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Statistics Norway
Department of Coordination and Development

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Use of Geographical Information Systems (GIS) in Statistics Norway

Contents

This paper has been written for the ECE Work Session on Geographical Information Systems (GIS) in Washington, 15-18 April, 1996.

1. Introduction

The needs for better presentation and interpretation of statistics, together with improved and more available tools for geographical analyses and statistical mapping, have put geographical information systems (GIS) on the agenda in most national statistical institutes. The widespread use of such tools has contributed to increased demand for regional and georeferenced statistics. To meet this demand, producers of statistics also have to increase their knowledge and experience in this field.

A national statistical institute is the main institution for establishing and dissemination of official statistics. Statistics Norway (SN) also uses statistics for analyses and research. However, until now GIS-technologies have only been used to a limited extent in SN. Data collection has been based on censuses or surveys with samples drawn from registers, and with the exception of land use statistics, there has been no need for using geographical methodology in data collection. Even if large parts of statistical data are georeferenced (i.e. to municipality), there has been little tradition for analyses of regional and geographical patterns in SN. Most of our research has been on macroeconomic conditions, where time series data without geographical dimensions are used. Hence, GIS technology has not been used in analyses to any significant extent in SN. However, several new GIS activities have just started or are planned, and the use of presentation tools for statistical thematic mapping is increasing in SN.

This paper gives an overview of the use of GIS and thematic mapping in Statistics Norway. The significance of new market and technology trends in this area is discussed. The use of GIS has been particularly relevant in environment statistics, and a case study from this field is presented in some detail.

2. Status

Earlier use of maps and GIS in Statistics Norway has in particular been connected to land use statistics and population and housing censuses, in addition to some use of statistical thematic mapping in general. Cooperation with the Norwegian Mapping Authority has been important when working with maps in SN. In this chapter earlier and present use of maps and GIS in SN are considered, with the exception of use within environment statistics, which is represented by a case study considered in more detail in chapter 4.

Tools used within Statistics Norway today are ArcInfo/ArcView (GIS for PC) and Mapviewer (presentation tool).

2.1. Land use statistics

One particular application of GIS in Statistics Norway was in fact developed before GIS technology was available and GIS was a well known concept. Land use accounts were established as a part of the general development of Norwegian natural resource accounts around 1980. Land use accounts were based on point sampling on maps and air photographs, and provided a survey of land use in the whole country and in particular in urban areas (Sæbø, 1983). For urban areas tables showing changes in land use from 1955 to 1975 were set up. The point sampling was very time consuming, though to a lesser extent than complete mapping would have been. The technique also allowed for some analyses which today are carried out by GIS technology, such as combinations of different geographical data (land use, altitude, geology, production potential for forest etc.) and mapping of land use changes. However, the demand for data and statistics was not large enough to justify the updating of land use accounts. Complete land use accounts are therefore not worked out in Norway today, but for some important land use types (such as agricultural land) reasonable statistics are based on various traditional data sources. SN is responsible for some of these statistics (e.g. agricultural statistics), and has an overall coordinating responsibility.

Because of better possibilities for using register information and increasing interest for land use statistics in later years, SN has just started reconsidering these statistics. In addition to coordination and standardisation, SN will concentrate on land use statistics in urban areas. The idea is to utilise georeferenced and digitised information from a register for ground properties, addresses and buildings (see paragraph 3.2). The possibilities for automatic updating of urban settlement boundaries and main urban area land use classes will be investigated.

2.2. Population and housing censuses

The first Norwegian population census was conducted in 1769. Since 1890 censuses have been held at the beginning of each decade with the exception of 1940. After an identification number for each individual was introduced in 1964 and used in various administrative registers, the role of the census has changed dramatically. For some years it has been the policy of Statistics Norway to collaborate with various governmental agencies in order to use administrative registers in production of statistics. In the 1990 Population and Housing Census, information from registers was combined with data collected from a representative sample of some 28 per cent of the population. Use of administrative registers in Norwegian censuses has been described by Thomsen, 1995.

The use of maps and geographical information technology in connection with censuses has so far been limited to thematic mapping for presentation of results and for drawing boundaries for georeferencing purposes. Censuses have played an important role in georeferencing of statistics, providing a basis for thematic mapping and geographical analyses in general. For georeferencing of census data, SN has established *basic (statistical) units* and *urban settlements.*

Basic units were established during the preparation of the 1980 census, and were to some extent based on former enumeration districts. A thorough revision was carried out in cooperation with local authorities. There are about 13 700 basic units with an average population of 300 in Norway. The total population is 4.4 mill.

An *urban settlement* in Norway is defined as an agglomeration having at least 200 residents, and where the distance between the houses - as a rule - does not exceed 50 metres. There are 870 urban settlements in Norway. It is worth noting that urban settlements are delimited and coded independently from the basic units.

Statistics have been produced and made available for basic units and urban settlements on the basis of the 1980 and 1990 population and housing censuses. Both censuses were in fact carried out through a combination of register information and postal enquires - even partly as a sample in 1990.

The basic units have no function as a tool for handling the enumeration process, but only as a tool for the analysis and dissemination of the results. The boundaries of and a central point in each basic unit and urban settlement have been digitised. This was done by Statistics Norway as part of the preparation of the 1980 census. The aim was to make documentation easier and to be able to produce thematic maps in a simple way. The digital boundary files have also been transmitted to the Norwegian Mapping Authority, where the data have been processed and used on maps, e.g. a map of population distribution 1980, scale 1:250 000.

