Modelling the built environment at an urban scale—Energy and health impacts in relation to housing

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Abstract

In order to develop the concept of sustainability in the built environment there must be increased use of detailed predictive tools, both at an individual building level and at urban scale. A number of tools exist for predicting the energy and environmental performance at an individual building level. However, there are few tools available to predict performance at an urban scale. This paper describes the Energy and Environment Prediction (EEP) tool which was developed to model existing urban scale built environments, incorporating building energy use, traffic flow and health.

1. Introduction

It is generally accepted that the built environment is a key factor in the move towards a more sustainable future. However, in recent years the main emphasis has been focussed on the design of new buildings and little attention has been given to the existing building stock and the infrastructure that supports it.

In the UK buildings are replaced at about 1% per annum (DCLG, 2006), which can be considered typical for a developed post-industrial country. If the built environment is to be made more sustainable and if targeted carbon dioxide reductions are to be realised, then the problem of how to improve the existing built environment must be addressed (European Union, 2002). It is generally accepted that considerable energy savings can be achieved by upgrading the existing building stock but currently there is little incentive to do so. Energy is still regarded by many to be relatively cheap. There are therefore a number of issues and barriers to address when considering the sustainability of the existing built environment.

Reducing the energy use of existing buildings is, in many ways, a management problem and not one of design, unless it is a straightforward refurbishment situation. The framework of tools and approaches required will often be different from those associated with the design of new buildings. In many cases estates of buildings, or whole local authorities, will need to be addressed rather than individual buildings. Organisations, such as local authorities, who are responsible for large numbers of buildings, need tools to help them manage improvements to the built environment and to identify where best to invest their limited resources to make the most beneficial improvements.

In order to manage the use of energy by the built environment in a more sustainable way and to minimise carbon dioxide (and other) emissions, the performance of the city in sectors or ‘as a whole’ must be considered. To fully understand the inter-relationships between buildings, transport and industry, and the potential for using renewable energy sources on a city-wide basis, a model is required that can predict the various interactive processes. An Energy and Environmental Prediction model (EEP) has been developed in collaboration with local authorities in South Wales, UK, as part of a unified effort to plan for sustainability and to predict and account for reductions in carbon dioxide and other emissions (Jones et al., 2000). The computer model provides information for implementing urban energy management and environmental planning, enabling decision makers to plan for improved energy efficiency. Initially developed around Neath Port Talbot District Borough Council (NPTCBC), EEP has been used in other local authorities in the UK and Australia (Jones et al., 1999). It can be transferred to other cities to predict the effects of future planning decisions from a whole city level down to a more local level.

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The framework for the EEP tool is shown in Fig. 1. The user can access the tool via a 'primary user interface', which takes the user through a decision making process, presenting information and options and the opportunity to enter data in a straightforward manner. The interface has access to a range of external procedures or sub-models, selected according to the users needs, for example, to predict the city’s energy and emissions from buildings, transport and industry.

The EEP model presents results through the associated Geographical Information System (GIS) which contains an Ordnance Survey (OS) map of the city describing the buildings and roads. Sub-models exchange data through a 'data highway', making all data available to all sub-models. Data can then be mapped using the GIS facilities, for example identifying houses of high energy use predicted by the energy sub-model in EEP.

This paper will discuss the development and practical use of EEP for two main applications, namely energy prediction for housing and health impacts for housing and neighbourhoods, both drawing from work in Neath Port Talbot County Borough Council (NPTCBC).

2. Energy prediction for housing

One of the main drivers for developing the EEP model was to be able to assess the energy use of a whole local authority’s building stock and in particular its housing. Local Authorities in the UK, as part of the Home Energy Conservation Act (HECA) (Department of the Environment, 1995), have been required to consider and implement strategies that show a significant improvement in housing energy efficiency. The EEP model has been developed to help guide local authorities to a more sustainable energy efficiency policy. The EEP model helps local authorities to assess the annual energy use and carbon dioxide emissions for the housing stock and estimate improvements due to the application of energy saving measures.

The EEP model is created using built environment data associated with a region or city under investigation and can then be used to examine large to small areas enabling the user to pinpoint excessive energy use and associated carbon dioxide emissions ‘hotspots’. Data can be displayed to postcode unit level within the model—on average there are about 30 dwellings in a postcode unit. Postcode units consider areas to a suitable level of detail for use within the EEP model and are designed to simplify the identification of an address of a property. Data is stored within the model on an individual property level.

