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# A comparison of multivariate and univariate time series approaches to modeling and forecasting emergency department demand in Western Australia.

Objective: To develop multivariate vector-ARMA (VARMA) forecast models for predicting emergency department (ED) demand in Western Australia (WA) and compare them to the benchmark univariate autoregressive moving average (ARMA) and Winters’ models. Methods: Seven-year monthly WA state-wide public hospital ED presentation data from 2006/07 to 2012/13 were modeled. Graphical and VARMA modeling methods were used for descriptive analysis and model fitting. The VARMA models were compared to the benchmark univariate ARMA and Winters’ models to determine their accuracy to predict ED demand. The best models were evaluated by using error correction methods for accuracy.

Results: Descriptive analysis of all the dependent variables showed an increasing pattern of ED use with seasonal trends over time. The VARMA models provided a more precise and accurate forecast with smaller confidence intervals and better measures of accuracy in predicting ED demand in WA than the ARMA and Winters’ method.

Conclusion: VARMA models are a reliable forecasting method to predict ED demand for strategic planning and resource allocation. While the ARMA models are a closely competing alternative, they under-estimated future ED demand.

Time series analysis (TSA) and forecasting are used extensively in business for tactical, strategic or operational planning and management.

Modeling techniques

1. VARMA Models

VARMA models are used to study the dynamic relationship between multiple variables, as well as improving the accuracy of predictions. The VARMA method was used to develop multivariate time series models to forecast statewide WA public hospital ED demand. The VARMA modeling technique allowed several dependent time series to be modeled together and accounted for both cross- and within-correlations of the series.

1. The ARMA models are developed from univariate time series modeling methods with a modeling process that is similar to the VARMA method. However, unlike the VARMA models, where several time series are modeled together, the ARMA method allows only one time series to be modeled at a time. This method was developed by Box and Jenkins [13]. The model was developed to provide a general framework for forecasting non-stationary observed time series data.

1. Model identification: First, historical data were used to identify a tentative model, where seasonal and/or non-seasonal trends and variability in the data were examined and removed by differencing and appropriate transformation, in the case of variability. Once stationarity was achieved, the autocorrelation function (ACF) and partial autocorrelation function (PACF) plots of the stationary ED presentation data were examined by comparing them to theoretical ACF and PACF to tentatively identify the orders for autoregressive (AR) and moving average (MA).

2.Model estimation: The parameters of the tentatively identified model were estimated using maximum likelihood estimation and the resultant residuals were checked for white noise.

3.Diagnostic check: Various statistical techniques were used including Akaike Information Criterion, Schwarz Information Criterion or Schwarz Bayesian Criterion and residual analysis of ACF and PACF to judge the goodness-of-fit of the model. If necessary, an alternative model was considered and the process was repeated until the best model was obtained.

Conclusion: VARMA models are a reliable forecasting method to predict ED demand by patient subgroups, and provide a more accurate fore- cast for ED demand than the normal or standard univariate ARMA and Winters’ methods. We observed that the prediction deviations (residuals) were smaller in the VARMA models, result- ing in smaller confidence intervals, making VARMA models an attractive method to forecast ED demand for strategic planning. The ARMA models are a closely related competing model for fore- casting ED demand. However, they under-estimated ED future demand compared with the VARMA models.