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Procedures for the estimation of vehicle emissions in an urban environment

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Abstract

Air pollution from road transport is a major environmental problem in urban areas. The steps undertaken in developing an emissions estimation procedure for road traffic in Greater Manchester is presented. This process builds on the existing traffic flow database, by incorporating the facility to estimate current and future emissions from road traffic by entering emission factors, the composition of the vehicle fleet and the daily traffic flow profile. The use of this procedure allied with tools such as Geographical Information Systems, will be important in helping to formulate local air quality management plans and improve the capability of urban transport planning.

Introduction

Pollution from road transport is possibly the major environmental problem of the present day. This is particularly so in urban areas, where the effects of traffic in terms of pollution and congestion are most acutely observed. Consequently much attention is now focused on attempting to alleviate this increasing problem. The recent Royal Commission Report [1] brought together many of the issues that relate to traffic pollution, and has come at a time when there appears to be an acceptance by central government, that current road building programmes cannot continue in their present form [2]. Government policy in the last two decades has been to provide capacity to meet travel demand based on projections of economic growth [3]. This is despite the continuous arguments, expressed as far back as 1977 [4], that estimations of future road traffic were flawed and that procedures to evaluate new roads failed to take proper account of environmental factors. This has been a continuing theme of the Standing Committee on Trunk Road Appraisal (SACTRA) reports [5] and culminated in their most recent report that concluded that the building of more roads was likely to generate more traffic than that which it was

supposed to displace [6].

There is an increasing need then, for the effects of road traffic in urban areas and the policies used to reduce the impact that emissions of pollutants have on urban air quality to be re-examined [7]. There has been extensive research into which pollutants from road traffic cause concern. What is needed now are the tools to help policy makers, particularly at the local level, assess the scale of the problem and furthermore how those decisions that they take will effect levels of road traffic and pollution. This research is designed to help local authorities, initially in the Greater Manchester conurbation, do this by estimating emissions from road traffic and then forecasting what effect changing transport parameters have on levels of pollution emitted. The use of emission inventories which incorporate methodological assumptions that limit their final accuracy, are nonetheless useful and can be used for the evaluation of policies aimed at emission regulation and transport management [8].

Emission estimation procedures

The use of emission estimation procedures in providing detailed estimates of vehicle pollution is an ongoing and increasingly complex task. Refinements to the various models that are now used by national and supra-national organisations, such as the EU, will continue to improve their accuracy and reliability. As with any major study involving many parameters and sources of input data, a detailed and logical methodology is required to calculate emissions and estimate the effect of altering traffic parameters in future years [9]. The derivation of emission factors is a particularly difficult task, and studies such as this can only make use of the most current estimates. In calculating emission factors many differing vehicles in terms of age, performance and reliability are tested in the laboratory and on the open road. The resulting pollutant emissions are analysed and compared, to determine an emission factor that is representative of driving cycles on a particular type of road, for different types of vehicles.

Measurements carried out in tunnel studies in California and remote sensing of passing vehicles, indicate that emission levels are higher than those calculated by tests in laboratories on dynamometers. Furthermore as a small percentage of vehicles (20%) were found to contribute to 80% of CO and VOC emissions, and that these high emitters are not generally tested on dynamometers, then their emission levels are either not included in calculating fleet wide average emission factors or are only estimated, thus leading to the under-estimation of vehicle emissions[10]. These high emitters which do not meet emission standards (based on the performance of new vehicles) fail largely due to poor and infrequent maintenance [11]. Engine maintenance has been shown to be the most significant parameter affecting the level of emissions [12].

Traffic flow in Greater Manchester

Information on the volume and type of traffic in the conurbation is collected and used in models to provide forecasts of future road usage and assist in the complex task of planning the areas transport policy [13]. Traffic counts are carried out on motorways, 'A' roads, 'B' roads and some minor roads in the Greater Manchester area. In all there are counts on 70 motorway links, 595 'A' road links and 291 on 'B' road links spread across the conurbation. These are done using a combination of automatic and manual counts. The count is conducted for both directions of the carriageway and whenever a particular count is undertaken it is repeated three years later on the same day of the year. It should be noted that on a given piece of the road network or link the count site may not be in the centre of that link. But the results obtained from that count are considered to be representative of the whole length of the link. The counts themselves consider several classes of vehicle: cars, buses, motor cycles, pedal cycles and three categories of goods vehicles.