2.1. Data collection

The EEP housing sub-model requires data on the size, shape and age of the properties to be modelled in order to be able to make a suitably accurate energy use prediction. For the housing energy sub-model the data is collected in three stages.

2.1.1. Stage 1: desktop survey

Ordnance Survey (OS) (OS, 2006) provide electronic maps for the UK including raster maps of areas or vectorised maps such as the Landline™ and Mastermap™ ranges. The vectorised maps used in EEP’s GIS system allow the accurate measurement of building features such as floor area and front/end façade lengths.

A desktop survey was carried out for NPTCBC took during the early stages of EEP development in 2001. At this time the only OS digital maps available were Landline™ maps. These were fully digitised vector maps, but the lines representing a building outline (see example in Fig. 2a and b) were not a single polygon, as illustrated in Fig. 2c. However, during the desktop survey NPTCBC commissioned a set of polygons to be created for all the buildings in the local authority area. This step allowed the compilation of the ground floor, front and end façade area data required by EEP. The OS has subsequently produced a vector map for NPTCBC with polygons representing buildings called Mastermap™.

2.1.2. Stage 2—historical data

The second stage of data collection involves assessing the buildings age, from which a number of assumptions can be made concerning its construction including U-values of walls, floors and roof and the number of chimneys.

Historical OS maps allowed the age of properties to be estimated. In the UK historical OS maps are commonly available in three editions—the first edition published c.1870–90, second edition appeared c.1895–1905 and a third or provisional edition c.1919–1922, with a further update for some rapidly changing urban areas c.1937. This allows for confirmation of the site surveyors estimate of property age, for example, if a building outline appears on the third edition map but not the 2nd
2.1.3. Stage 3—drive by survey

The main source of data for the domestic sub-model was a ‘drive by’ survey of dwellings. Data was collected for each dwelling for:

- built form (detached, semi detached, end terrace, mid terrace, flat);
- number of storeys;
- number of chimneys;
- storey height;
- front window area.

For NPTCBC the survey was undertaken on approximately 55,000 dwellings. Between 700 and 1500 dwellings per day were surveyed within an area depending on the variation in properties. Once this data had been collected it was input directly into the EEP GIS model. For NPTCBC the collection of data (including other building types, industry and roads) took about 18 person-months.

2.2. Energy analysis

The domestic energy sub-model used within the EEP is based on the UK government Standard Assessment Procedure (SAP), which is an energy rating method for dwellings (Building Research Establishment, 1998). Information regarding fabric, glazing, ventilation, water heating, space heating and fuel costs is required to carry out a SAP calculation. A SAP rating can be calculated for a domestic property which is an energy rating expressed on a scale of 1–100, the higher the number the better the standard. This allows comparisons to be made regarding the energy performance of a home. The calculation also predicts the energy use and associated carbon dioxide emissions.

As large numbers of dwellings are included within the domestic sub-model when studying a city or region, information about each dwelling has to be analysed with relative ease and speed. A procedure was developed for use within the model that groups together dwellings with similar energy performance characteristics creating ‘house types’. This needs fewer calculations when the whole or large sectors of the local authority are investigated. For example, if all houses within an area can be reduced to 100 types, then subsequent calculations only have to deal with 100 house types and not every house (for example, 55,000) in the area. This allows real time calculations to be carried out, such as estimating the consequences of applying specific energy saving measures.

A cluster analysis technique was used to identify dwellings with similar energy consumption and carbon dioxide emissions. The cluster analysis procedure ‘forces’ dwellings into a specified number of groups or ‘clusters’ based on selected built form characteristics and the age of the dwelling. The five characteristics used to describe an individual dwelling in order to create clusters are:

- heated ground floor area (m²);
- facade (m²);
- window to wall ratio;
- exposed end area (m²);
- property age.

These features are considered to have the greatest influence on domestic energy performance. Other features, such as heating system, insulation level, type of glazing were estimated from the age of the property and were used within the SAP calculations. A SAP result was therefore calculated for each of the 100 ‘house types’ created.

Further SAP analysis was undertaken to allow for the effect of the installation of different combinations of the six commonly used energy efficiency measures, as illustrated in Table 1, to be calculated.

