link Visual Basic with a proprietary GIS software. When developing the Quantifiable City Decision Support System, the Dynamic Data Exchange (DDE) mechanism has been used to link Visual Basic GUI and MapInfo GIS.

There is a range of books on Visual Basic programming, for example [Feldman *et al* 1993] is well suited for a novice. Also, an on-line help is very useful.

B.2.2 Components of the QCDSS GUI

Currently developed components of the Quantifiable City Decision Support System include:

- (i) A set of introductory screens giving access to various parts of the system (Figures 7-11).

Figure 10 shows a range of issues to be addressed by the QCDSS.

- (ii) The screens displaying maps of emissions of NO_x and VOC based on 1km x 1km grid (Figure 12). Data underlying the map has been obtained by Ko, within a project supervised by Clarke [Ko 1995]. The map demonstrates spatial variations of air quality within the city of Leeds. To access these screens, click on the Air pollution icon on the Sector form (Figure 10), then click on the Other data button, and then click on the Emission inventory button.

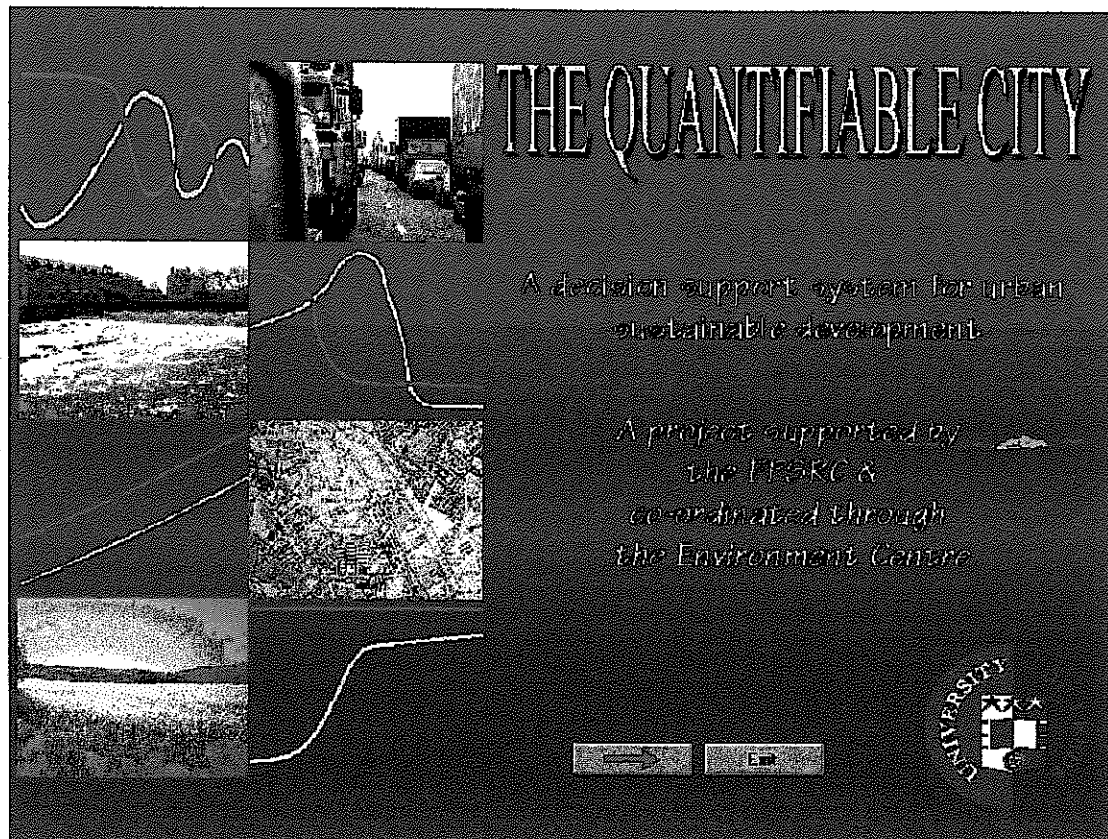


Figure 7. The Opening form of the QCDSS.

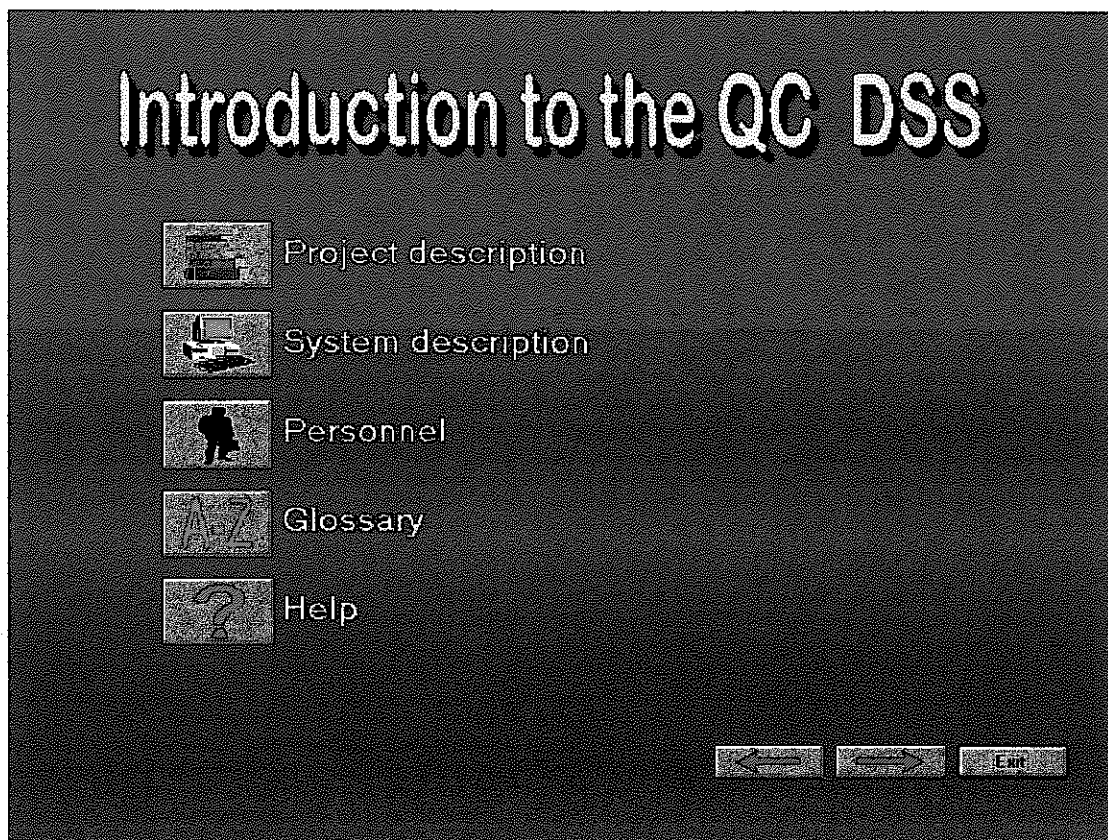


Figure 8. The Intro form of the QCDSS.

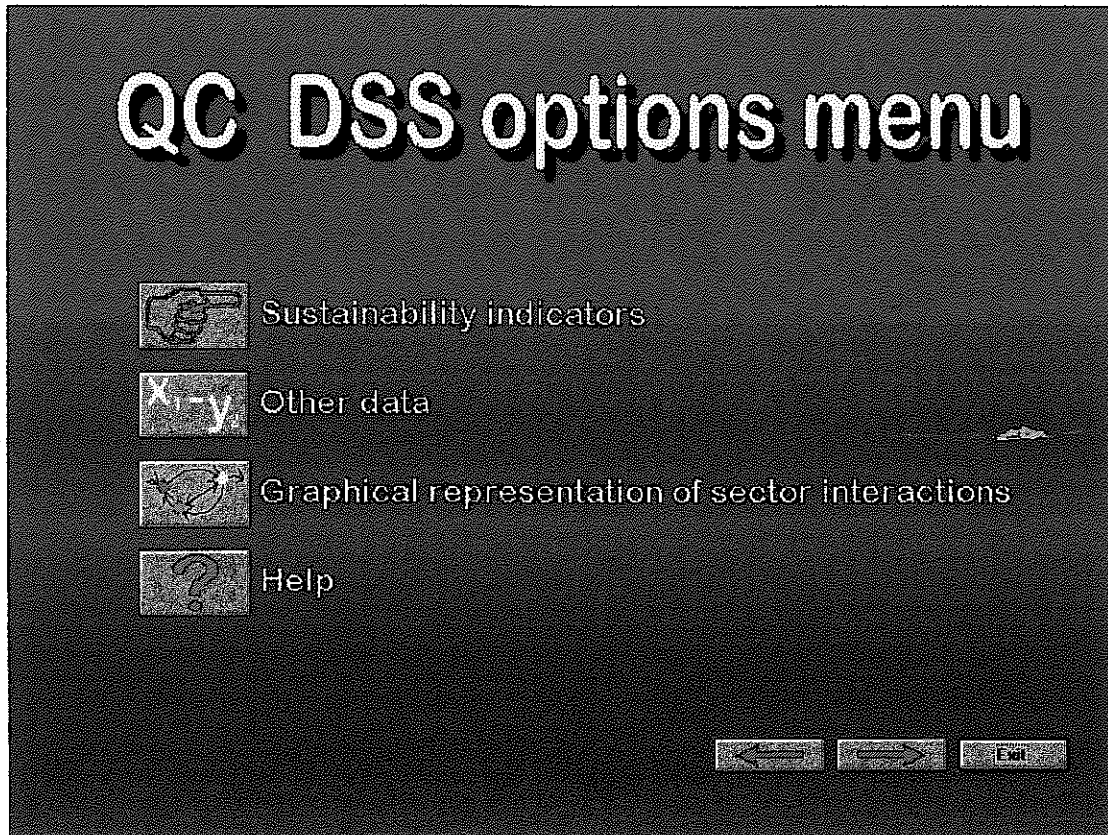


Figure 9. The Opt_menu form.