The counts of traffic flow for the various types of vehicles can be looked at for many different time periods. The standard twelve hour count which is carried out from 7am to 7pm can be broken down into morning rush hour, off peak and evening rush hour. The flow on the motorway and 'A' road links can be looked at hour by hour for the whole 24 hour period as a sample of these are monitored automatically. By undertaking a small sample of surveys over 16, 18 and 24 hour periods, a set of conversion factors have been derived which enable a traffic flow figure for any of these periods to be calculated from the standard 12 hour count. Similarly there are conversion factors to enable an annual average daily traffic flow to be calculated for a particular day of the week or month of the year [14].

Traffic flow data

The traffic flow data is available for the 956 links of the "Principal road network" of the conurbation. Two forms of data are available, 24 hour annual average weekday traffic (AAWT) and 24 hour annual average daily traffic (AADT). This is presented as follows:-

DoT code number e.g. 6029
Road number e.g. M63
Ordnance survey grid number e.g. 35684020
Duration of count e.g. 12 (Hours)
Day of week count conducted e.g. 1 (1=Monday,....,7=Sunday)
Date of count e.g. 30/9/91
Car flows e.g. 9518
Light Goods Vehicle flows e.g. 2061
Medium Goods Vehicle flows e.g. 1379
Heavy Goods Vehicle 3 axle flows e.g. 154
Heavy Goods Vehicle 4+ axle flows e.g. 972
Bus & coach flows e.g. 90
Motor cycle flows e.g. 52
Total flow e.g. 14226

The transformation of these data is complicated by their collection and storage in a variety of formats. These need to be unified prior to further use in this procedure.

Emission factors

Before applying the relevant emission factors to the different vehicle categories a suitable set of emission factors that correspond to the vehicle data has to be found, so as to maximise the vehicle flow information. Considering the number of organisations that provide emission factors and the different vehicle classifications that they use, a compromise had to be reached in adapting them to suit the traffic data available. Currently, the emission factors that are being used are those provided by the National Atmospheric Emissions Inventory [15], and factors published by the Departments of Transport and Trade and Industry [16]. These comprise emission factors for 12 categories of cars and other vehicles on 4 different driving cycles.

Vehicle fleet information

Within the car category there are further subdivisions to be made. This is into car engine size and the distinction between different fuel types and control technology used. First, the percentage of cars that are petrol or diesel fuelled, use leaded or unleaded petrol, and those that have a catalytic converter fitted needs to be known. So that the total number of cars in each of these groups can be derived from the number of car movements which is given in the traffic flow data as a single total. Secondly the number of cars that are small (<1.4l), medium (1.4-2.0l) and large (>2.0l) was obtained, using information from the Department of Transport [17] and the Department of the Environment [18] to enable the application of more specific emission factors.

Emission calculation

The emission estimation procedure and the process needed to prepare the original traffic flow data for use, which has previously been described, is shown in Fig.1. The box termed "emission estimates" on this diagram, encapsulates the equation for determining the emission totals and is the culmination of all the steps described earlier. The equation for determining estimated emission totals can be given as thus:-

$$T_{s,t} = V_v \times L_r \times EF_{p,v,r} \qquad (1)$$

Where

T=Emission Total (Tonnes)
V=Vehicle Flow (AAWT, AADT)
L=Road Length (km)
EF=Emission Factor (g km^{-1})

and can be given by

s=scale descriptor (road, district, conurbation)
t=time period (hour, day, week, month, year)
v=vehicle type (fuel, control technology,engine size)
r=road type (motorway, "A", "B")
p=pollutant (CO, CO_2, HC, NOx, PTC, SO_2)

The following is an example of the calculations used to obtain the emission total for a section of the M61 in Bolton. This is based on AAWT data and is the estimated amount of NOx emitted in a 24 hour period by the car group (Petrol, No Catalyst, Leaded fuel with engine size less than 1400cc).