Table 1
Energy efficiency measures commonly installed and costs

<table>
<thead>
<tr>
<th>Measure</th>
<th>Assumed improvement</th>
<th>Cost (at 2001 in NPTCBC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fully draught proofed</td>
<td>All windows and doors</td>
<td>£75</td>
</tr>
<tr>
<td>Hot water tank</td>
<td>Jacket of 100 mm thickness</td>
<td>£12</td>
</tr>
<tr>
<td>Wall insulation</td>
<td>U-value 0.4 W/m²K</td>
<td>£240 for cavity</td>
</tr>
<tr>
<td>Loft insulation</td>
<td>U-value 0.25 W/m²K</td>
<td>£140</td>
</tr>
<tr>
<td>Double glazing</td>
<td>U-value 3.3 W/m²K</td>
<td>£3000</td>
</tr>
<tr>
<td>New boiler</td>
<td>Condensing boiler efficiency</td>
<td>£2000</td>
</tr>
</tbody>
</table>
Each of these SAP ratings were then adjusted to take into account different domestic heating fuel types (as shown in Table 2). This was derived from a household questionnaire sent to 2000 occupants in NPTCBC to gain knowledge on occupancy, heating type and fuel, age of heating system and energy efficiency measures installed.

The costs of the energy efficiency measures that could be installed are shown in Table 1 at the time of the survey. These costs are based upon measures already installed in NPTCBC by the local authority.

The combination of these figures enables an average SAP rating for the 100 ‘house types’ to be calculated, the energy use and carbon dioxide emissions estimated taking into account the domestic heating fuels use. Predictions of potential energy use and emission savings and the cost of this work can also be made using the figures provided in Table 1.

2.3. Area resolution

The EEP model is able to display results as thematic maps, based on small areas down to postcode unit size which is the ideal size for visual analysis of small areas such as a village or small town (Fig. 3). For larger scales, such as whole local authority areas, postcode units can be too detailed, with too many areas to be displayed (over 3500 postcode units in NPTCBC). With this number of postcode units, it proved difficult to identify the ‘hot spots’ required for a focussed based approach for the installation of energy efficiency measures.

It was therefore decided to allow for the aggregation of data to a higher level, which would enable the identification of larger problem areas, before focusing on the more localised ‘hot spots’. Ward level analysis (Fig. 4) was chosen as an appropriate size (a ward typically includes 65 postcode units or 1300 houses) as a maps are available to illustrate the results, ward areas are clearly defined and understood by local authority staff and additional information is available for these areas.

2.4. House SAP rating predictions

The energy efficiency of the local authority housing stock in NPTCBC has been aggregated to illustrate the range of SAP ratings.
Fig. 5. Distribution of the SAP ratings of NPTCBC local authority housing stock at baseline energy efficiency levels.

ratings (Fig. 5). This shows that the dwellings are mostly in ‘band E’ (SAP rating of 40–54) based on the scale introduced in the Home Information Pack (ODPM, 2003).

The Welsh Assembly Government has introduced the Welsh Housing Quality Standard (Welsh Assembly Government, 2002), as a common target standard for social housing in Wales. The EEP model is able to provide information to establish the energy efficiency standard for local authority and rented housing. The requirement is that a dwelling must be assessed using the SAP rating system, and have a rating of between 58 and 70 depending upon the floor area of the dwelling (Table 3).

The completed survey of NPTCBC owned domestic properties formed the basis of a series of ‘what if scenarios’ that enabled testing of the best method of meeting the standard. The local authority owned 9853 properties during the survey period (2001) and these were assessed and compared to the Welsh Housing Quality Standard required. It was found that only one dwelling achieved the standard at the time of survey, whilst 304 dwellings would require extensive energy saving measures, and the rest requiring some improvements. If all of the energy saving measures listed in Table 4 were applied to all 9853 dwellings the cost would have been an estimated £53 million. The improvement in SAP ratings in NPTCBC as a result of this ‘blanket’ approach is illustrated in Fig. 6. However, if a targeted approach was used, where particular packages of measures were applied to different house types as appropriate, the cost would be reduced to an estimated £26 million to more precisely achieve the standard which is illustrated in Fig. 7. The most appropriate package of measures for each house type was chosen by cost of installation, existing standard of the property and measures possible, based on the type of property.