Figure 10. The Sector form.

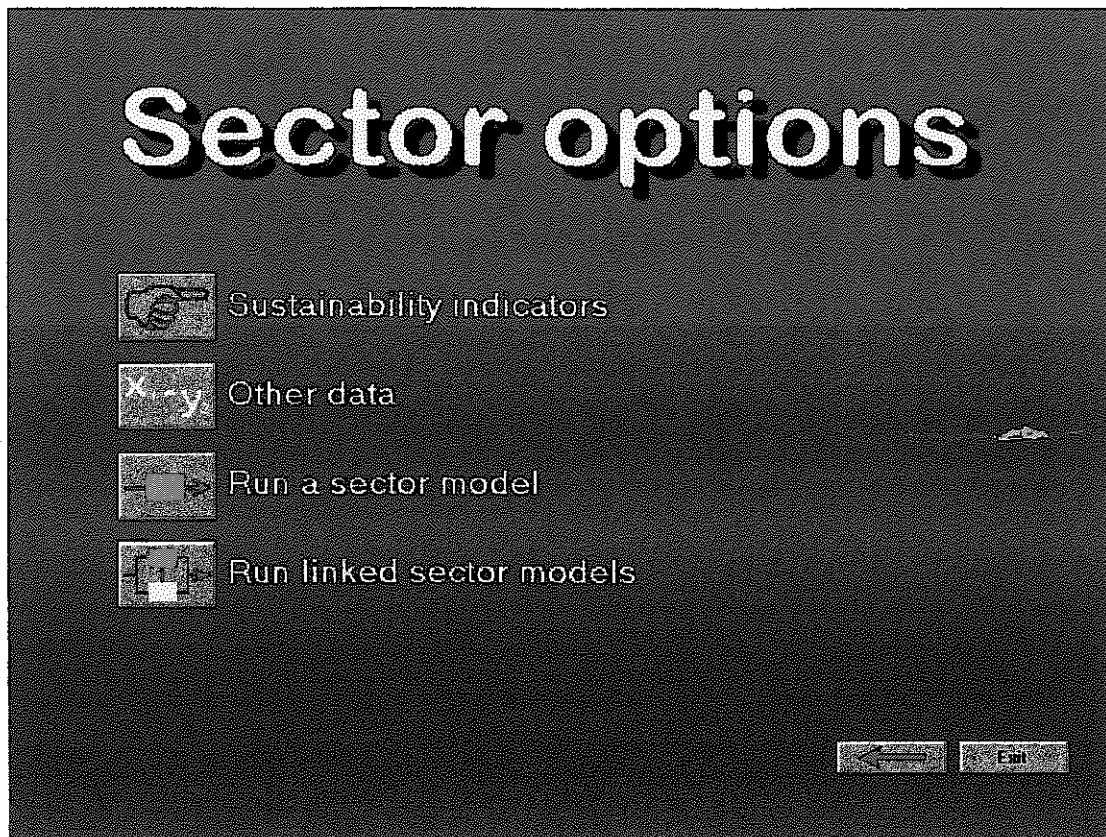


Figure 11 The Sect_opt form.

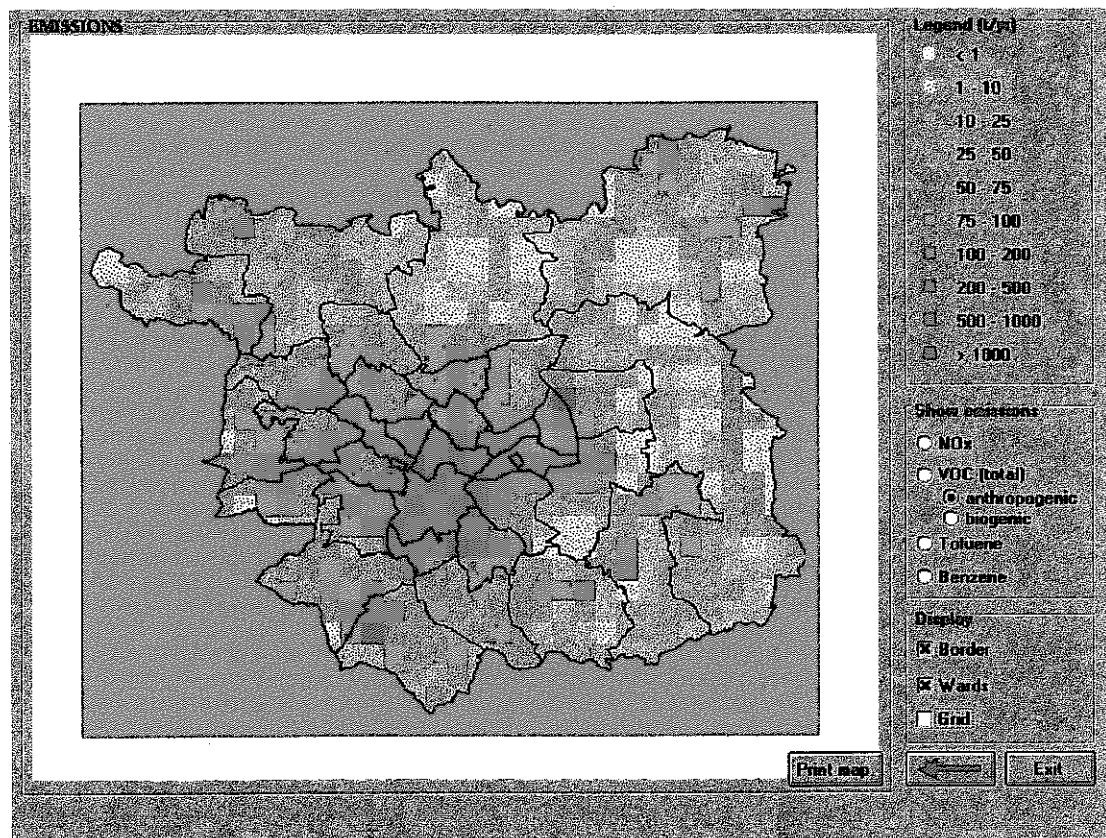


Figure 12. The Vocemmap form.

- (iii) The screens displaying data on water quality in the river Aire (Figures 13-16); Histograms for eight years (1985-1992) presented on Figure 16 show a reduction in the number of river reaches of class 4, the most polluted, demonstrating a trend towards sustainability. To access these screens, click on the Water icon on the Sector form (Figure 10), then click on the Other data button.
- (iv) Screens displaying data from the Census 1991 (Figure 17-19) and asthma data (admissions to hospital) (Figures 20). These screens have been developed to demonstrate how to link Visual Basic and the MapInfo GIS using MapBasic and the DDE (Dynamic Data Exchange) mechanism, and to show how to customize the MapInfo menus using MapBasic. To access these screens, click on the Other data button on the Opt_menu form (Figure 9).
- (v) A link to the Catalogue of Urban Hydrocarbons (Figures 21-26), a visualisation system displaying concentrations of a number of volatile organic compounds (VOC) and polycyclic aromatic hydrocarbons (PAH) as obtained in monitoring campaigns conducted in Leeds in 1993-1994 under the supervision of Pilling [Hassoun *et al* 1994, Lewis *et al* 1995]. Concentrations of VOC are given in $\mu\text{g}/\text{m}^3$, PAH in ng/m^3 . Data are kept in the Access database files: pah.mdb and voc.mdb. The Catalogue of Urban Hydrocarbons (CUH) has been developed using Visual Basic, within a project funded by the Department of the Environment [Kupiszewska 1994]. The link between the QCDSS and CUH demonstrates the advantages of modular structure of the system and the philosophy of a step by step system development. To access CUH, click on the Air pollution icon on the Sector form (Figure 10), then click on the Other data button, and then click on the Measured concentrations button.

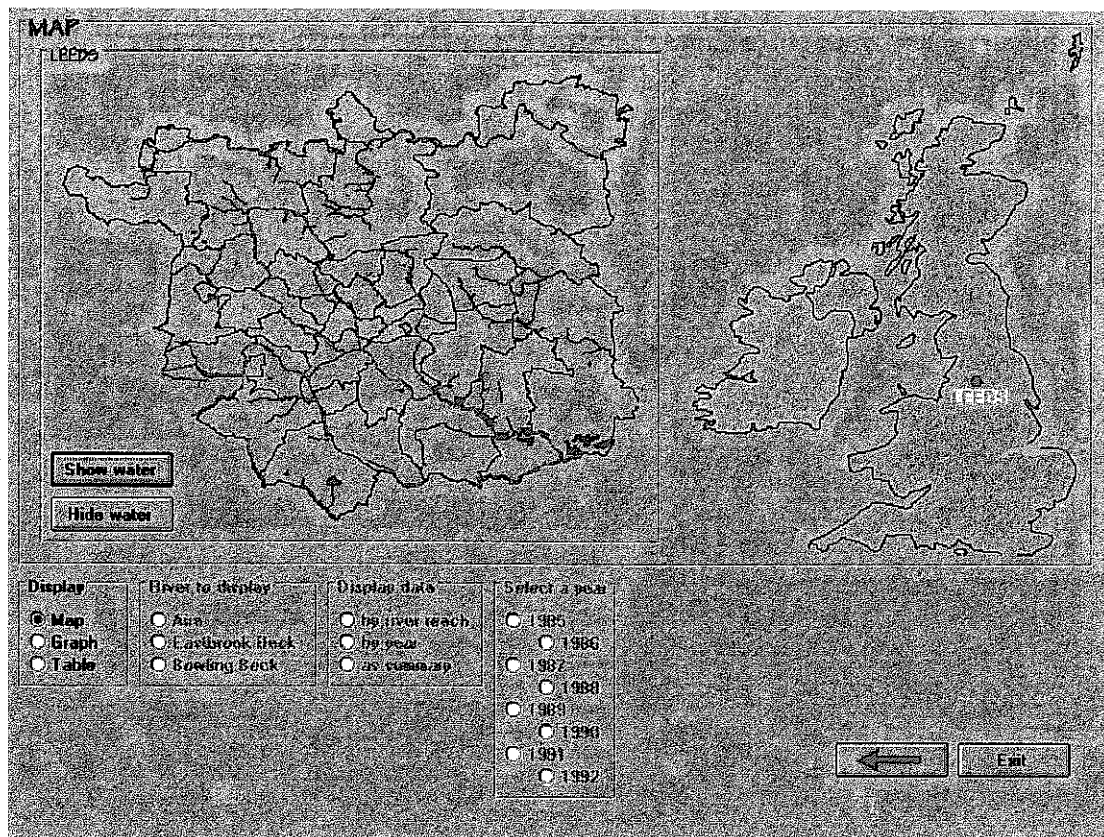


Figure 13. The Water form of the QCDSS.