$$(V)\ 11566.1 \times (L)\ 0.724\ km \times (EF)\ 4.21\ g\ km^{-1} = 0.035\ Tonnes$$

Output and results

In addition to all of the individual road data, there are totals for all the districts in the conurbation, and for the Greater Manchester area as a whole. These include the total amount of emissions in each of the 19 vehicle groups for each road type within each of the ten districts. The total emissions for all roads in all 10 districts in the base year of 1992 is shown in Fig.2. Additionally the amount of pollutant emitted per kilometre of the road network is given. This is easily calculated by dividing the net totals given above, by the length of the appropriate part of the road network. Calculating this total, enables comparisons to be made between each district and road type, of the amount of pollution emitted by the vehicles on that part of the road network. The emissions per kilometre of NOx on motorways in three of the ten districts is presented with the aid of a Geographical Information System in Fig.3 as an example.

Future modelling

Future estimates of pollutant levels will be the next stage in this research. Referring back to the diagram of the estimation procedure (Fig.1), the effect of changing road traffic forecasts, updated emission factors, a changing road network in the conurbation and the changing composition of the vehicle fleet will be incorporated into the model, and the effect of different scenarios evaluated. Perhaps the most important and interesting aspect of this work will be seeing the effect of strategies to reduce traffic and its related pollution. For example, recommendations made by the Royal Commission [1] and locally by MAPAC [7], to encourage more use of public transport, cycling and restrictions on traffic movement will effect the levels of traffic flow and hence emissions. Furthermore, a procedure will be developed which identifies those roads that pose a pollution "problem", and so can theoretically be targeted with abatement strategies, to see what effect these have on vehicle flows and emission levels.

Conclusion

This paper has detailed the process undertaken in establishing an emissions estimation procedure for road traffic emissions in Greater Manchester. This procedure will be useful in the context of transport planning and local air quality management [19]. The policy advisory tool that this procedure will eventually become, will aid local authorities in trying to assess the implications of their traffic and pollution management policies. For example, the setting of

overall targets to be met by urban areas, which may include the definition of maximum emission guide levels for the transport sector that will require appropriate methods to meet them in a defined period [20], would mean that local authorities will need policy advisory tools such as this in order to effectively implement any future strategies.

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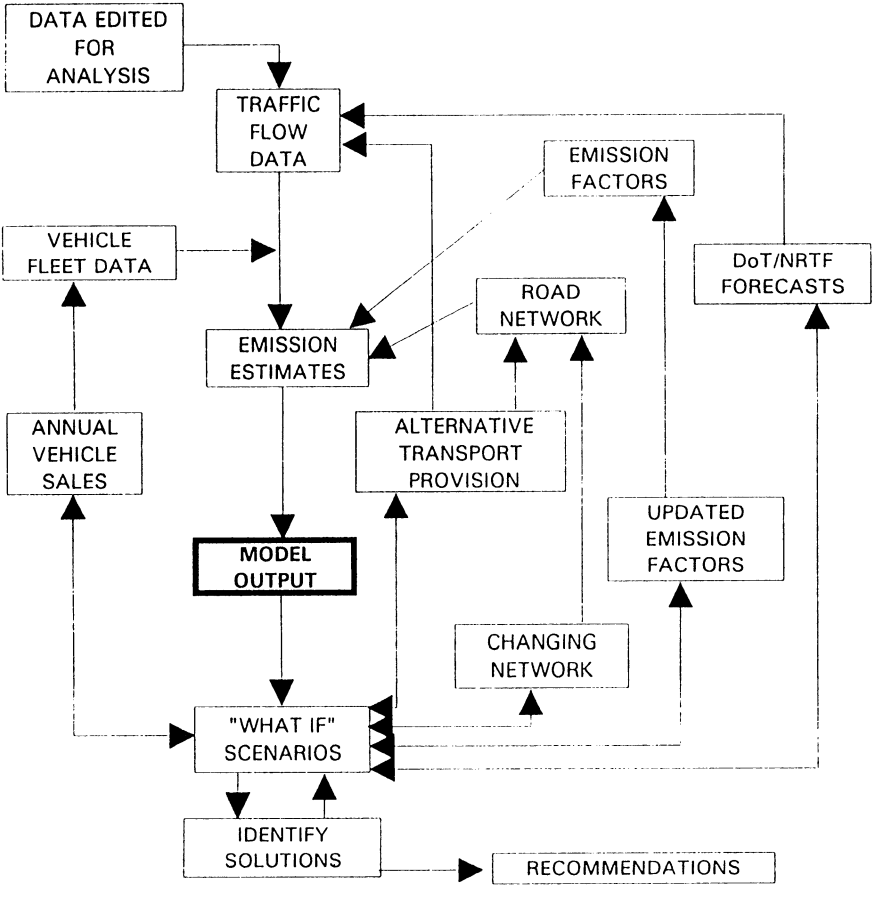

