ESTIMATING PERSONAL EXPOSURE TO AIR POLLUTION ON THE JOURNEY TO AND FROM SCHOOL USING GPS, GIS AND MOBILE PHONE TECHNOLOGY

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INTRODUCTION

Personal exposure to air pollution has traditionally been assessed through the integration of temporally invariant pollution surfaces, or surrogates, and simplified representations of place of residence or employment, such as a postcode (for a comprehensive review, see *Briggs*, 2005). In reality, pollutant concentrations vary in time and space in response to variations in meteorology and emissions from different source sectors (e.g., road transport, industrial sources) and people move in time and space in order to complete their daily activities.

Recent developments in personal exposure assessment have seen the deployment of high-flow personal samplers and particle counters to assess spatial and temporal variations in air pollution in urban microenvironments with particular emphasis on ultrafine particles (*Kaur et al*, 2004, *Gulliver and Briggs*, 2004, *Kaur et al*, 2005) which are considered particularly harmful to human health. Parallel developments have also occurred in the development of GIS-based exposure models which attempt to reproduce the spatial and temporal dynamics of traffic-related pollution and the behaviour of the individual (*Gulliver and Briggs*, 2005).

Both approaches have their merits. Mobile forms of air pollution modelling facilitate direct forms of exposure assessment, however, are typically expensive to deploy, hence tend to be used to study small groups of individuals travelling within small, well-defined geographic areas. Modelling approaches, in contrast, offer a cheaper, indirect form of exposure assessment and are capable of generating estimates for large sample sizes over larger geographic areas, subject to model assumptions concerning the treatment of the air pollution and individuals in time and space.

This paper describes a hybrid approach to personal exposure assessment that uses GPS and 3G mobile phone technology to record the detailed movements of children in time and space on their journeys to and from school, and a dispersion model, ADMS-Roads, to derive temporally and spatially variant estimates of traffic-related pollutant concentrations. These data are integrated within a GIS environment to provide individual estimates of exposure to traffic-related air pollution.

The GEOBLOG application developed for this project also provides children with the means with which to comment on the factors that influence them on their journeys to and from school through the capture of time and place-stamped texts and photographs. These data, used in conjunction with information derived from follow-up interviews, provide useful insight into the daily factors governing the choice of routes to and from school and other influencing factors.

METHODOLOGY

This presentation reflects work in progress with a group of 30 school children (aged 12-13) who study at a local comprehensive school in Lancaster, NW England. The city has a long-

standing problem with traffic congestion and the city council has recently declared an air quality management area for NO_2 around the entire one-way system. The children taking part in this study attend a school that is located towards the centre of this one-way system, hence are likely to encounter significant variations in traffic-related air pollution on their journeys to and from school.

Each participating child has been provided with a 3G mobile phone and a GPS unit and has been asked to use a customised application, GEOBLOG, to capture text and photographs on their journeys over four one-week periods throughout the year. The mobile phone and the GPS unit are linked through a Bluetooth connection. The position of each child is automatically logged at 1-second time intervals. Text and photograph entries are automatically time and place-stamped by the application at time of capture.

The dispersion model, ADMS-Roads, is used to generate 15-minute concentrations of traffic-related pollution across the city using a combination of manual and automated traffic count and composition data for major roads within the city and modelled estimates of count and composition from the traffic simulation model PARAMICS for minor roads within the city. A complete, detailed representation of the road network is an essential pre-requisite for exposure assessment. Similarly, sub-hourly traffic count and composition data are necessary so that the model can effectively reproduce pollution concentrations associated with the early morning and late afternoon rush hours, times when children are typically travelling to and from school.

RESULTS

Figure 1 shows a small selection of some of the many routes captured by the children using the GEOBLOG application during the first sampling period, February 2007. (An hourly PM_{10} surface is used here to illustrate significant spatial variations in traffic-related pollution across the city).

Scott* typically cycles to school. On this occasion he cycled at variable speeds (5-20 mph) along a variety of lightly and heavily trafficked routes. Ella, in contrast, typically walks to school. On this occasion she walked at speeds of up to 4 mph with the latter stages of her route taking her through a local park. Louise also walks to school, on this occasion at a similar pace of 3-4 mph. On first inspection it would appear that she walked alongside a busy road, however, closer inspection (Figure 3) reveals that her route is more complex. Reasons for this will be explored later.