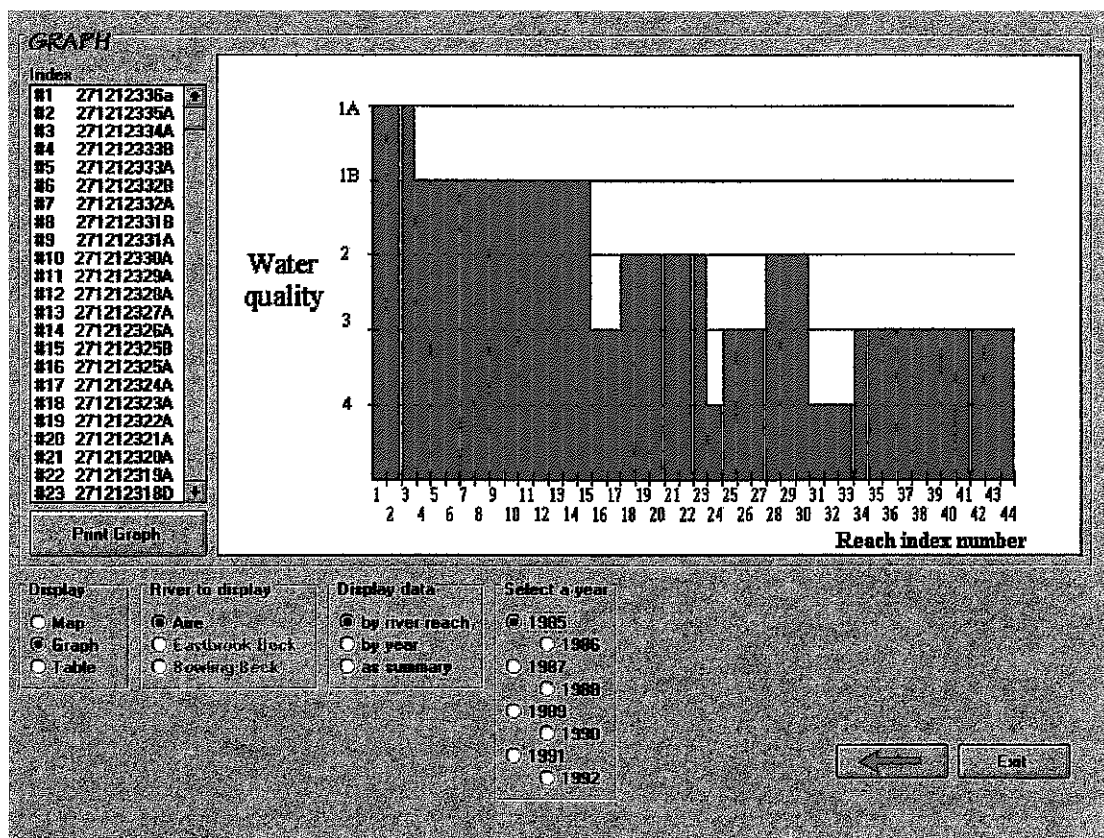


Figure 14. The Water form showing changes of water quality along the river.

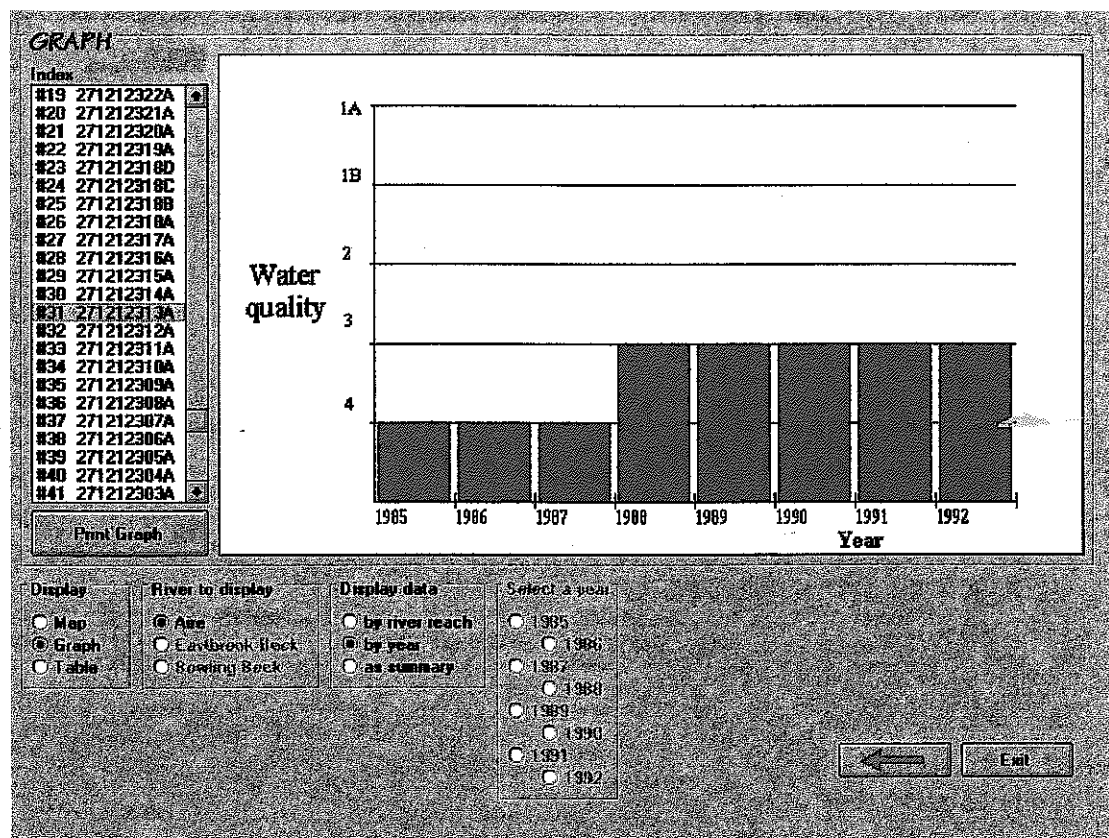


Figure 15. The Water form showing changes of water quality in the selected reach.

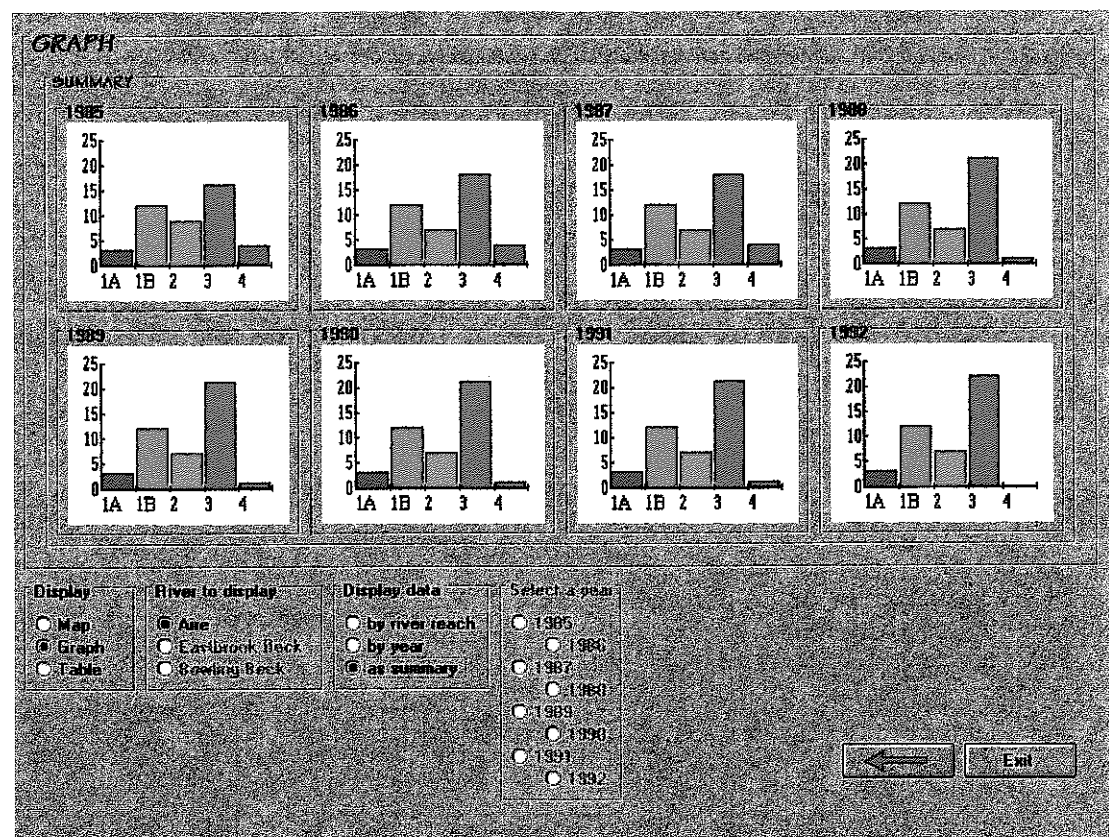


Figure 16. The Water form showing the number of river reaches in each quality class.