The overall energy efficiency of the local authority housing stock with targeted measures installed improves the majority

<table>
<thead>
<tr>
<th>Floor area (m²)</th>
<th>SAP rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 35</td>
<td>58</td>
</tr>
<tr>
<td>36–40</td>
<td>59</td>
</tr>
<tr>
<td>41–45</td>
<td>60</td>
</tr>
<tr>
<td>46–50</td>
<td>61</td>
</tr>
<tr>
<td>51–55</td>
<td>62</td>
</tr>
<tr>
<td>56–60</td>
<td>63</td>
</tr>
<tr>
<td>61–70</td>
<td>64</td>
</tr>
<tr>
<td>71–80</td>
<td>65</td>
</tr>
<tr>
<td>81–90</td>
<td>66</td>
</tr>
<tr>
<td>91–100</td>
<td>67</td>
</tr>
<tr>
<td>101–110</td>
<td>68</td>
</tr>
<tr>
<td>111–120</td>
<td>69</td>
</tr>
<tr>
<td>Over 120</td>
<td>70</td>
</tr>
</tbody>
</table>

Table 3
Welsh Housing Quality Standard target SAP ratings per floor area

Table 4
Energy efficiency packages to achieve the WHQS target

<table>
<thead>
<tr>
<th>Energy efficiency measure</th>
<th>Number of properties</th>
<th>Total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cavity wall insulation</td>
<td>253</td>
<td>£60,720</td>
</tr>
<tr>
<td>Non-cavity wall insulation</td>
<td>14</td>
<td>£56,000</td>
</tr>
<tr>
<td>Loft insulation, double glazing and draught proofing</td>
<td>20</td>
<td>£64,300</td>
</tr>
<tr>
<td>Double glazing and draught proofing</td>
<td>2</td>
<td>£6150</td>
</tr>
<tr>
<td>New boiler</td>
<td>898</td>
<td>£1,796,000</td>
</tr>
<tr>
<td>New boiler and loft insulation</td>
<td>407</td>
<td>£870,980</td>
</tr>
<tr>
<td>New boiler and cavity wall insulation</td>
<td>6665</td>
<td>£14,929,600</td>
</tr>
<tr>
<td>New boiler and non-cavity wall insulation</td>
<td>392</td>
<td>£2,352,000</td>
</tr>
<tr>
<td>All measures</td>
<td>897</td>
<td>£5,162,235</td>
</tr>
<tr>
<td>Unable to reach standard</td>
<td>304</td>
<td>£837,520</td>
</tr>
<tr>
<td>Standard achieved</td>
<td>1</td>
<td>£0</td>
</tr>
<tr>
<td>Total</td>
<td>9853</td>
<td>£26,135,505</td>
</tr>
</tbody>
</table>

Fig. 6. Distribution of the SAP ratings with all energy efficiency measures installed in all local authority owned properties.
of dwellings to ‘band D’—SAP rating of 55–69. If all of the
energy saving measures listed in Table 4 were applied to all
9853 dwellings the majority would be in ‘band C’—70–84 SAP
rating. The Welsh Housing Quality Standard requires domestic
properties to be in ‘band D’—SAP rating of 58–70. By specifi-
cally targeting resources rather than using a ‘blanket—one size
fits all’ approach funds can be utilised more effectively and large
financial savings can be made.

2.5. Stock profiling

Although the main purpose of collecting data for housing was
to estimate energy performance, once the data was collected it
proved to have other uses. The survey of 55,000 dwellings in
NPTCBC allowed for a complete stock profile to be produced,
according to property age (Fig. 8), heated floor area and number
of storeys. This could then be compared to national or regional
figures where available.

3. Public health

Maintaining and improving quality of life is a major goal of
sustainable development. The impact of the built environment on
health is an area that is often discussed but there is little evidence
of real relationships between aspects of the built environment
and their health impacts. The expansion of the EEP model to
include health predictions involved the creation of a multi-level,
cross-disciplinary framework for evaluating the impact of the
built environment on the health of people and communities.
A ‘health’ sub-model was developed to fit into the existing
EEP model framework, which can then be used to measure, dis-
play and predict links between the built environment and health.
This new health sub-model was initially developed to relate to
three built environment scales and three health outcomes illus-
trated in Table 5. The development of the health sub-model was
dependent upon the findings of a number of discrete studies
conducted in the three public health domains of cardio-vascular
disease, injuries in the home and mental health, in relation to the
indoor environment, house layout and neighbourhood. Table 6
summarises the purpose of evaluation in each of these studies
and the associated development tasks.

