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MET OFFICE

Review of the Met Office Model for Emergency Admissions to Hospital

Final Report

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Executive Summary

1. BACKGROUND AND OBJECTIVES

Statistical models were developed by the Southampton group (led by Arjan Shahani) to forecast emergency admissions to hospitals on a regional basis for the Met Office's *Forecasting the Nations Health* (FNH) project.

There were 156 models developed to forecast emergency admissions for:

- Medical;
- Non-medical;
- 0-14 years;
- 15-64 years;
- >64 years;
- Total emergency admissions.

This report identifies, describes and critically appraises the technical characteristics of these models as part of YHEC Ltd's evaluation of FNH. The focus of this review is on:

- Data used to model emergency admissions;
- Estimation techniques used to project NHS activity;
- Statistical diagnostic tests;
- Future areas for development/improvement.

2. METHODS

We comment here on the census data used to construct 5 socioeconomic clusters for England, the construction of the temperature variables for each of the socioeconomic clusters, the other explanatory variables, and the methods for estimation.

Diagnostic tests of model adequacy are conducted using four models (two *good* and two *poor*) from two regions:

- Northern Region, socioeconomic group 1, (i.e. the *poor* models);
- Southeast Region, socioeconomic group 1, (i.e. the *good* models).

For each of these regions, models for total admissions and medical admissions were assessed.

Diagnostic tests applied included tests for autocorrelated errors, heteroskedasticity (i.e. non-constant variance), normality of residuals (i.e. whether the error had the properties of a normal distribution), non-stationarity (i.e. trends in the error terms), and independence (i.e. correlation of errors between models).

3. RESULTS

There are nine Public Meteorological Service (PMS) regions in England. These were disaggregated into 26 postcode clusters based on socioeconomic characteristics. Up to five socioeconomic groups were identified within each of these PMS regions, through a principal components analysis and a cluster analysis was a useful and a commendable approach, facilitating detailed cross-section data to be used in time-series analysis. The five socioeconomic groups were later aggregated into three groups; this has led to some inefficiency (statistically) with respect to the weather variables. In addition, the census data provided, on which this socioeconomic grouping was performed, was restrictive and is inevitably likely to be out of date despite it being the most up-to-date data available at the time.

Isothermal cluster analysis was also undertaken to identify different areas within each of the five socioeconomic groups, within each PMS region. Weather data was restricted to maximum temperature and lowest maximum temperature for each of the isothermal clusters in each socioeconomic group, for the previous (arbitrarily chosen) 2, 7, 10 and 15 days. The aggregation of socioeconomic groups 3, 4 and 5 into one group meant that temperature data from one isothermal region in one socioeconomic group is potentially used to forecast emergency admissions in another socioeconomic group. The clustering of weather data into isothermal clusters appears to be of limited value, it is cumbersome to work with, and offers little explanatory power. An improved approach might be to use weather data for each socioeconomic group as a whole rather than disaggregating into isothermal clusters.

Models were developed using daily data on hospital admissions, weather and GP consultation rates for infectious diseases for the four years from April 1995 to March 1999. A step-wise regression procedure was used to include/retain/exclude variables from the models. The coefficients from these models are used to forecast admissions in 2003. This is four years later, and it is not unlikely that socioeconomic boundaries and management practices for emergency admission have changed. In addition, it is likely that there may be substantial population changes in some areas over this time, with increases in total population and the proportion of older people.

With the exception of simple correlation coefficients between the forecast and actual admissions, no statistical diagnostic tests were undertaken by Southampton. The statistical tests undertaken by YHEC show there is substantial autocorrelation in errors. There was some heteroskedasticity in one of the four models tested. Tests for trends showed substantial non-stationarity in three of the four models. One model had errors that were not normally distributed, and all models suffered from either excess kurtosis or skewness. In addition, there was statistically significant correlation of errors between regions, suggesting that factors causing forecast errors in one region also cause forecast errors in another (i.e. non-independence of errors). Given these diagnostics, variables are likely to have been incorrectly included or excluded in the step-wise procedure used.

Implementing the models by the Met Office has required an error-correction mechanism ("error tracking") to adjust forecasts to reasonable levels. It is noted that this was the first attempt at developing a model and implementing the model with live forecasts. As such, suggested improvements will be beneficial. As a minimum, trends should be included in the models, and ideally, if the models are to be used for the next few years, short-run and long-run dynamics should be incorporated.