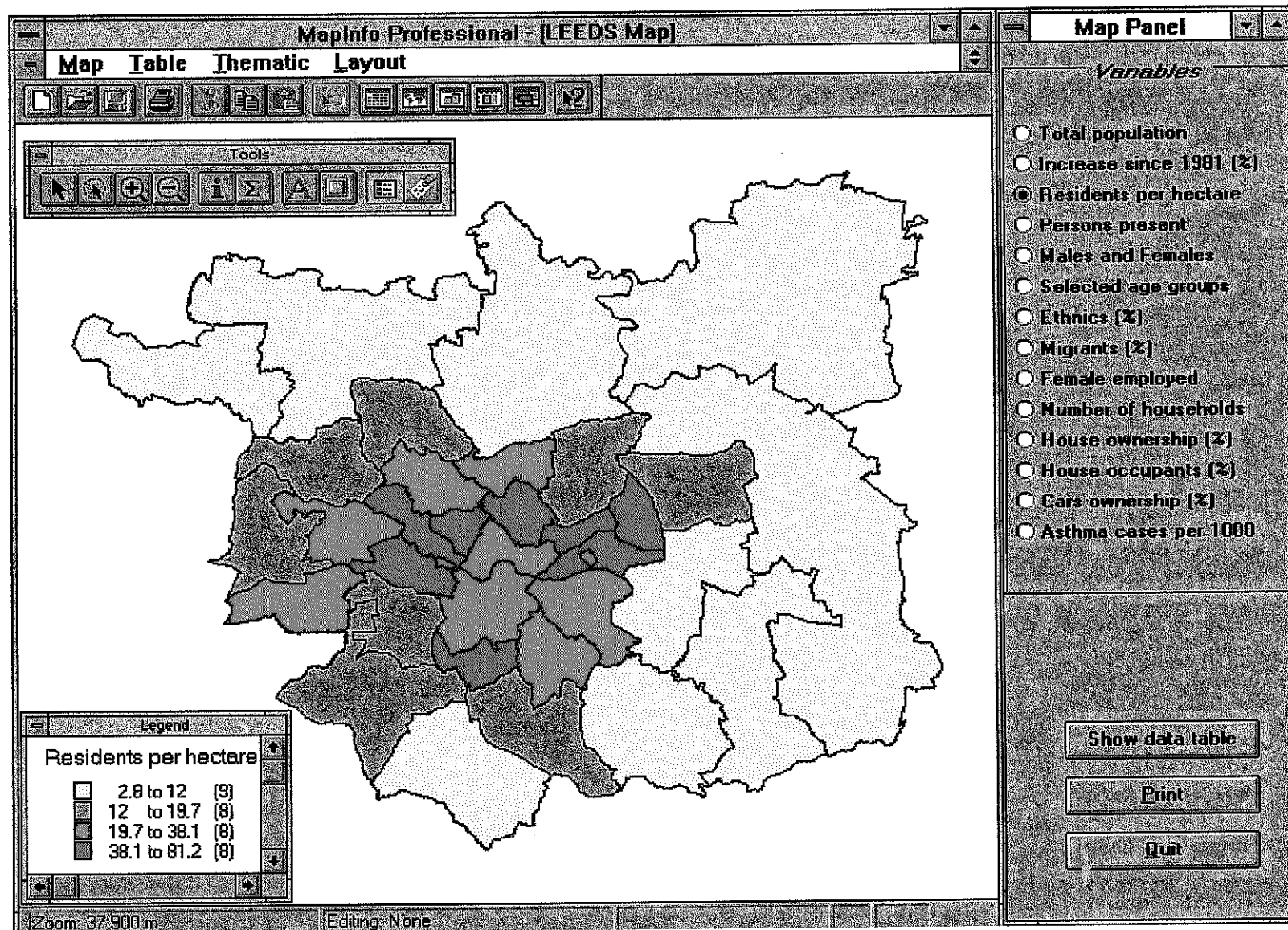


Figure 17. The census1 form and the MapInfo map showing number of residents per hectar, by ward, in Leeds.

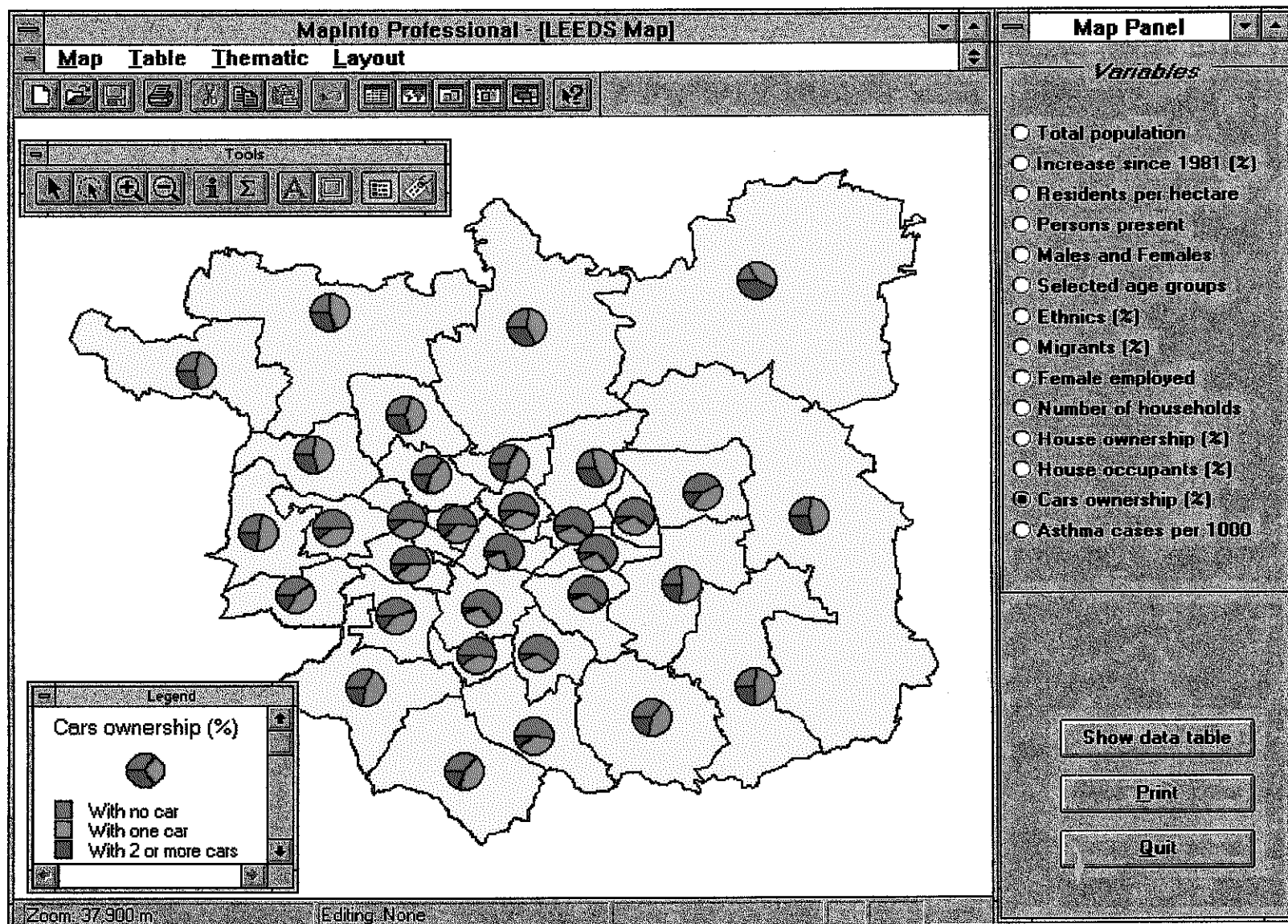


Figure 18. The census1 form and the MapInfo map showing car ownership by ward in Leeds.