The Norwegian Mapping Authority has the responsibility for updating boundaries of the basic units. Statistics Norway has just completed a project to update the boundaries of the urban settlements. Updating of both types of boundaries is done in cooperation with the municipalities, and the aim is to establish routines for a regular updating, having the 2000 census in mind.

For the 2000 Population and Housing Census geographical information technology is planned to play an important role for the first time. This census is mainly planned to be based on administrative registers for persons, buildings and enterprises. In principle, data from such registers are or can be georeferenced down to mapping coordinates. These registers are briefly described in paragraph 3.2.

GIS techniques may be used for more or less automatic updating of boundaries for urban settlements defined as above. The project mentioned in paragraph 2.1 on land use statistics will investigate this. Updating of basic units may also be easier with use of GIS. In addition, SN plans to use GIS both for analyses and presentation purposes in the 2000 census.

Georeferencing of people and activities and other digital mapping information provide a basis for different analyses where distance or distance concepts (e.g. travelling time) are key variables. Examples of issues for the users of statistics can be planning and location of schools, nurseries, shops and other service enterprises or institutions. Travel distance between home and work is an example of a variable well suited for geographical analyses.

Use of maps for presentation purposes will probably be the most important use of GIS techniques also in the 2000 census. The assumed use of administrative registers enables georeferencing not only to basic statistical units, but exact georeferencing of persons, households and enterprises to coordinates and in principle to any geographical level such as squares in a one by one kilometre grid. In practice, confidentiality will delimit dissemination possibilities, see paragraph 3.5.

Byfuglien, 1995, and Hartvedt, Ottestad and Sæbø, 1995, have also considered use of GIS in relation to census statistics. Byfuglien, 1994, has discussed the issues in relation to urban units and other units for geographical analysis in a European context.

2.3. Thematic mapping

Tools for thematic mapping are available in Statistics Norway, and even if the potential for statistical thematic mapping is still underdeveloped, the use of maps for presentation and dissemination of statistics has increased over the last years. A cooperation with the Norwegian Mapping Authority has promoted this development (see next paragraph). Maps are widely used in environment statistics, but also in other regional statistics maps are used to disseminate geographical distributions. In most cases these maps show variables by county or municipality, but there are also examples of thematic maps illustrating the value of a variable georeferenced to points (for example the capacity of waste water treatment plants).

Byfuglien, 1993, has given some examples from Norway in relation to a discussion of thematic maps and presentation of statistics.

Figure 2.1 shows an example of a statistical thematic map in one of our publications.

2.4. Cooperation

Statistics Norway and the Norwegian Mapping Authority have had a formal cooperation since 1993 (and an informal cooperation for many years). The cooperation has been based on a number of projects:

- Exchange of experience
- Coordination of standards
- Coordination of land use statistics
- Statistical thematic mapping
- CD-ROM with statistics, maps and GIS.

In addition, cooperation with the Norwegian Mapping Authority will be central in connection with establishing a register of dwellings in connection with the 2000 Population and Housing Census, see paragraph 3.3.

Exchange of experience is done by allowing employees from the two institutions to participate in each others' courses. One common course «Statistics on maps» has been set up, and in 1995 this course was run twice with a total of 25 participants from each institution.