4. DISCUSSION

The models developed by Southampton were a major undertaking and form the basis for future development. Many aspects of the model development are commendable (for example, the socioeconomic data from the 1991 Census was used in such a way that enabled geographic regions within England to be defined and hospital admission data to be subsequently disaggregated; see Section 2.1).

The models developed for total admissions provided the best fit between actual and forecast admissions (with a mean goodness-of-fit of 71%) and models for the 0-14 year age-group provided the worst fit (mean goodness-of-fit of 34%). That is, forecasting accuracy was better with higher levels of aggregation. However, modelling the volatility apparent in disaggregated data is of greatest use and interest.

There are many limitations with the models developed; some of these are relatively minor and pertain to the data used, some are statistical issues on how the data was used, and some are conceptual issues. All of these limitations need to be addressed in future model-development work on forecasting hospital admissions.

The major limitations were:

- Socioeconomic clusters were based on the 1991 census; these groupings are likely to have changed over the last 12 years and/or compared with the 2001 census;
- The models were constructed with hospital and temperature data from April 1995 to March 1999; the coefficients from that period were used to generate forecasts in 2003. Forecasts made four years into the future based on four previous years of data (although this was the best available at the time) are unlikely to be robust. (This is the subject considered in a separate report by YHEC reviewing the forecasts for the winter of 2002/03);
- Trends in hospital admissions and population growth were not considered. This results in poor forecasts and invalid statistical tests (e.g. *t*-tests and *F*-tests).

There are some important aspects that need to be refined and addressed in future development of the models. These include:

- Updating socioeconomic cluster boundaries based on the 2001 Census data;
- Aggregating temperature variables to match with the boundaries of the socioeconomic groups;
- Including trends in the analysis;
- Avoiding use of a step-wise approach or control for autocorrelation;
- Including dynamics for population and hospital changes over time.

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Forecast Verification

Final Report

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JULY 2003

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Key Findings

Between November 2002 and March 2003 the Met Office generated forecasts for trust admissions and collected data on actual admission levels. This report presents findings from the comparison of these two sets of data. It is important to note that development of this type of model is an iterative process and that this report only documents preliminary findings.

The key finding relating to emergency and medical admissions are very similar and so will be discussed together with differences between the two types of admission highlighted.

- **Forecast accuracy does not appear to be sensitive to how far in advance a forecast is made**

This suggests that the model may not be sensitive to new information predicting changes in the weather. Alternatively, it may reflect the accuracy of weather forecasting or the appropriateness of the way weather variables are represented within the model. Another explanation could be that weather *per se* may not have a strong influence on UK demand for hospital admission.

- **Forecasts of hospital admissions show a narrower range of variation than seen in real life**

The chosen modelling technique is most appropriate for broad analysis of averages and trends. Since, as far as hospital management is concerned, the greatest potential benefits of forecasting concern unexpected extremes of demand which are by nature rare events, it is likely that the current model may need to be modified or enhanced by additional modelling aimed at rare event prediction.

- **Under- and over-estimates of demand**

It is evident that forecasts of emergency admissions tend to under-estimate demand, whereas the forecasts for medical admissions tend to over-estimate the level of demand. As estimates are based on historic data calibrated to reflect expectations of the future we suspect that this may be due to the way in which adjustments have been made to reconcile past experience with current demand levels.

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Analysis of Trusts' Use of FNH Website and Forecasts

Final Report

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C O N S O R T I U M

Executive Summary

York Health Economics Consortium were commissioned by the Met Office to evaluate its 'Forecasting the Nation's Health' (FNH) project. As part of this evaluation, trusts' use of the FNH website during the winter period (December 2002 to March 2003) was assessed. The aim of the FNH project was to predict changes in admissions and thereby, permit trusts to accommodate fluctuations in demand. Forms were distributed to participating trusts each week during the winter period, who then completed and returned them. These weekly reporting forms were designed to capture access to the website by trusts and record any action taken on the basis of the forecasts. This report outlines the results obtained from these weekly forms.

Generally the response rate from the weekly logs was high (75%), although there was a slight one-off fall over the Christmas period. Almost 66% of trusts' responses stated that they had accessed the website during the winter period. Furthermore, of the 30 trusts participating in this pilot, 25 (89%) answered that they had accessed the website at least once over the winter period. Trusts' use of the website declined over time. One possible reason for this decline is that trusts use the website in times of severe weather to aid in planning for anticipated admissions. This explanation is supported by the noticeable decline in use after February, coinciding with the end of the second influenza peak and relatively mild weather conditions.