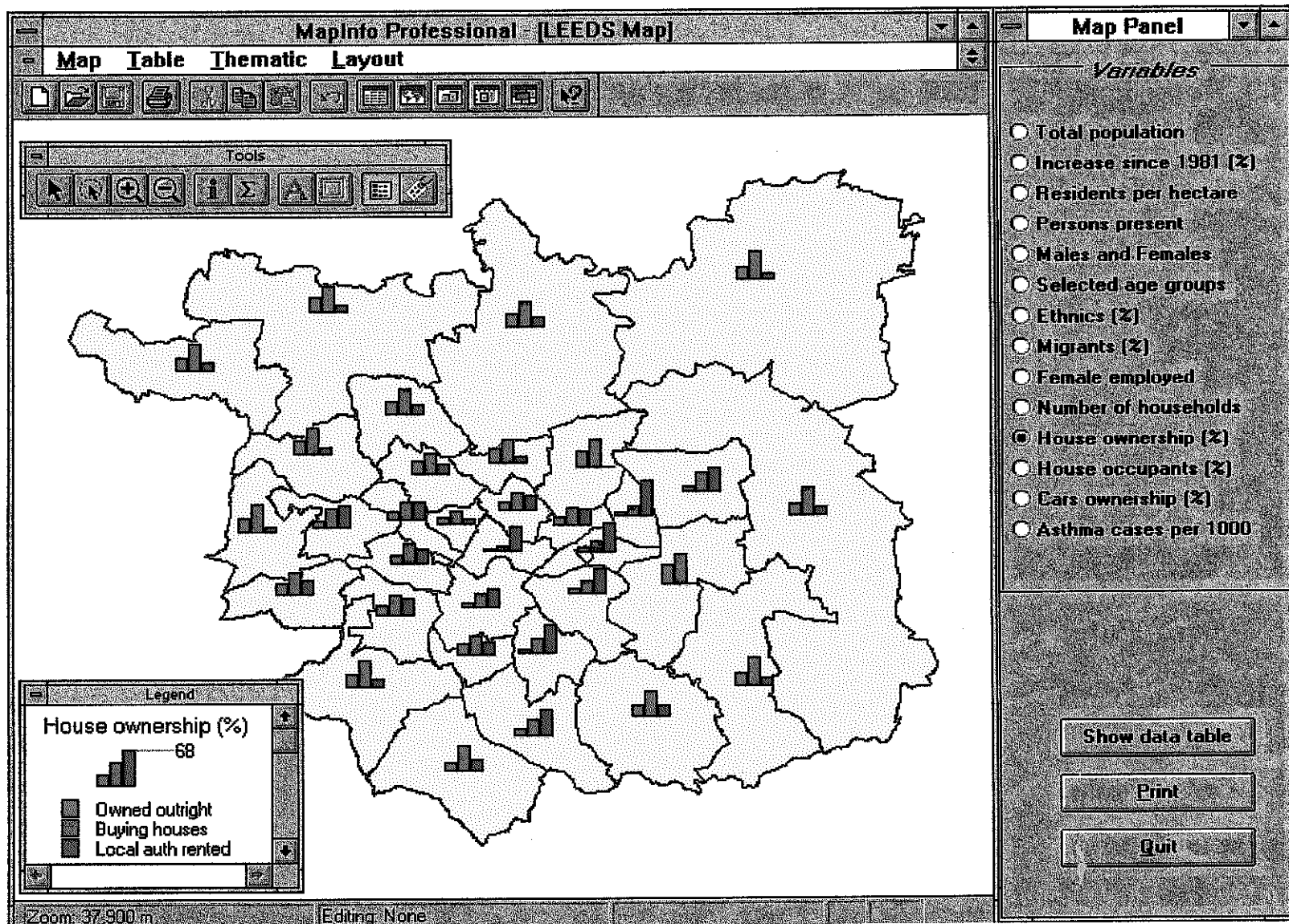


Figure 19. The census1 form and the MapInfo map showing house ownership by ward in Leeds.

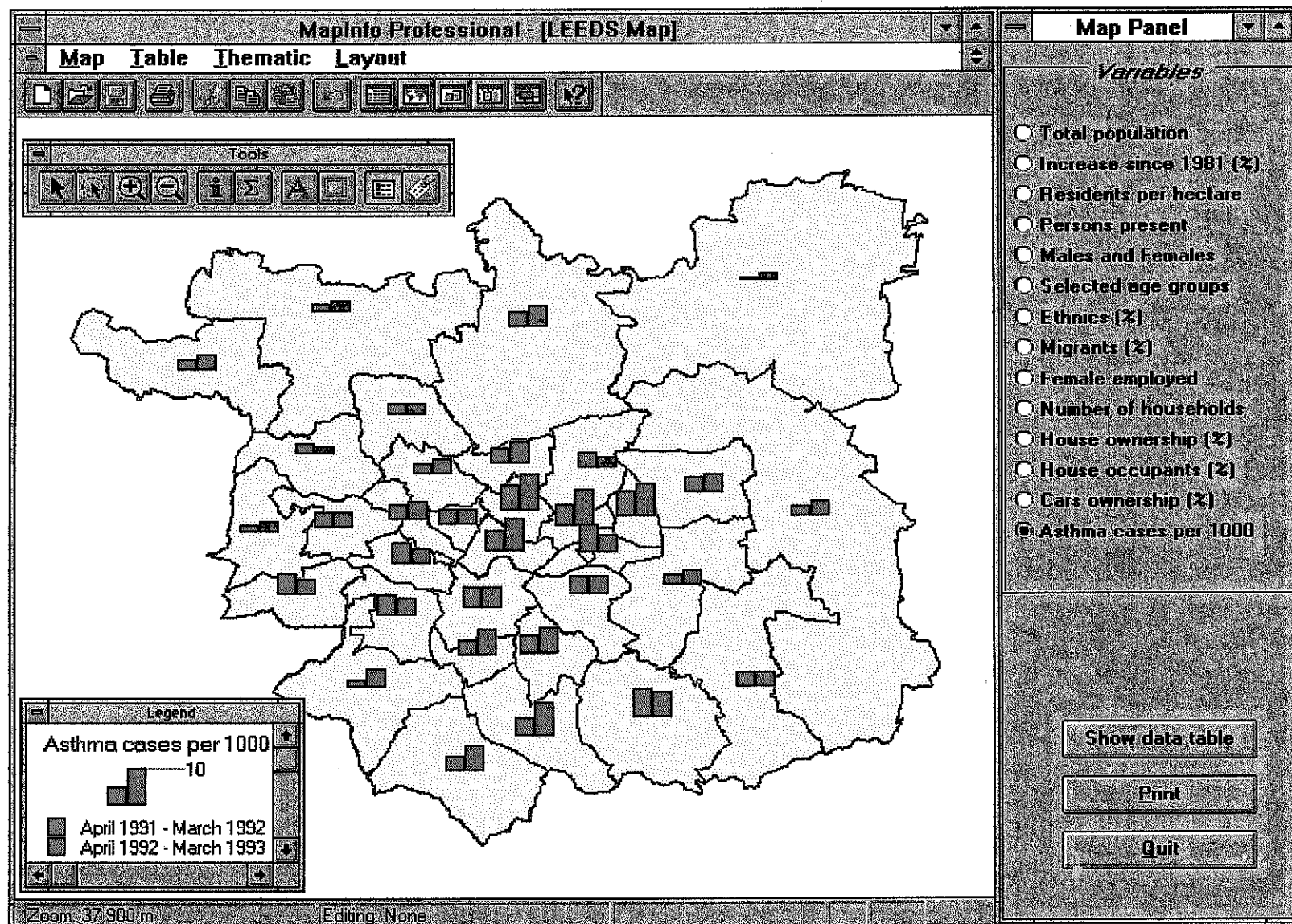


Figure 20. The census1 form and the MapInfo map showing asthma admissions to hospitals by ward in Leeds.

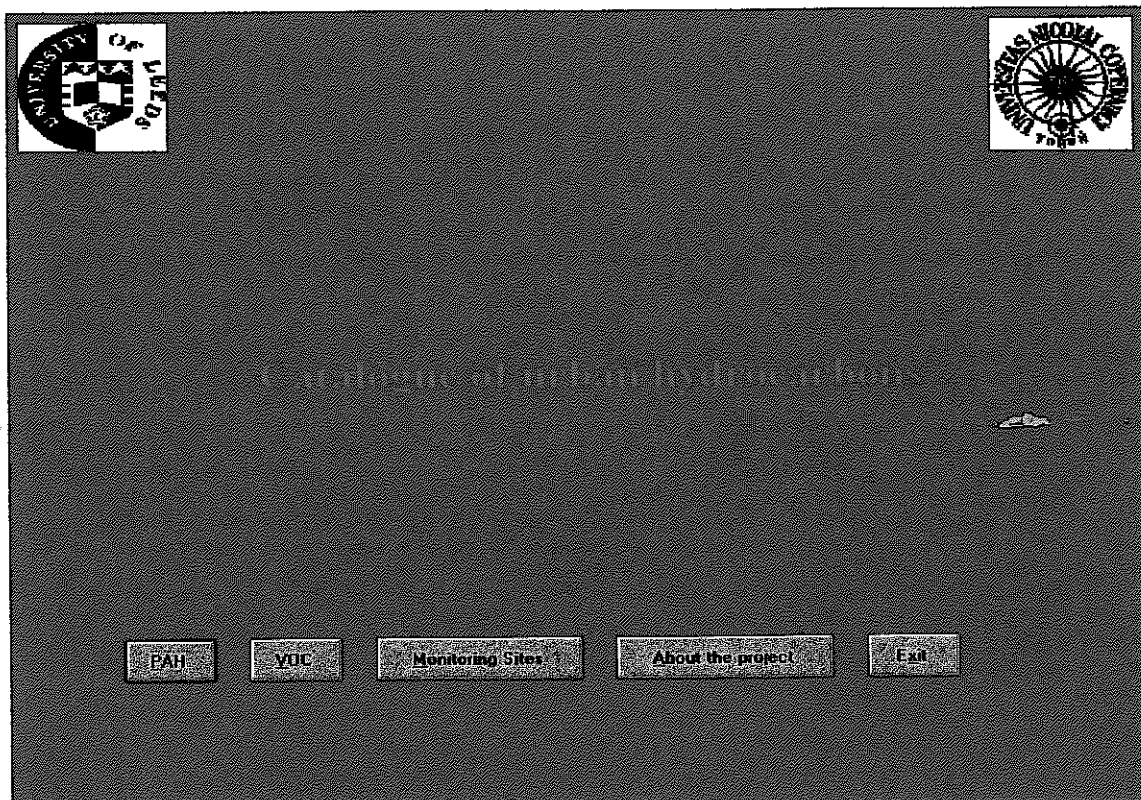


Figure 21. The Start form of the Catalogue of Urban Hydrocarbons.