Data from the existing sub-models within EEP were used and
developed upon by the health studies. This included a descrip-
tion of the total housing stock for NPTCBC, which was used
to provide a unique sampling frame for population surveys of
different types of housing. The studies also required the develop-
ment of a number of survey tools to measure aspects of the
built environment not already covered by the EEP model. These
survey tools and techniques covered aspects of neighbourhood
quality, indoor and outdoor home injury hazards and indoor air
quality.

3.1. Mental health and neighbourhoods study

The role of the built environment on mental health is com-
ing under close scrutiny as the built environment is potentially
modifiable by interventions by local authorities and central gov-
ernment. However the mechanisms by which place affects the
people who live there are not entirely clear (Barton, 2003;
Brown et al., 2003). The mental health and neighbourhoods
study, involved measuring the association between neighbour-
hood quality and the prevalence of common mental disorder
adjusting for individual characteristics. The aim of the study
was to identify whether peoples mental or psychological health
is affected by the characteristics of the neighbourhood they live
in, independent of the characteristics of the people. This involved
measuring the association between neighbourhood quality and
mental or psychological health, that is common mental disor-
ders of depression and anxiety, before and after adjustment for
individual characteristics, and also to measure the association
between neighbourhood quality, social capital and social sup-
port and mental health scores. Two tools were applied, one to
assess the neighbourhood quality, and one to assess the mental
health of the people.

The tool designed to measure neighbourhood quality, Res-
idential Environment Assessment Tool (REAT), was a survey
Table 5
Spatial levels and disciplines of the health sub-model

<table>
<thead>
<tr>
<th>Spatial level</th>
<th>Environment</th>
<th>Scientific discipline</th>
<th>Public Health application</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Indoor air quality</td>
<td>Building physics</td>
<td>Cardio-respiratory diseases</td>
</tr>
<tr>
<td>2</td>
<td>Housing layout</td>
<td>Design</td>
<td>Injury prevention</td>
</tr>
<tr>
<td>3</td>
<td>Neighbourhood and community</td>
<td>Social science/planning</td>
<td>Mental health</td>
</tr>
</tbody>
</table>

An instrument used to record data about observable characteristics of urban residential environments. Information was collected at a postcode unit level during a site visit where observations relating to physical environmental characteristics, associated with neighbourhood quality and desirability were recorded using the tool. Physical environmental characteristics which were expected to be associated with neighbourhood quality and desirability, as well as reflecting social aspects of the neighbourhood were scored using the tool. The tool focuses on those aspects of a neighbourhood that can be easily and reliably observed from the street and are not likely to vary at different times of the day. Items were measured at:

- A property level—how well maintained is the front garden? Number of properties with trees in the front garden.
- Postcode unit level—how littered is the street? What is the condition of the footpaths?

The data collected using REAT enabled an overall 'attractiveness' score to be calculated, for each postcode unit sampled.

The NPTCBC Citizen Panel was also surveyed as part of the study in order to weight the relative importance of different aspects of the neighbourhood. The NPTCBC Citizen Panel comprises of a representative group of residents from a range of ages and socio-economic backgrounds—97 members replied (65% response rate). Thirty seven responses were also received from members of staff at the local authority when the survey was included on the local authority website. This survey helped to determine the importance of different neighbourhood characteristics, for example, abandoned cars in a street versus presence of recreational space nearby. Using this information a scoring system was devised and a REAT score was recorded for each of the 51 postcode units with a high score representing low neighbourhood quality.

A cross-sectional questionnaire survey was undertaken in NPTCBC. One thousand and fifty eight (68%) responses from 647 households in 51 postcode units were returned. This questionnaire included items on mental health, social aspects, feelings about the local area and more general population questions.

The questionnaire and a neighbourhood quality tool were applied in the same 51 postcode unit areas. These were selected to ensure that both urban and rural areas and a range of levels of deprivation, as measured by Townsend scores (Townsend et al., 1988), were included. A postcode unit, often a single street of houses, was considered to be an easily measurable, readily defined geographical area that would reflect important area differences in physical appearance and also complimented the data already collected within the EEP model.

Findings have shown that mental health is overwhelmingly associated with economic factors such as income and jobs. In the NPTCBC study a significant association with the REAT score at postcode unit level was not found (Dunstan et al., 2005). Attractiveness scores for the 51 sample postcode units using REAT can be mapped ranging from 8 (good) to 46 (poor) are presented in Fig. 9. Thus postcode unit results can be produced illustrating overall attractiveness score, or to look at particular features such as the level of physical incivilities or amount of territorial functioning in order to assist the local authority in identifying areas that need to be targeted for improvement.