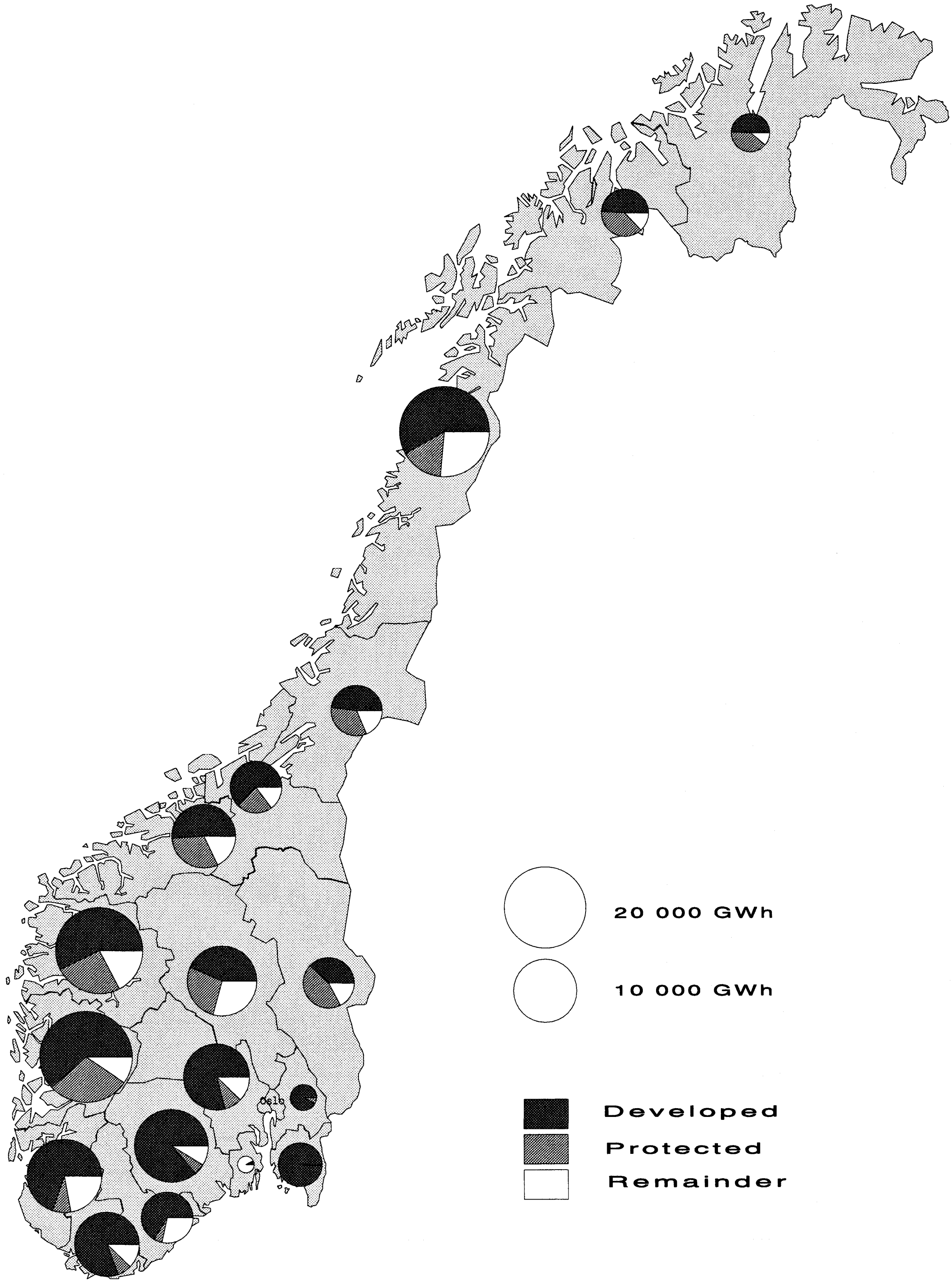
Cooperation on standards comprises standards of georeferencing and exchange formats for data and digital maps.

A coordination committee with representatives from various institutions involved in the production of land use statistics has been set up.

Cooperation on statistical thematic mapping includes contributions from the Norwegian Mapping Authority to the Statistics Norway publication on regional statistics. Four times a year this monthly publication contains a colour map to illustrate the statistics. The Norwegian Mapping Authority will on the other hand inform about their own relevant products in the publication.

A CD-ROM containing statistical data, digitised maps from the Norwegian Mapping Authority and simple GIS software from the Norwegian distributor of ArcView is due to be released in autumn 1996. The software consists of ArcView Data Publisher, which is basically ArcView with reduced functionality, but specially linked and adapted to the data on the CD-ROM. Other GIS and mapping software has also been considered.

Figure 2.1 Norwegian hydropower resources by county. 1 January 1995



Digital map boundaries: Norwegian Mapping Authority

3. Market and technology trends: Possibilities and challenges

3.1. Market trends for statistics and GIS

Data is not information in the meaning of knowledge. Data has to be put together, analysed and interpreted to become information. Statistics are figures characterising a group or a phenomenon, based on compilation and analysing data. Statistics are closer to information than data alone, but normally still need interpretation to provide knowledge. At the same time as users today want more information in the form of interpreted statistics, more detailed data are demanded for own analyses.

Important trends in the market for statistical data and information are:

- Common users want more information and less «noise».
- Expert users want data as input in own research and planning tools.
- Users and competitors increase the requirement for better timeliness in our statistics.
- Statistics for several sectors (e.g. environment, population and economy) are demanded at the same time.
- Demand for regional statistics increases in particular.

GIS is an issue in connection with several of the market trends:

- GIS can be used for analyses and presentation purposes, increasing the information value of statistics.
- GIS users will need georeferenced data as input. Availability of GIS technology probably accounts for some of the increasing demand for regional and multi-sectoral data.

To meet the demand for georeferenced data, geographical coordinates are included in or added to statistical data to an increasing extent, in particular within environment statistics. Increasing use of administrative registers as a basis for statistics, described in next paragraph, enables more georeferenced statistics.