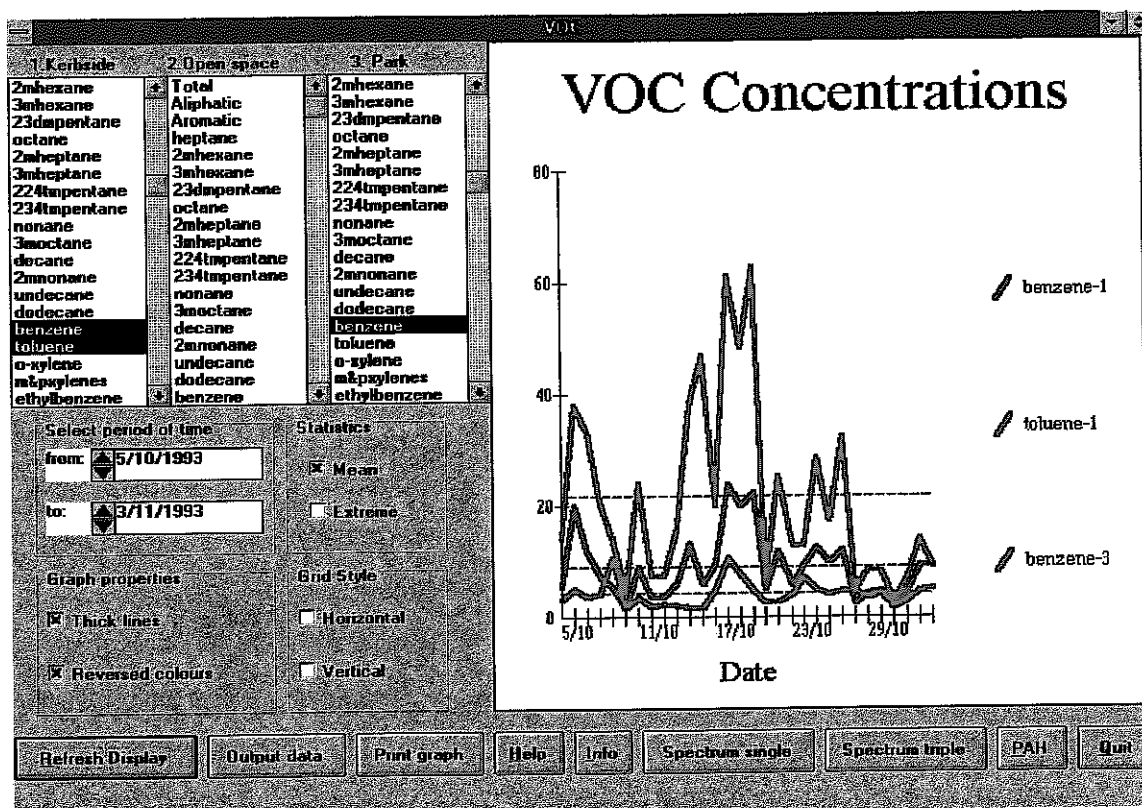


Figure 22. The voc form displaying concentrations of VOC selected by a user as a function of time.

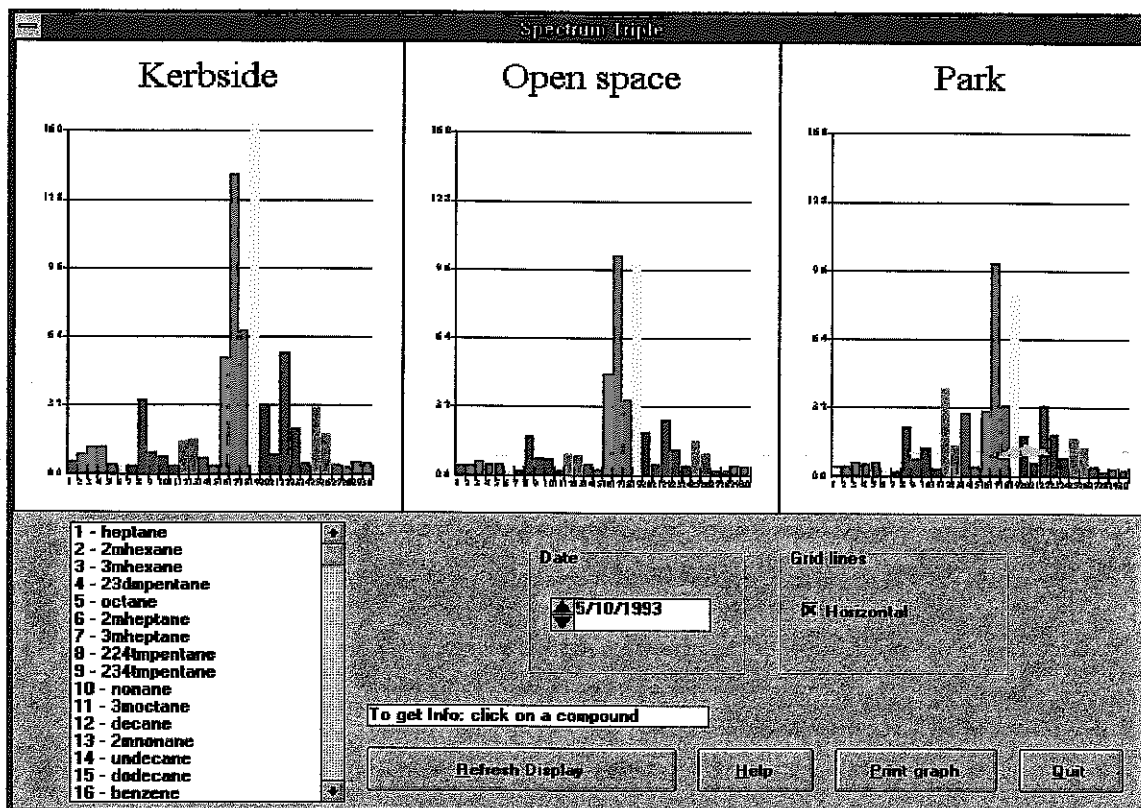


Figure 23. The vocspttp form showing concentrations of measured compounds in three monitoring sites on the selected day.

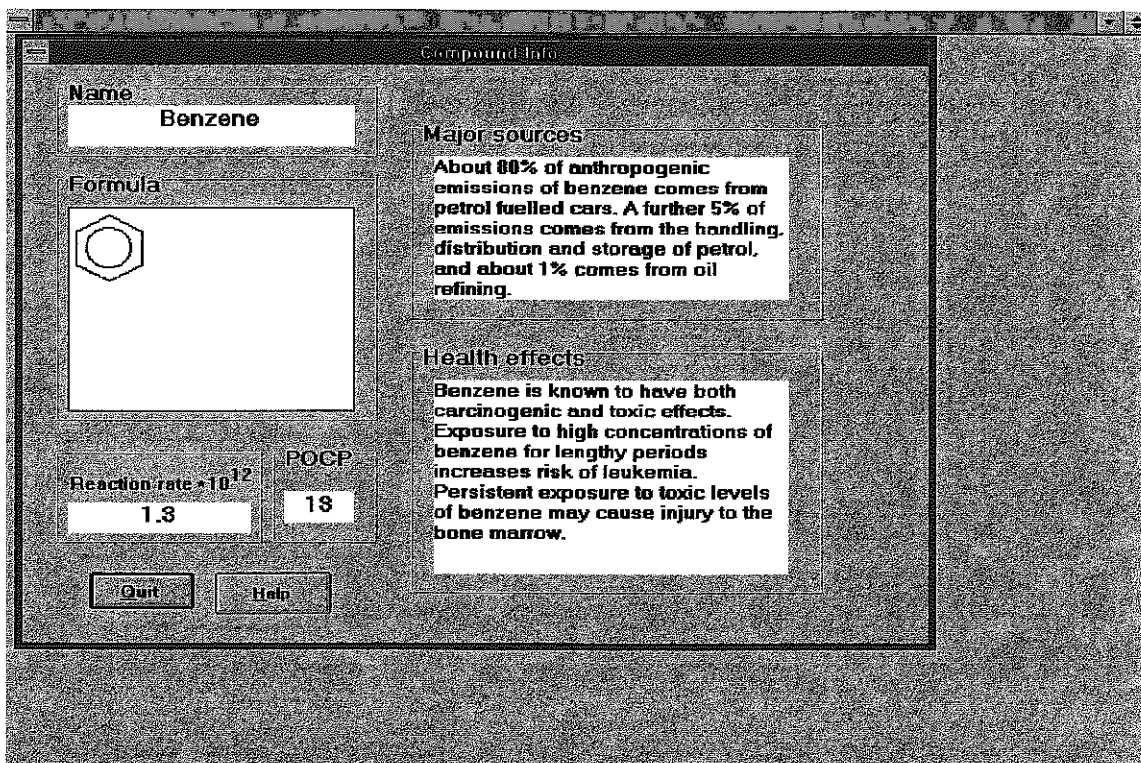


Figure 24. The vocinfo form presenting basic information about the selected compound.

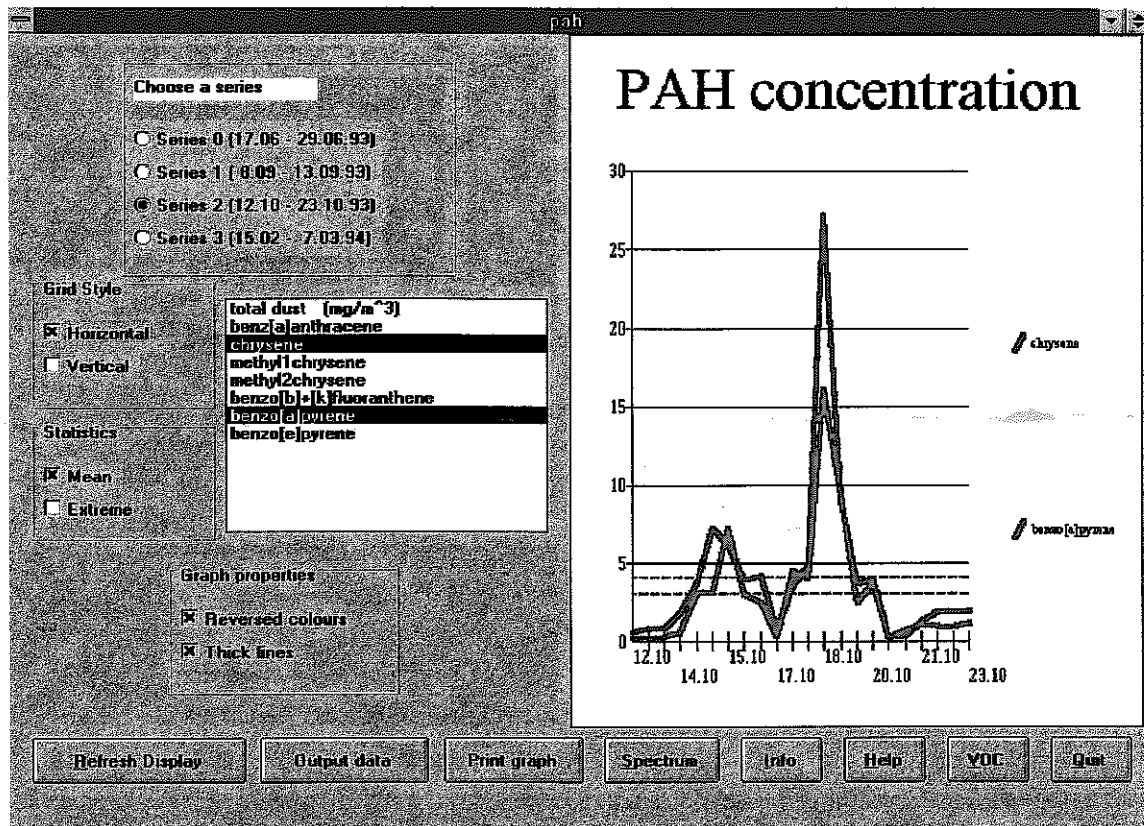


Figure 25. The pah form displaying concentrations of PAH as a function of time.