In a similar study in Caerphilly County Borough Council local authority area included a much larger sample (12,408) in 325 enumeration districts and 36 wards. Significant area effects were stronger at the smaller enumeration district level. Preliminary findings have identified that individual mental health is significantly associated with area deprivation, social capital and postcode unit level REAT contextual variables after adjusting for characteristics of individuals.

Table 6
Health domain, associated development tasks and nature of evaluation

<table>
<thead>
<tr>
<th>Health domain</th>
<th>Development task</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mental health</td>
<td>Health sub-model to measure quality of neighbourhoods</td>
<td>Variations in mental health score by neighbourhood quality</td>
</tr>
<tr>
<td>Injuries</td>
<td>- Relate accident data to postcode units</td>
<td>Variations in injury rates by type of house to identify risk factors</td>
</tr>
<tr>
<td></td>
<td>- Measurement of safety features</td>
<td></td>
</tr>
<tr>
<td>Cardio-respiratory disease</td>
<td>- Sub-model to identify houses with specific moulds and CO problems</td>
<td>- Evaluation of methods to reduce moulds and carbon monoxide</td>
</tr>
<tr>
<td></td>
<td>- Techniques for measuring specific environmental exposures</td>
<td>- Correlation of bio markers with environmental exposures</td>
</tr>
<tr>
<td></td>
<td>- Biomonitoring techniques</td>
<td></td>
</tr>
</tbody>
</table>
3.2. Home injuries

Injuries are the leading cause of death amongst children over the age of 1 year and prevention is therefore a public health priority (Lyons et al., 2006a). The injuries study investigated whether certain types of home were more hazardous (Lyons et al., 2006b). This involved linking data on the occurrence of home injuries with population data and using the EEP model information to determine if certain types of home appear to be more hazardous. It required the development of a survey instrument to measure home hazards and utilisation of this to determine whether certain types of homes contain more hazards.

The tool, ‘Safehome’, developed at the Welsh School of Architecture (Pockett et al., 2004) (Fig. 10) created for the injuries study was the home survey. This was developed to measure existing home hazards on a room-by-room basis in an attempt to identify whether hazards are related to different property types. This tool included questions and measurements from the garden and internal built environment and included factors that the research team considered might be important, including questions and measurements relating to each room within a house, outside spaces such as gardens and balconies and some personal questions regarding previous injuries and general health. Recruits for the survey were obtained from the A&E ward at Port Talbot. These were people who were attending with an injury that had occurred whilst in the home or garden. Non-injured individuals were identified from a random sample of properties selected from across NPTCBC. The survey
was carried out by Environmental Health Officers from the borough. A total of 216 responses (from 574 homes) were achieved (response rate 37.6%). The frequency of hazards per home was recorded and a hazard score calculated.

Further analysis could also be undertaken using data within the All Wales Injury Surveillance System (AWISS) (Lyons et al., 2002) which contains individual accident data from emergency departments. As personal accident data is covered by the Data Protection Act the research team could not have access to data for each dwelling. However, NPTCBC housing information collected as part of the EEP model could be sent to NHS staff who manage injury data. This meant that property level data could be matched up with accident occurrence. This involved the development of a unique anonymous data matching method involving academic and NHS bodies to calculate injury rates in different house types (Newcombe et al., 2005).

54,913 addresses in NPTCBC were assigned EEP house type codes relating to type of dwelling (detached, semi-detached, converted flats, purpose built flats, and terraced), size and age as discussed in Section 2.1. Eighteen thousand and forty four attendances at hospital with an injury occurring in the home from a population of 112,248 took place over the period of 2 years (1999 and 2000). Sixteen thousand three hundred and fifty eight (90.6%) of these could be matched to the EEP database of homes. Property types were matched with a NHS list of all people registered with free use of primary health care in Wales to give age and sex details for each property type. This information was combined to provide information on the number, age and sex of people in each of the 94 property types.

The results of linking information from accident and emergency departments with types of homes and the number of people living in those homes showed the following:

- Injuries in the home are very common—16% of people attended A & E with an injury in the home over a two year period.
- For less severe injuries people living near hospitals are more likely to attend so simple maps of attendance rates can be misleading.
- Home injuries are more common in less affluent areas but not by a large extent.
- Contrary to government reports the research did not find that older homes were more hazardous.
- People living in purpose built flats had twice the rate of overall injuries and more than five times the rate of poisoning compared with other homes.
- Many people with injuries in the home were reluctant to allow council officers access to inspect the home for hazards.