3.2. Register based statistics

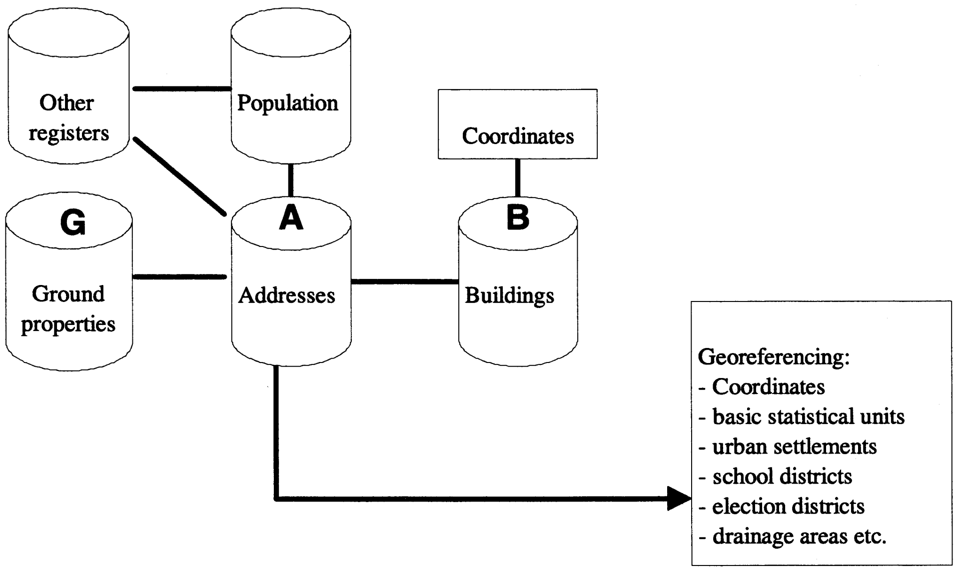
Statistics Norway has a strategy of increasing the use of administrative registers as a basis for statistics. This makes it possible to reduce the use of surveys thus reducing the response burden on persons and enterprises. Today, about one third of Norwegian statistics (censuses not included) is based on registers alone, one third is based on questionnaires and one third on a mixture of registers and questionnaires. We use about 120 administrative data systems for production of statistics annually. However, the use of registers provides new challenges in quality control and treatment of consistency and definitions. In Norway, there are three basic registers where important statistical units such as persons, enterprises and buildings are identified and updated:

- The Central Population Register
- Register of legal units
- Register for Ground properties, Addresses and Buildings (GAB system).

All registers contain *address* as the main key for linking persons and enterprises to buildings and their geographical coordinates in the GAB system. The address register also provides possibilities for positioning data to geographical areas like basic statistical units and urban settlements. It has for example been possible to produce population statistics on a regular basis down to enumeration district level for municipalities based on linking the population register and GAB. The Norwegian Mapping Authority is responsible for the GAB system.

The main principles for georeferencing of register based statistical information in Norway are illustrated by figure 3.1.

Figure 3.1. Georeferencing of register information



The basic registers and others such as the registers of employers/employees, income and education will be the basis for the 2000 Population and Housing Census. However, one important component of a census is to provide statistics on households and their living conditions, and this will require information on housing and not only on buildings. In order to carry out the 2000 census exclusively as a register census, it is necessary to expand the building register in the GAB system into a register of dwellings in order to establish households (not only families). The decision on doing this has however not yet been taken.

3.3. Reference databases

The demand for multi-sectoral statistics in electronic form makes it necessary to establish databases as sources for statistics. These databases should be basis for publications (on paper or electronic) and for output of data for dissemination.

A *reference database* is a multi-sectoral macro database (as opposed to various micro databases used in production of statistics). In addition to official statistics a reference database contains metadata (data about data sources, definitions, standards, precision etc.). In Statistics Norway we have two types of reference databases:

- Time series database
- Regional database.

The Regional Database (RD) is particularly relevant in connection with GIS. It contains mainly statistics for *basic units, municipalities and counties.* A new version of this database is being developed in an open environment (UNIX and Oracle) with a user-friendly interface. However, for confidentiality reasons RD is only open to users within Statistics Norway, but it can be a basis for dissemination databases, for example on Internet. It is a goal to include digital maps in RD to form a basis for GIS applications.

3.4. Dissemination

Even if paper publications still dominate the way of disseminating statistics, electronic dissemination is increasing. Statistics Norway uses both diskettes, CD-ROMs and on line data distribution via Internet. Diskettes are mainly used for transferring data in reply to inquiries. In cooperation with the other Nordic countries we have produced a Nordic CD-ROM with Nordic statistics down to the municipality level every year since 1992. Data from this CD-ROM can be converted to different formats relevant to GIS users, such as Excel and Dbase-format.

Statistics Norway has disseminated statistics via Internet since March 1995. Some georeferenced data (municipality-level) can be downloaded to the user's PC (as ASCII or worksheet files), and this gives an interesting perspective for GIS users. This concerns statistics on population, economy, health and social conditions in the municipalities. So far, all statistics from SN on Internet is free of charge.

3.5. Confidentiality

Georeferencing down to small areas or even points, combined with statistics from many sectors represents a problem, since the number of units within each group can be too small for dissemination. SN will usually not distribute data for groups or table cells with 3 or fewer units. Confidentiality has in particular become an issue in connection with an increasing demand for data from commercial companies who disseminate data to local authorities and others. It is a dilemma that we may not be able to provide highly demanded statistics with today's confidentiality rules. Possible solutions include defining and redefining of suitable geographical units, imputation of random errors in data on individuals and software to automatically check if data for selected aggregation levels can be disseminated.

4. Case study: GIS in environment statistics

Statistics Norway's main role in environment statistics is to produce statistics on environmental pressures, such as statistics on emissions to air, discharges to water and soil and waste. Other institutions are responsible for collecting data and compiling statistics on environmental quality, but these statistics are put together and disseminated together with other statistics by SN. Some environment statistics are derived from other statistics. This in particular concerns statistics on emissions to air which to a large extent is produced on the basis of energy statistics. Environmental quality data are often exactly georeferenced, while data on pressures like energy use and emissions to air originally are referenced to regions like most other statistics. GIS techniques has turned out to be convenient to link statistics on pressures and quality geographically, in addition to their traditional use in presentation of environment statistics. In the following, two related projects caused by the need for such linkage between pressure and environmental quality are presented.