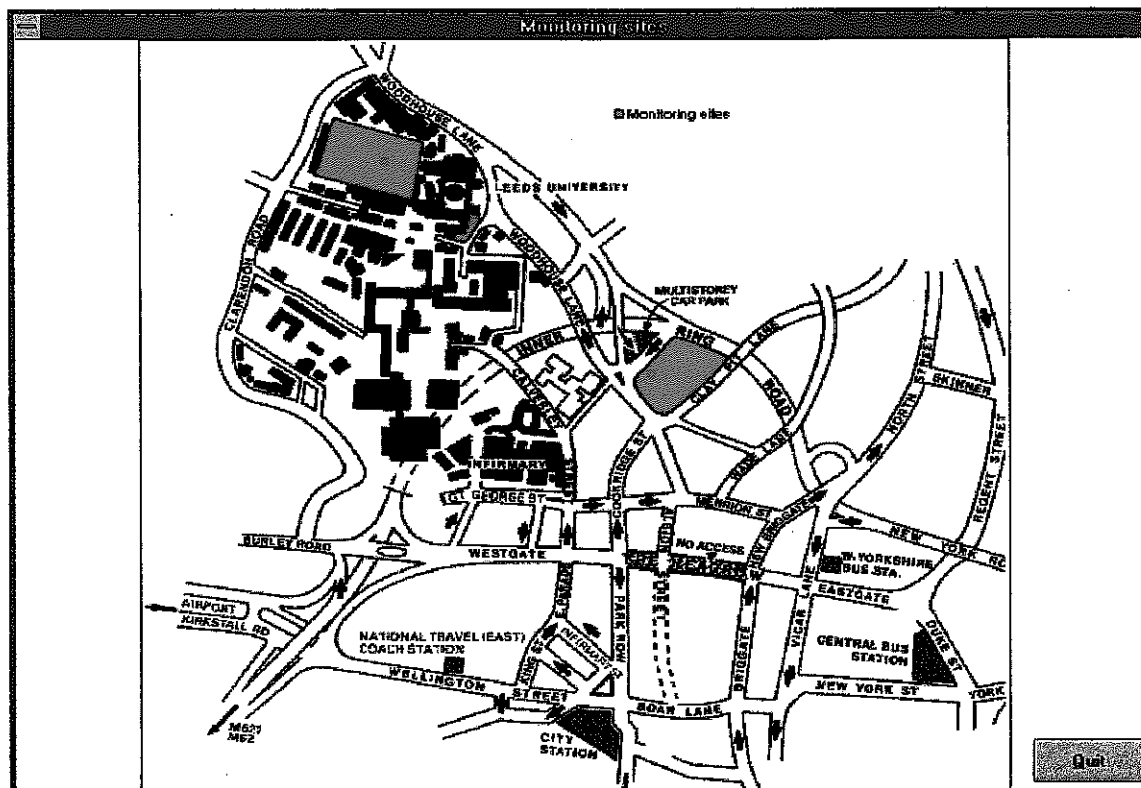


Figure 26. The Sites form displaying the map of the Leeds city centre with the location of monitoring sites.

B.2.3 Technical details of the QCDSS GUI.

The GUI for the Quantifiable City Decision Support System has been developed as the Visual Basic application qcdss.mak, that was compiled to qcdss.exe. All files needed to develop further the QCDSS are in the catalogue c:\q_city\dss. The main component files of the qcdss.mak are listed below:

- (i) Introductory forms (catalogue c:\q_city\dss\):
 - opening.frm (Figure 7)
 - intro.frm (Figure 8)
 - opt_menu.frm (Figure 9)
 - sector.frm (Figure 10)
 - sect_opt.frm (Figure 11)
 - air .frm
- (ii) Emissions of NO_x and VOC (catalogue c:\q_city\dss\):
 - vocemmap.frm (Figure 12)
- (iii) Water quality
 - water.frm (Figures 13-16)
- (iv) Census and asthma data ((catalogue c:\q_city\dss\census):
 - census1.frm (Figures 17-20)
- (v) Catalogue of Urban Hydrocarbons (catalogue c:\q_city\dss\vocpah):

start.frm (Figure 21)	vocinfo.frm
exitform.frm	vocinfo.frm (Figure 24)
about.frm	pah.frm (Figure 25)
map.frm	pahsp.frm
sites.frm (Figure 26)	pahinfo.frm
voc.frm (Figure 22)	pahinfo.frm
vospsng.frm	global.bas
vocsptp.frm (Figure 23)	printing.bas

Additionally, the catalogue c:\q_city\dss contains files voc.mdb and pah.mdb, that are Access database files with data on VOC and PAH concentrations; and some auxiliary files (print.frm, datpanel.frm backform.frm). The form vocemmap.frm uses data files kept the

catalogue c:\q_city\dss\data: rivers.txt (data on water quality), leedsbor.txt (Leeds boundaries) and emissio.txt (emissions of VOC and PAH by grid square).

Displaying spatial information using MapInfo, implemented in the census1.frm, requires files lee.wor (MapInfo workspace) and lee1.mbx (compiled MapBasic program lee.mb). All files related to the census1.frm form are kept in the catalogue c:\q_city\dss\census. The Visual Basic code has been written to communicate with MapInfo version 4.0. In order to work with MapInfo 3.0 the line AppActivate "MapInfo Professional - [Leeds Map]" in the Activ subroutine in the Census1 form should be substituted with the line AppActivate "MapInfo - [Leeds Map]". Similarly, the line AppActivate "MapInfo Professional - [Leeds Browser]" in the subroutine Activ1 should be substituted with the text AppActivate "MapInfo - [Leeds Browser]".

All changes in the location of the files used by QCDSS must be reflected by the appropriate changes in the Visual Basic and MapBasic codes.

B.3 Sectoral models and the GIS

Our philosophy of a cost-effective strategy for the development of an integrated model of city sustainability is that this should be a gradual process exploiting as much as possible existing models. Theoretical formulations of models and operational models that might be used include: demographic models, economic models, land use and transport models, air pollution models, water supply, demand and quality models, etc. These models will have to be modified and linked with each other to address the new objective of sustainability modelling.

The usefulness of the integrated model depends to a large extent on the quality of its component modules and a particular attention must be paid to the selection of suitable sectoral models. Possible sources include: (i) models recommended by national government agencies, e.g. the US EPA (which are likely to be well-tested); (ii) models from commercial consultancies (scientifically more up-to-date, but expensive), and (iii) models from the academic community (possibly easier to acquire, but may require more testing). Most

models are available in a compiled form, which makes any modifications impossible. Therefore, it is important that selected models have a large number of controllable variables, so that a wide range of policies and scenarios can be tested.

A number of existing sector models, developed in Europe and in the United States, are listed in [Kupiszewska 1996b]. Models known as "large scale urban models" [Wegener 1994] has focused on land use, economic development, and transport demand and supply issues, and would need extensions addressing environmental processes and quality of life issues in order to be used for sustainability modelling.

When developing a model for a particular city one might check which models have already been developed and have been in use either by local authorities or in the academic environment, and only the missing elements would have to be developed from scratch. The order in which new elements are added to a system is not universal. Current areas of a particular concern should be addressed first, and the modelling process may help to identify major processes contributing to unsustainability.

An important part of a sustainability modelling system is a Geographic Information System. A GIS database is a place where all spatial data needed by various models are kept in a common format (see Section B.1.) Mapping capabilities of a GIS are particularly useful to present model outputs to decision-makers. At a modelling stage, a GIS is used for geographical analysis operations such as overlaying and buffering. There are two basic types of commercially available GIS systems: vector and raster (see Kupiszewska 1996b). For sustainability modelling a combination of both would be useful, with a vector GIS more appropriate for modelling socio-economic processes and a raster GIS for environmental processes. However, to map an output from environmental models, a vector GIS may be used as well, by covering the modelled area with a grid of square objects.

There are a number of advantages of the modular structure of a sustainability modelling system such as QCDSS:

- (i) The system may be developed step-by-step, beginning with a model of a small sub-system and then extending to other sectors.

- (ii) One can build on existing, well-established sectoral models that provide reliable results and that city planners are possibly already familiar with;
- (iii) Development work might concentrate on missing components;
- (iv) For each component, modelling process would cover each time only those interactions for which quantitative parametrisation might be established with confidence
- (v) A proprietary GIS system, possibly already in place and with a partially developed database may be used;
- (vi) As new and improved models become available, they can replace obsolete sub-models without the need to change the whole structure.