Cumulative exposure to PM_{10} is shown in Figure 2. Since exposure is primarily a function of pollutant concentration, duration of exposure and activity level it comes as no surprise to find that Ella experiences significantly lower levels of personal exposure to traffic-related air pollution than either Scott or Louise. Of more interest, given their very different routes and means of travelling to school, are the cumulative exposure estimates for Scott and Louise. Scott clearly cycles along a number of heavily polluted roads such as that highlighted with an 'x' on Figure 1. This results in a short but significant increase in personal exposure, highlighted by the rising limb marked 'x' on Figure 2. Louise, in contrast, does not cross any major pollution gradients on her journey to school and her exposure profile is smoother in comparison.

* Pseudonyms chosen by the children

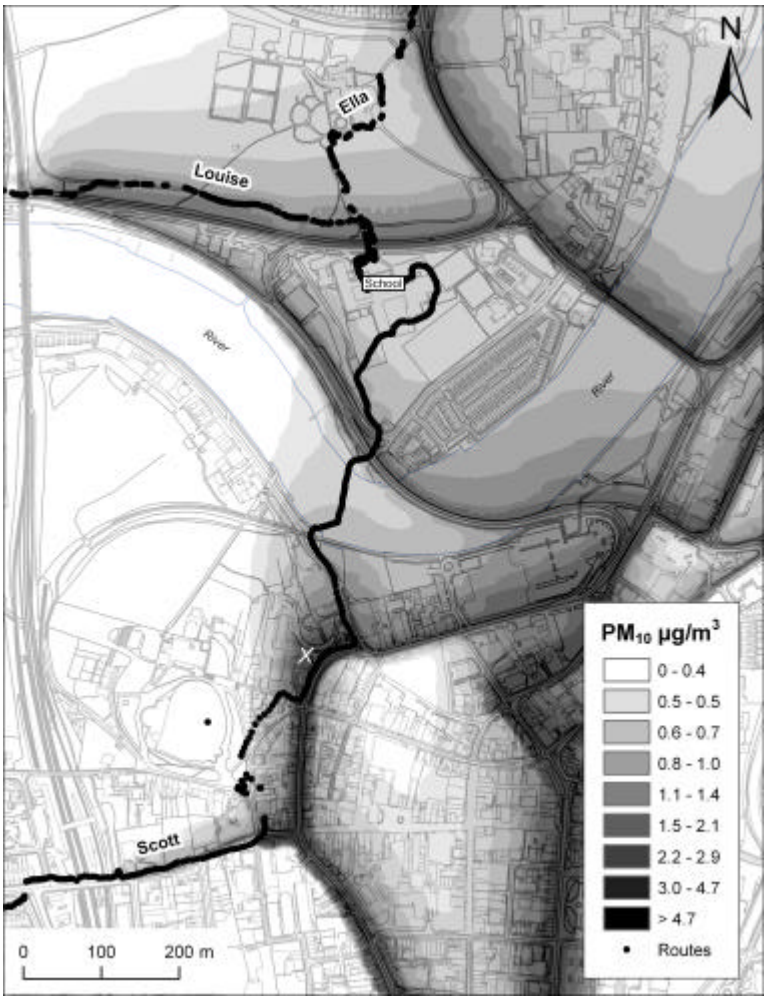

Figure 1. Selected journeys to school for Scott (cycles), Ella (walks) and Louise (walks) against an illustrative backdrop of hourly modelled PM_{10} from road sources.

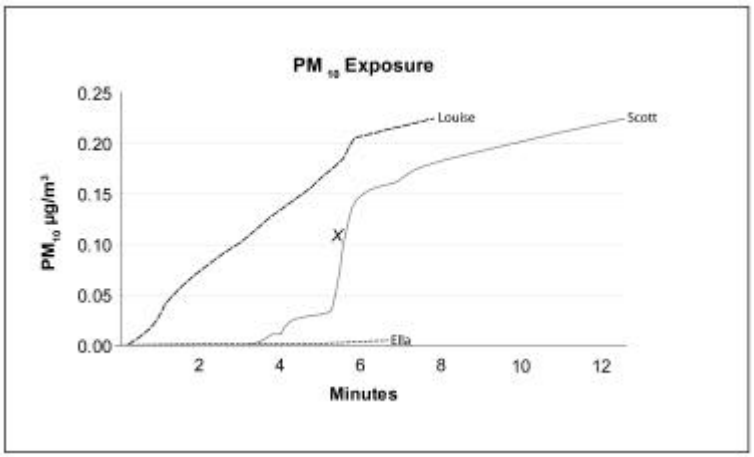

Figure 2. Cumulative exposure to PM_{10} based on integration of positional information derived from GEOBLOG and modelled pollution surface.