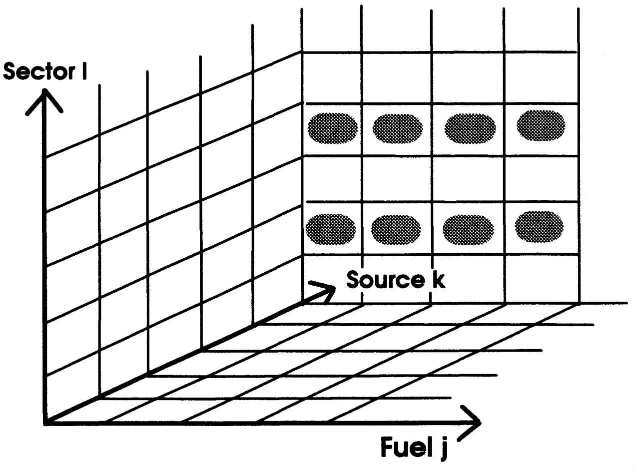
4.1. Emissions to air in municipalities

Statistics on emissions to air of a number of pollutants are estimated in collaboration between Statistics Norway and the Norwegian Pollution Control Authority (SFT). These statistics are to a large extent based on energy statistics and emission factors expressing emission per unit of fuel in different processes. SFT is responsible for emissions from large plants which are measured directly and emission factors generally. SN is responsible for data on activities such as energy use, the emission model and calculations.

The Norwegian model for estimating emissions to air is constructed as a «cube» with four axes (Rypdal, 1995). The axes are pollutants, emission carriers (in most cases fuels), technical sources (processes) and economic sectors. Emission values are calculated for each «cell» in this four dimensional cube. For each pollutant the cube will have three dimensions which are illustrated in figure 4.1 together with the mathematic expressions for calculating emission values.

Figure 4.1. Model for estimating emissions to air

Emission of one pollutant is calculated within each cell of the cube. The calculation can be done within each region.



The steps in the calculation of emissions can be expressed mathematically in the equation:

$E_{ijkl} = [C_{jkl} - CPS_{jkl}] * EF_{ijkl} + EPS_{ijkl} + ENC_{ijkl}$,

where

E_{ijkl} = Emission of pollutant i from combustion of fuel j in source k in sector l.

C_{jkl} = Consumption of fuel j in source k in sector l.

CPS_{jkl} = Consumption of fuel j in source k in point sources in sector l.

EF_{ijkl} = Emission factor for pollutant i from combustion of fuel j in source k in sector l.

EPS_{ijkl} = Emission of pollutant i from combustion of fuel j in source k in sector l from point sources.

ENC_{ijkl} = Non-combustion emission of pollutant i from emission carrier j in source k in sector l.

The model is easy to understand with respect to emissions from combustion: A fuel is combusted in an equipment in a certain economic sector, and the corresponding energy figures are multiplied by emission factors for each combination of fuel, technical source and economic sector. Non-combustion emissions are calculated by combining appropriate activity data (such as the number of cattle, data on waste water treatment etc.) with emission factors or by more complicated methods.

Information about the geographical distribution of emissions is useful for control purposes and modelling. At least three areas of use of georeferenced emission figures can be identified:

- Information to counties and municipalities on local status and development.
- Basis for considering measures against local air pollution.
- Atmospheric/chemical models and dispersion models aiming at linking emissions, air quality and deposition regionally or locally.

The emission model has been developed to handle allocations to geographical units, in first round down to municipality (Rypdal, 1995 and Daasvatn, Flugsrud, Hunnes and Rypdal, 1994). The spatial distribution of emissions introduces a another dimension (axis) to the emission model. Emission factors may in principle be municipality specific. Emissions from point sources are allocated directly to the municipality. This for example concerns emissions from larger industries which are measured directly (reported from the Norwegian Pollution Control Authority) or determined by mass balances at major manufacturing plants. Other emissions from combustion are calculated by multiplying energy consumption in the municipality by emission factors and adding non-combustion emissions cell by cell in the cube in figure 4.1. The model is a straightforward extension of the non-spatial model, but requires detailed geographical data on energy use and other relevant activity measures. In Norway good and sufficiently detailed energy data exist on a national and partly on a county level, but different methods and statistics have to be used to distribute these data geographically. For some sectors (e.g. manufacturing) figures can be based on non-published information available in SN, for others surrogate distribution keys such as population, number of cars, employees (in services) etc. have to be used.