Using the results from the comparison of injury data and property types a risk map was produced as illustrated in Fig. 11 for the whole of NPTCBC using the risk ratio for a postcode unit. This can allow for pinpointing of hotspots of accident risk in order to target funding to reduce risks.

3.3. Cardio-respiratory disease study

Two hundred asthmatic adults and children, who resided in homes with mould contamination, were recruited to take part in the study to link asthma to house environmental conditions. Identification of asthmatics was undertaken in collaboration with local GPs. Baseline measurements were made of symptoms and lung function as well as of mould types and concentrations.

The survey technique developed to identify and measure mould in domestic properties was based upon a systematic approach to site visits which included the collection of airborne moulds, measurement of temperature and air humidity in the affected rooms, taking mould samples from the walls and assessing occupants’ peak flow and allergic response. Homes were randomly divided into either intervention (received treatment) or control (no treatment) groups.

Fig. 11. Map illustrating postcode units shaded according to accident risk.
The mould survey identified houses for an intervention study. The intervention consisted of the removal of surface mould with a chemical water based wash, followed by installation of a positive pressure fan in the loft space of the dwelling. This fan introduced air into the home at a low continuous rate encouraging air from inside to outside. This diluted, displaced and replaced old contaminated air in the home with drier and filtered air. Respiratory symptoms and environmental measurements were taken again 6 and 12 months after baseline. After 6 months, the people from whose houses the mould had been removed were much more likely than the others to report improvement in their symptoms. At 12 months the difference appeared to be somewhat less. The intervention was effective in the long term eradication of mould and that getting rid of indoor mould is feasible and is helpful to people with asthma.

In attempting to recruit the sample for this study a much larger set of homes responded to questionnaires and ‘self-reported’ mould. Using the EEP model for this self-reported data it was found that single and three storey properties and also flats experience contamination by moulds more frequently than others, i.e. this data was used to inform the sub-model, which uses built form data for the Borough to calculate the number of potential properties with mould (Fig. 12).

The cardio-respiratory disease study also compared environmental measurements of indoor carbon monoxide (CO) and biomarker measurements of individual exposure to CO again to identify houses with specific CO problems. The aim was to find out if indoor background levels of CO were sufficient to effect enzyme levels involved in cardiovascular disease. One hundred individuals in the age range 55–75 were recruited. Households with a resident smoker were excluded, as were individuals who were on nitrate medication (used to treat heart conditions). In addition 23 households with a resident smoker were monitored for comparison. Environmental concentrations of CO in the living room were measured and logged every 5 min over a period of 7 days. Mean environmental concentrations were very low, less than 1 parts per million (ppm). Short-term peak levels over approximately 1 h increased up to 22 ppm but this still remains within the World Health Organisation’s guidelines of 26 ppm. In homes of smokers mean environmental levels were 2.5 ppm with short-term peaks up to 54 ppm. On one occasion in the summer and one in the winter, during the week of environmental monitoring each individual gave a blood sample. Although the levels of environmental CO measured were very low throughout the year, surprisingly a paired analysis of individuals showed that the concentrations of blood enzymes were significantly higher in the winter months compared to the summer months. Generally, there were no harmful effects of CO detected in the study.

Fig. 12. Map illustrating postcode units where mouldy homes are likely to occur.
4. Conclusions

The EEP model enables the prediction of housing energy use and carbon dioxide emissions, neighbourhood quality, home hazards and mouldy homes for a whole local authority by extrapolating the findings of the study samples. The data can be represented by using thematic maps, which highlight variation between areas in terms of particular health outcomes or environmental factors enabling easy identification of areas that can be targeted with financial incentives for necessary improvements to improve the environment and health.

The main barrier to the wider uptake of EEP is the time and resource needed to survey the building stock of a city or local authority. For example about 18 person-months of effort were needed to collect all the data for NPTCBC. A new research project has just started at the WSA, Cardiff University which aims to automate the collection of data through the use of pattern recognition and satellite imaging to identify building types and age. This would considerably speed up the access and acquisition of data and make it possible to quickly model whole regions containing many properties.

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References


Dunstan, F., et al., 2005. An observation tool to assist with the assessment of urban residential environments. J. Environ. Psychol. 25, 293–305.