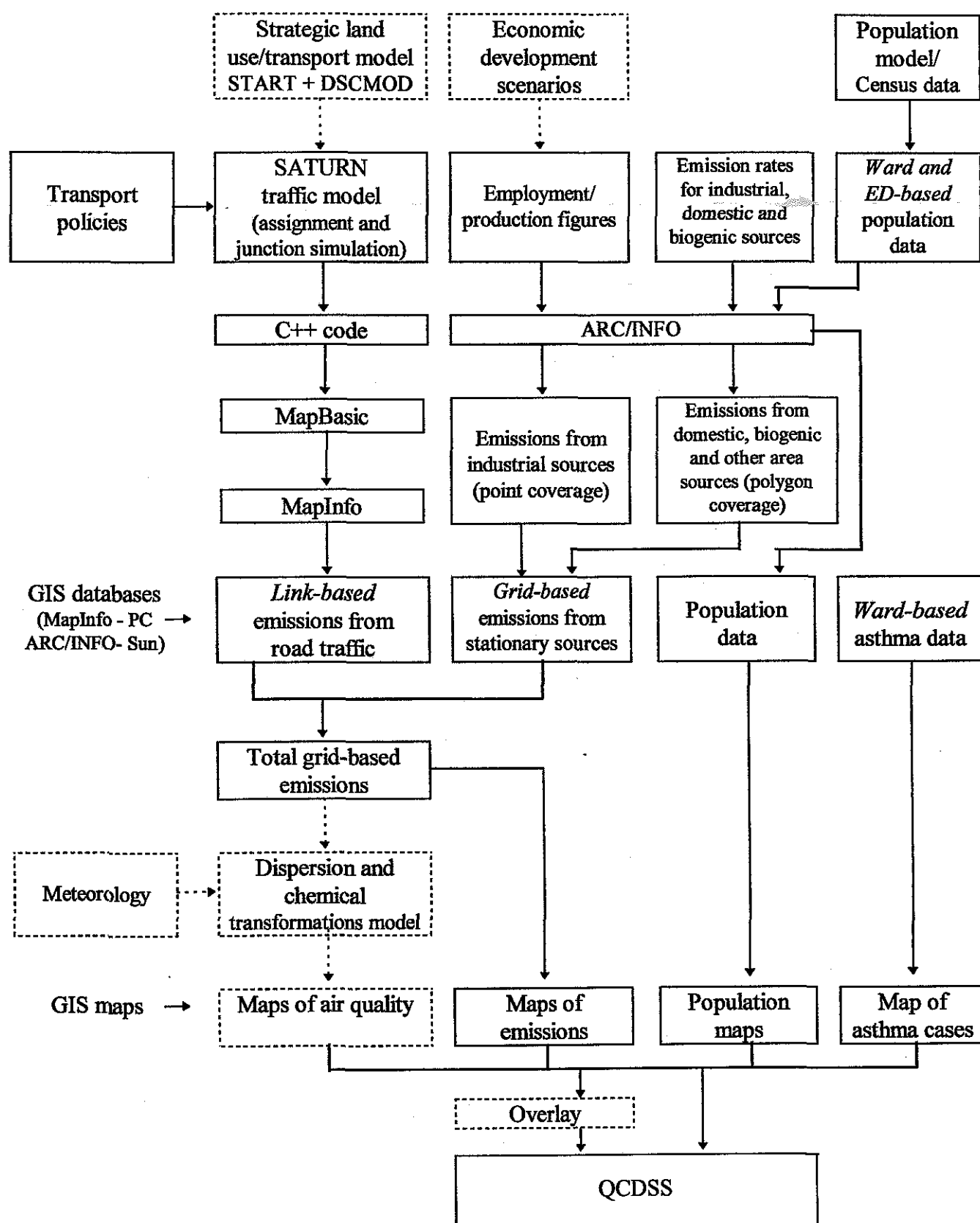
When implementing the QCDSS for Leeds, the SATURN traffic model has been the starting point. MapInfo has been chosen as a GIS to be used on the PC platform, while ARC/INFO has been used on the UNIX workstation. The menu-driven MapInfo system is much more user friendly than command-driven ARC/INFO, that requires a specialist training, however the latter is in use by a number of local authorities and has much wider analytical capabilities. MapInfo has been linked with other models and the Database using MapBasic programming language.

C. Description of the exemplar model

The development of the Graphical User Interface described in Section B.2 has addressed mainly the question of visualisation and graphical analysis of data and sustainability trends. The exemplar model presented in this section has been designed to address computer modelling issues related to forecasting and policy testing, and to test the concept of the modular structure of the QCDSS described in Section B.

The exemplar model (Figure 27) concerns modelling of links between human activities, emissions from mobile and stationary sources, air quality, and impacts of air pollution on human health. It aims initially to model emissions from traffic, domestic emissions and emissions from industrial sources, and to provide a tool for testing an influence of transport policies on emission levels and their spatial distribution. At a later stage an air pollution model will be added, to model dispersion and chemical transformations of pollutants, and

Figure 27. Modelling links between traffic and stationary sources, air quality and population exposure to pollutants.



resulting pollutant concentrations. The latter component is indispensable to model concentrations of reactive and secondary pollutants, in particular ozone.

The core part of the exemplar model, called MUPPETS (Modelling and mapping Urban Pollutants Emissions from Transport and Stationary Sources) is described in detail in a separate document [Kupiszewska 1996b]. MUPPETS is composed of two main sub-models: MUPPET and MESS (Modelling Emissions from Stationary Sources), which address respectively emissions from mobile and stationary sources. Traffic flows needed to evaluate emissions from mobile sources are calculated for peak and inter-peak hours using the SATURN model, a combined simulation and assignment model that calculates traffic flows at equilibrium conditions [Van Vliet 1982]. The SATURN model has been developed at the Institute for Transport Studies of the University of Leeds and is commercially available from W.S. Atkins Consultants.

Calculation of emissions from stationary sources in MESS is based on the methodology described in [Ko 1995] and has three components: (i) emissions from industrial sources, based on employment figures for individual firms or industry sectors, and emission rates per employee by sector or Standard Industrial Classification; (ii) emissions from domestic sources, based on population data from Census (by enumeration district) and emission rates per capita, obtained from national emission inventories; and (iii) emission from biogenic sources (farming and natural sources), based on land use data and emission rates per hectare.

The model of emissions from mobile sources and the model of emissions from stationary sources are linked with GIS systems (MapInfo and ARC/INFO), which are used (i) for mapping purposes; (ii) for recalculation between link-based, grid-based and zone-based data formats; (ii) to overlay the traffic and environment data with the data from Census (or population model) in order to evaluate population exposure and social equity.

Several extensions of the core system are possible. In order to test the impact of land-use policies, the START model [Bates *et al* 1991] could be implemented, and the DSCMOD+ model (from David Simmonds Consultancy) could be used to model feedback from

environment to land-use. Temporal variations of traffic might be evaluated using the DRACULA dynamic micro-simulation model [Liu 1995]. A promising candidate for the air dispersion model is the recently released ADMS-Urban model from Cambridge Environmental Research Consultants (CERC).

Modelling links between air pollution and health is particularly difficult and we are not aware of any operational model that could be used here. Initial investigation might include overlay of air quality maps with a map of asthma cases (relevant data on admissions to hospitals by ward are available), however a possible correlation between high pollutant concentration levels and a number of asthma attacks would not necessarily imply any causal link between the two, due to the large number other intervening factors.

Acknowledgements

The work described in this paper has been conducted within the Quantifiable City project of the Sustainable Cities program funded by the Engineering and Physical Sciences research Council.

We acknowledge the participation of Tempus students from Torun, Poland (Mariusz Nasiadko and Marek Jagodzinski) in the development of part (i) and (iv) of the QCDSS Graphical User Interface.

D. Bibliography

1. Bates, J., Brewer, M., Hanson, P., McDonald, D., Simmonds, D. (1991) Building a strategic model for Edinburgh, *PTRC 19th Summer Annual Meeting*, Proceedings of Seminar G.
2. Bourgeois, D.T. (1994) Visual Basic 3.0, *Computer*, 27, pp. 94-97.
3. Dale, A., Marsh, C. (1993) *The 1991 Census User's Guide*, HMSO, London.
4. Feldman, P., Jennings, R., Seymour, B., Eidson, B., Palmer, P., Gillmor, S., Pessoa, J. (1993) *Using Visual BasicTM 3*, Que.

5. Harley, J.B. (1975) *Ordnance Survey maps: a descriptive manual*. HMSO, University Press, Oxford.
6. Hassoun, S., Bartle, K.D., Kupiszewska, D., Pilling, M.J. (1994) Volatile Organic Compounds in the Urban Atmosphere, [in:] P. Sandra, G. Devos (ed.), *Proceedings of the Sixteenth International Symposium on Capillary Chromatography*, Vol. I, Hüthig GmbH, Heidelberg.
7. Ko, Y.-H. (1995) *An assessment of emissions of nitrogen oxides and volatile organic compounds in Leeds*. Ph.D. Thesis, Department of Fuel and Energy, University of Leeds.
8. Kupiszewska, D. (1994) *Visualization of data on air pollution*. School of Chemistry, University of Leeds.
9. Kupiszewska, D. (1996a) *MUPPETS - a computer tool for modelling and mapping emissions from urban transport and stationary sources*. ITS Working Paper 522, Institute for Transport Studies, University of Leeds
10. Kupiszewska, D. (1996b) *Modelling for sustainable cities: Conceptual approach and a review of existing sectoral models for demography, land use, transport and air pollution modelling*. ITS Working Paper 520, Institute for Transport Studies, University of Leeds.
11. Lewis, A.C., Kupiszewska, D., Bartle, K.D., Pilling, M.J. (1995) City Centre Concentrations of Polycyclic Aromatic Hydrocarbons using Supercritical Fluid Extraction, *Atmospheric Environment* 29, p. 1531.
12. Liu, R. (1994) (1994) *DRACULA microscopic traffic simulator*. Working Paper 431, Institute of Transport Studies, University of Leeds, U.K.
13. Van Vliet, D. (1982) SATURN - A modern assignment model. *Traffic Engineering and Control*, Vol. 23, pp. 578-581.
14. Wegener, M. (1994) Operational urban models. State of art. *Journal of the American Planning Association*, Vol. 60, No. 1, pp.17-29.