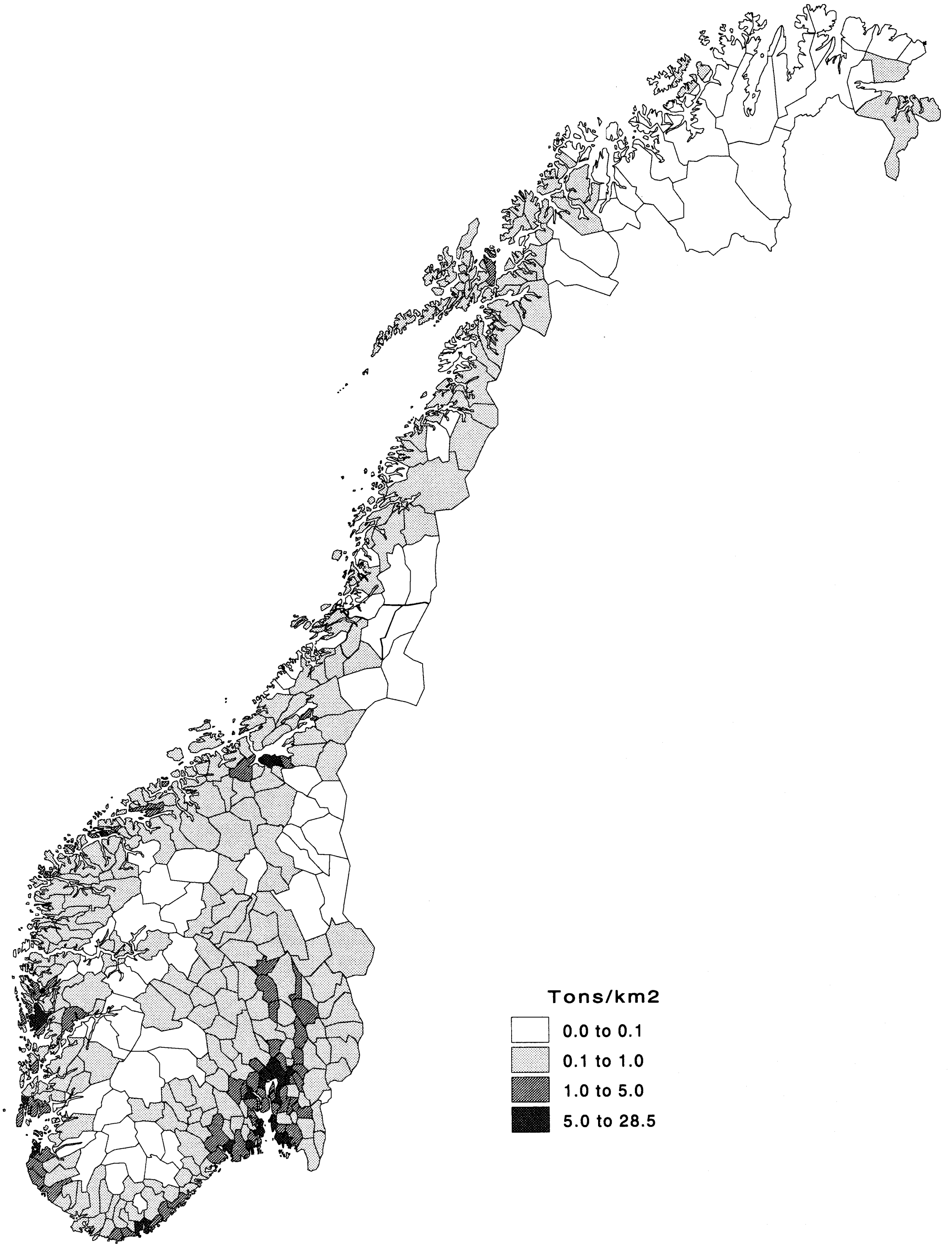
Figure 4.2 shows the emissions of NO_x per km^2 in the Norwegian municipalities in 1992.

To consider regional damage caused by emissions to air, European countries annually reports emissions of SO_2, NO_x, NMVOC and NH_3 ditributed by a 50 km x 50 km grid to EMEP (Cooperative programme for monitoring and evaluation of the long range transmission of air pollutants in Europe). One project using GIS consists of allocating emissions to these grid squares on the basis of municipality figures and some other sources. This project is briefly described in the following. A project using geographically more detailed statistics (e.g. basic statistical units) for controlling local pollution in larger urban areas is described in next paragraph.

GIS-techniques is used for allocation of municipality statistics to the EMEP-squares. Emissions from point sources are georeferenced to coordinates and thus to any regional unit. Other emissions from a municipality are allocated to EMEP squares by area proportional distribution using ArcInfo software. The result of an overlay of EMEP squares and municipality is a map with polygons with same municipality number and EMEP square number. The main drawback of this method is that errors may occur for squares crossing municipalities with very uneven distribution of emissions, though separate treatment of point sources counteracts such errors.

Emissions of NO_x by EMEP squares are shown in figure 4.3.

Figure 4.2. Emissions of NO_x per km^2 in Norwegian municipalities 1992



Digital map boundaries: Norwegian Mapping Authority

Figure 4.3. Norwegian emissions of NO_x by EMEP squares 1992

Digital map boundaries: Norwegian Mapping Authority

Further work on this project include more detailed georeferencing of line sources such as roads (emissions from road traffic) and (inland) shipping routes. One separate activity aims at mapping emissions from coastal shipping. All major ship traffic routes are digitised, and information from route tables and ship logs are used to allocate total emissions from this sector to lines and other geographical units including EMEP squares (Flugsrud and Rypdal, 1996).

4.2. Emissions and air quality in urban areas

Traditionally, monitoring air quality in major Norwegian urban areas has been based on measurement stations located primarily in the city centre or along main roads. Models combining measurement results and assumptions on local emissions with meteorological information are used to map and warn against pollution in different areas. It is a problem that the representativity of the measurement points could be questioned from a statistical point of view. The information on emissions used in the models has not been consistent with the official statistics on emissions available on a national and a municipal level calculated by the methods described above. One way to improve the models is to increase the number of measurement points, but this is expensive.