DISCUSSION

The Royal Commission has recently completed a review of environmental impacts in urban environments (2007) with associated press coverage focussing upon practical means through which individuals may reduce levels of personal exposure to air pollution. Suggested

measures include avoiding walking along busy streets and thoroughfares, standing well back from kerbs whilst waiting to cross roads, avoiding getting stuck for too long on central reservations and avoiding periods of high traffic congestion wherever possible.

Figure 3 shows the detail of Louise's route as she approaches school. It is interesting to note that she does not walk along the busy road all the way to school, rather, she cuts through the park and follows a parallel path towards school before rejoining the road and crossing into the school grounds. This is reflected in the corresponding exposure profile with the two peaks reflecting the time spent closest to road side. Her decision to cut through the park on this occasion has clearly resulted in a lower level of exposure to traffic-related air pollution.

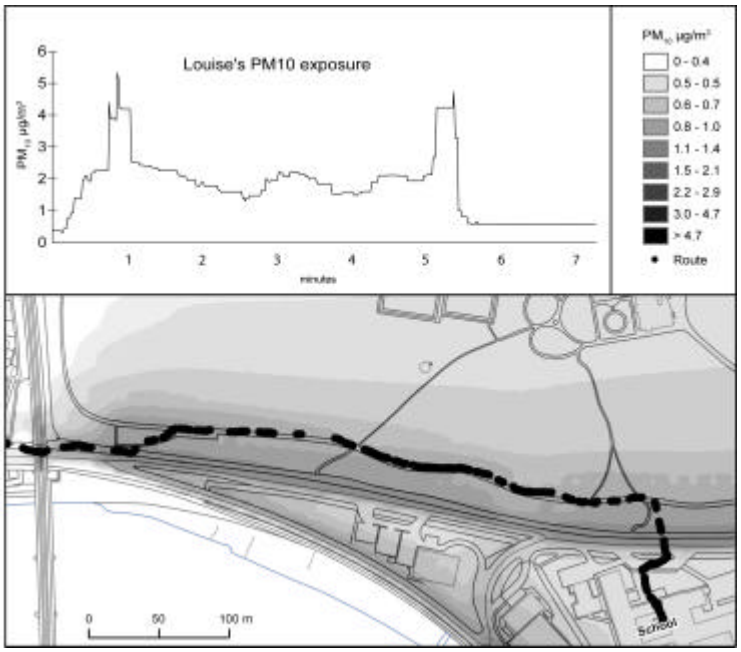

Figure 3. Detail of Louise's route (shown in Figure 1) with associated exposure profile.

The GEOBLOG application not only allows us to explore the detailed routes of children on their journeys to and from school, it also allows us to gain an insight into their perceptions of the environment as captured through texts and photographs. Used in conjunction with transcripts taken from follow-up interviews with the participating children these data can provide a rich account of factors affecting both the choice of route and positive and negative impressions of the local environment.

Figure 4 depicts a GEOBLOG entry made by Vernon close to the school entrance. The photograph and accompanying text suggest negative perceptions of the environment at this part of his journey caused by slow moving traffic and unpleasant weather. This was confirmed in a follow up interview in which he stated that he was *"not feeling me"*…. was *"usually happy"* that *"bad traffic usually got him annoyed"* and the rain *"just made it totally worse"*. A follow up interview with Louise, whose route was reviewed earlier (Figure 3) revealed that she didn't like the noise of the cars, hence tended to avoid walking alongside busy roads whenever possible. However, she was only allowed to walk certain routes in the summer for reasons of personal safety. These two relatively simple examples highlight the value of considering contextual information in addition to route-based information in personal exposure assessment studies.

Bad traffic not feeling me and its raining

Figure 4. GEOBLOG entry by Vernon close to the school entrance.

CONCLUSION

This work in progress clearly shows the potential of combining GPS and mobile phone technology within a GIS environment to derive estimates of personal exposure. Initial results suggest significant variability in likely levels of personal exposure to traffic-related air pollution based on choice of route in relation to the configuration of the road network. These findings are entirely consistent with those derived from more complex studies based on personal exposure monitoring (e.g., *Kaur et al*, 2006).

The application, GEOBLOG, also provides a useful insight to the factors that influence route selection. If the UK Government really is committed to actively promoting the concept of exposure reduction (Royal Commission, 2007) it needs not only to understand the nature of the pollution climate in the urban area, but also the likely behaviour of individuals whose choice of routes is as likely to be influenced by social factors as it is by any awareness of environmental risk.

ACKNOWLEDGEMENTS

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