

16 May 2022

To: Jeffrey A. Kline  
Editor-in-Chief, Academic Emergency Medicine

**Re:** Probabilistic forecasting of hourly Emergency Department arrivals

Dear Editor-in-Chief,

We would be grateful if you could consider for publication our manuscript entitled “Probabilistic forecasting of hourly Emergency Department arrivals” as an Original Research article in Academic Emergency Medicine. We believe that our research is a good fit to the journal and makes a meaningful contribution to the topic, adding a huge value to the current knowledge in the ED forecasting given similar published articles in AEM including McCarthy et al. (2008), Schweigler et al. (2009), Chase et al. (2012).

This study aims to generate probabilistic forecasts of the hourly arrivals using real data from a major Emergency Department in the UK. The research is motivated by a real forecasting problem faced by planners in using forecasts to inform scheduling. Moreover, there are a few limitations in the literature which encourage us to undertake this research and examine different forecasting approaches:

- (i) Current approaches to forecast hourly ED arrivals do not fully consider the feature of data such as multiple seasonal cycles and changing profile over time;
- (ii) Almost all research studies produce point forecasts and, at best, report prediction intervals. There is a lack of studies presenting the entire forecast distribution of hourly ED arrivals that better represent the uncertainty of future arrivals, providing a holistic picture of future demand for a planner;
- (iii) most studies are not reproducible, as it is almost impossible to reapply the approaches without the help of the authors of those papers;
- (iv) studies are limited in terms of the length of historical data used for training purposes and forecast performance evaluation and

(v) some studies in this area lack a rigorous experimental design, i.e. they do not use benchmark methods or report forecast accuracy.

In this paper, we aim at filling these gaps, and our contributions to the literature are summarised as follows:

1. We produce probabilistic forecasts, in addition to the point estimation, quantifying uncertainties in future hospital admission, and comparing different forecasting methods using a suite of well-established evaluation metrics;
2. We develop an advanced dynamic model to forecast ED arrivals based on exponential smoothing family of models accounting for intermittent nature of series and exogenous variables with a modification for multiple frequencies, which produced highly-accurate point forecasts;
3. We develop a novel model to produce a probabilistic forecast of ED arrivals based on Generalised Additive Models for Location Scale and Shape, which accounts for i) the bounded and non-Gaussian distribution of arrivals, ii) multiple seasonalities, weather and holiday effects, and iii) variation in forecast uncertainty;
4. We benchmark the accuracy of our model against appropriate models used when multiple seasonality is present, i.e. Prophet, TBATS, Poisson Regression, Exponential Smoothing State Space model (ETS) and the simple empirical distribution of the arrivals;
5. We provide data and code enabling reproduction and refinement of the proposed approach and benchmarks. The proposed approach could also be generalised to forecast hourly requirements in other services, such as inpatient and outpatient care services, the number of attended incidents in ambulance services, or call volumes in clinical desk services.

Thank you very much for your consideration of this manuscript. We are looking forward to hearing from you in due course.

Sincerely,

Bahman Rostami-Tabar, *Cardiff University*  
Jethro Browell, *University of Glasgow*  
Ivan Svetunkov, *Lancaster University*

## References:

McCarthy, Melissa L., Scott L. Zeger, Ru Ding, Dominik Aronsky, Nathan R. Hoot, and Gabor D. Kelen. "The challenge of predicting demand for emergency department services." *Academic Emergency Medicine* 15, no. 4 (2008): 337-346.

Schweigler, Lisa M., Jeffrey S. Desmond, Melissa L. McCarthy, Kyle J. Bukowski, Edward L. Ionides, and John G. Younger. "Forecasting models of emergency department crowding." *Academic Emergency Medicine* 16, no. 4 (2009): 301-308.

Chase, Valerie J., Amy EM Cohn, Timothy A. Peterson, and Mariel S. Lavieri. "Predicting emergency department volume using forecasting methods to create a "surge response" for noncrisis events." *Academic Emergency Medicine* 19, no. 5 (2012): 569-576.