Another approach is to use similar methods as described in last paragraph to estimate emissions down to a geographical level detailed enough to give input to the local air pollution dispersion models. Statistics Norway carries out a project on this together with the largest urban municipalities, the Norwegian Pollution Control Authority and the Norwegian Institute for Air Research (NILU). Our role is mainly to provide energy and emission figures. NILU has developed the model and designed the Environmental Surveillance and Information System (ENSIS), which was first developed for the 1994 Winter Olympics at Lillehammer. It will be the basic unit of the new Norwegian system for monitoring local air pollution run by the Norwegian Pollution Control Authority. The system consists of the following modules:

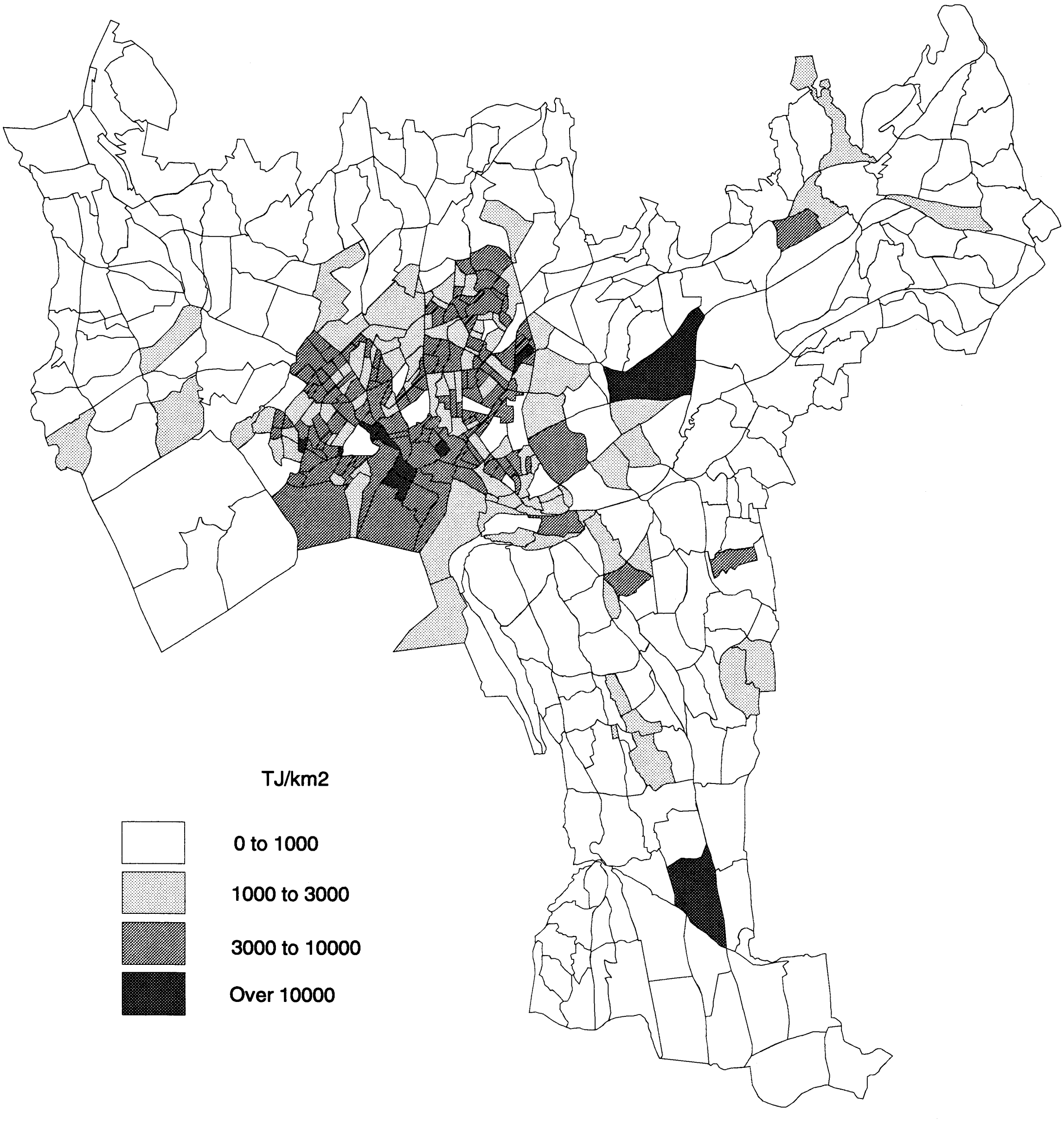
- Database with figures on georeferenced energy consumption and emissions (provided by SN), traffic and their time variations.
- Database with hourly measurements of pollutions and meteorological observations.
- The model system including a GIS-application comprising topography, divisions in basic statistical units, data on population and buildings and pollution dispersion models.

The present version of the system is called AIR-QUIS (Air Quality Information System). It is based on GIS software ArcInfo with ArcView as user interface. It is used in Oslo since February 1996, and later in 1996 in other major Norwegian cities. Compared to earlier systems, this system will contain more and better information on emissions and their origin, and the number of measurement points to calibrate the model can be reduced.