Over the entire winter period, approximately one-fifth (21%) of trusts answered that they had taken action on the basis of the FNH forecasts. Most actions taken were aimed at generating capacity. One-quarter stated that they were unable to take action due to capacity constraints. Interestingly, the proportion of trusts taking action increased over the winter period, while there was a decline in the percentage reporting capacity constraints. However, over half (55%) did not take action because it was not required. This may suggest that the full potential of the FNH forecasts was not revealed due to a comparatively mild winter.

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Qualitative Analysis of FNH Website and Forecasts

Final Report

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C O N S O R T I U M

Executive Summary

York Health Economics Consortium (YHEC) was commissioned by the Met Office to conduct an independent evaluation of their project 'Forecasting the Nation's Health' (FNH). As part of this evaluation, YHEC undertook an analysis of users' opinions of, and satisfaction with, the FNH project. The outcome of this assessment is presented in this report.

The aim of this qualitative analysis is to determine users' opinions of the service provided by the Met Office during the winter period (November 2002 to March 2003). Users were classified into two groups. The first consisted of acute hospital trusts who participated in the FNH project. The second group was made up of ambulance trusts, GP Co-ops and NHS Direct who also had access to the FNH website. Contact had already been established with the first group through another part of the evaluation which examined their weekly use of the forecasts.[1] Questionnaires asking about winter pressures, opinions of the FNH website and forecasts, and other mechanisms for predicting demand were distributed to these two groups. The questionnaire sent to the other participants also requested respondents to provide an estimate of their use of the website during the winter period.

In addition, to these two groups, questionnaires were sent to all acute hospital trusts in England (excluding those already participating in the project). This control group was asked to provide details of the winter pressures they faced and the factors that influenced decisions to change capacity. This information provided an indication of the scale of excess demand they experienced and the structure of the decision-making processes in the absence of access to the FNH forecasts.

The results of the questionnaires suggest that similar proportions of participating acute hospital trusts and those in the control group never experienced events such as red alert status or diversion.[2] When these events did occur, the proportion in both groups that experienced red alert status and closure was comparable. Conversely, the incidence of diversion was greater among the control group, while a larger proportion of participating trusts exceeded the four-hour trolley wait. This suggests that in general, any possible benefits attained through the FNH forecasts are not discernible because of the influence of other factors, such as geographical differences.

Of the trusts in the control group, 96% answered that they had taken action to increase capacity – largely in the form of opening additional beds or wards and/or increasing staffing levels. Increases in demand would have put additional pressures on hospital infrastructure as most were operating at bed occupancy of 95% or over. A significantly smaller proportion reduced capacity (less than one-fifth), mostly by closing wards. In contrast, no ambulance trusts, GP Co-ops or NHS Direct organisations replied that they took action due to excess demand. This is consistent with the finding that almost all of these organisations considered the pressures during the evaluation winter period to be manageable. The relatively lower degree of pressure on these institutions during this time may explain why just over half of the

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1 This information is fully reported in another YHEC report (YHEC, 'Analysis of Trusts' Use of FNH Website and Forecasts: Final Report', May 2003).

2 A trust may be put on red alert status to notify staff to possible risks. For example, a poor availability of intensive care beds may warrant a trust being put on red alert. The objective of diversion is to find alternative treatment locations for patients who would otherwise be admitted to hospital.

respondents had used the website, and almost one-fifth of these accessed it less frequently than monthly.

On average, participants in the FNH project were quite satisfied with the service offered. Of all the categories considered, respondents were least satisfied with the accuracy of the forecasts. Participants were also pleased with the background support provided by the health mailbox, the user guide and the training CD.

Interestingly, the acute hospital trusts' opinion of the usefulness of the FNH forecasts improved following their participation in the 2002/2003 pilot, but the opinion of other participants was unchanged. In particular, almost two-thirds of hospital trusts improved their opinion of the project. Related comments suggested that this was largely due to increasing awareness of the role of the forecasts in bed management. Moreover, almost three-quarters of participants found the forecasts slightly or fairly useful in making decisions with regard to capacity. However, compared to other tools used in capacity-related decisions (such as daily fluctuations or past experience), FNH forecasts were the least useful.

In conclusion, user satisfaction with the FNH project was relatively high, although there is room for improvement in some areas. There is also scope to develop the role of the FNH forecasts in capacity-related decisions for all NHS service providers.