Figure 1. Emission Estimation Procedures

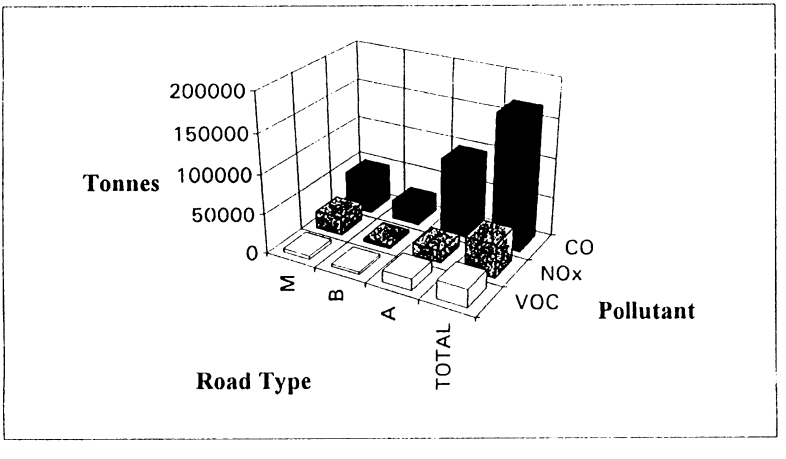

Figure 2. AADT 1992: Greater Manchester Yearly Emissions for All Vehicles

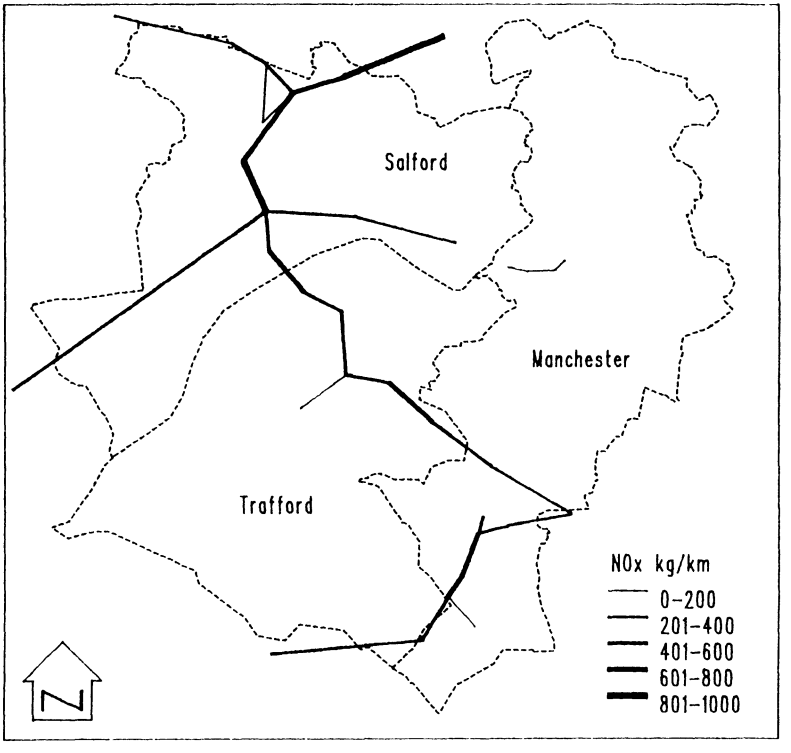

Figure 3. The emissions per kilometre of NOx on motorways in three of the ten districts.