The methodology used for georeferencing energy consumption and emissions is quite similar to what was described in paragraph 4.1, but more emissions are treated as point sources and the basic statistical units are used as the reference for other emissions (compared to the municipalities above). All major roads and streets with traffic registrations are regarded as line sources. In addition to point sources with known emissions, other important plants or enterprises are identified by help of the address and building register (GAB) considered in paragraph 3.2. Energy consumption according to industrial statistics is used as a basis for calculation of other emissions from manufacturing. Energy consumption is also the main statistical parameter that has to be georeferenced to the basic units, and this is done by using different keys such as population and information on heating systems among others registered in the 1990 Population and Housing Census (Flugsrud and Hunnes, 1996).

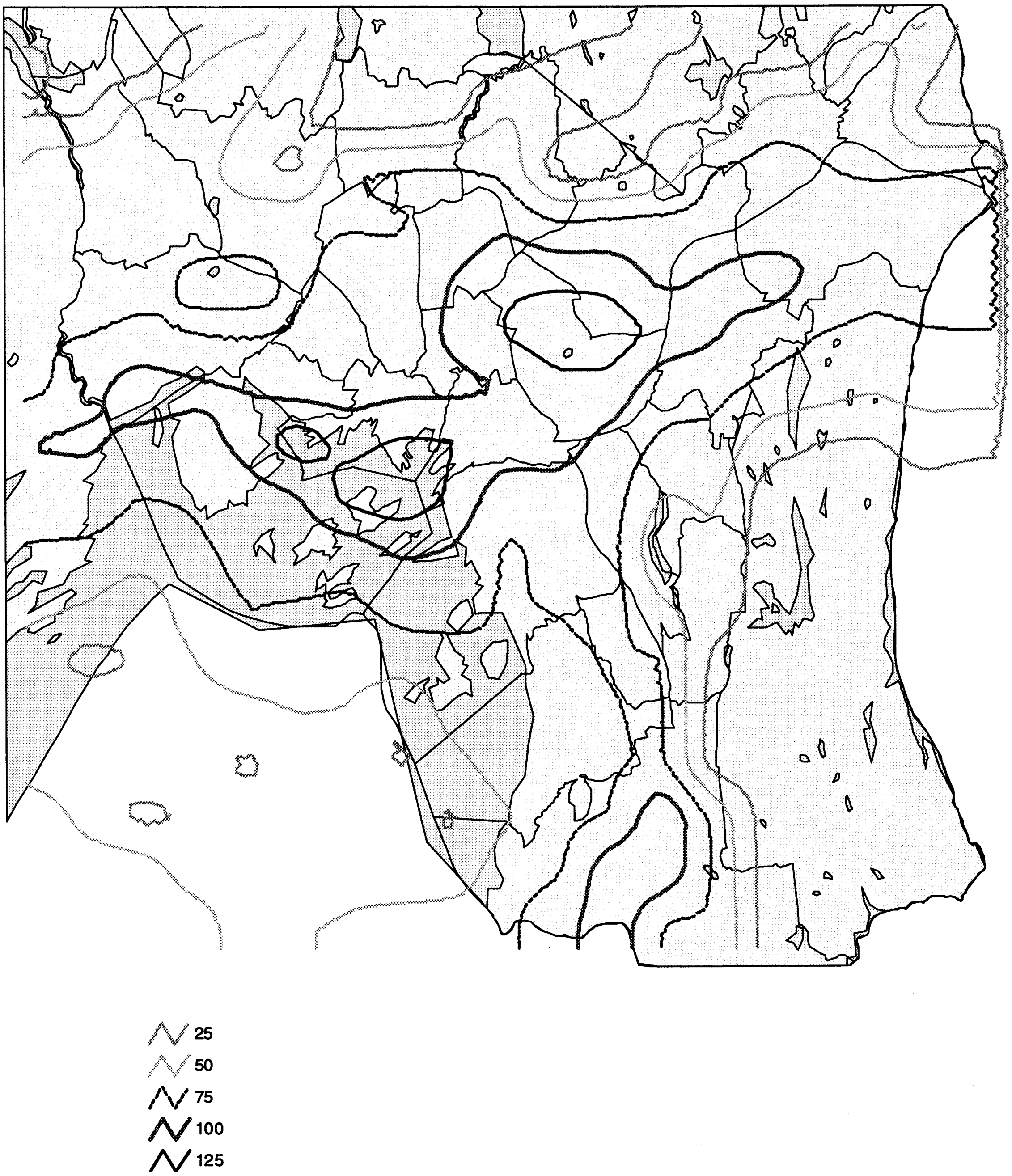
Figure 4.4 gives an example of input to the model for calculating local emissions. It shows use of fossil fuels from stationary sources per km^2 in the basic statistical units of Oslo, whereas figure 4.5 gives an example of an air quality map for Oslo as a result of all the calculations and modelling.

Figure 4.4. Use of fossil fuels from stationary sources per km^2 in basic statistical units in Oslo. 1992



Digital map boundaries: Norwegian Mapping Authority

Figure 4.5. NO_2 concentration in Oslo a typical hour in winter



Isolines for NO_2 concentrations. $\mu g/m^3$

Source: Department of Environmental Health, Municipality of Oslo

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