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Prof. Donald M. Yealy
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Subject: Paper submission for peer review

Dear Prof. Yealy,

We would be grateful if you could consider for publication our manuscript entitled *Hierarchical Time Series Forecasting in Emergency Medical Services* as an Original Research article in Annals of Emergency Medicine.

Time series forecasting problems at Emergency Medical Services have often inherent hierarchical and grouped structures. For example the ambulance demand (e.g. arrival calls, verified incidents, attended incidents) in the country could be disaggregated by region, then within each region by health board, within each health board, by station/hospital, and so on down to the post code area. Demand could also be disaggregated by other attributes that such as priority (e.g Red, Amber, Green) or nature of incidents. Despite the popularity of such data structure in EMS, the common practice is to produce point forecast for each time series independently and ignore the structure. This practice may lead to the lack of coordination and possibly undesirable and conflicting outcomes. Practices also rely on point forecasts, which does not acknowledge forecast uncertainty.

In this paper, we aim at filling these gaps identified in the academic literature and practice. We produce probabilistic forecasts of daily incident attended up to 84 days ahead using hierarchical forecasting methods for using state of the art forecasting methods. We apply hierarchical forecasting methods to produce a probabilistic and coherent forecast of attended incidents at multiple levels of aggregation. We use Exponential Smoothing State Space models, Poisson regression based on General Linear Models and tscount models, a Naive empirical distribution, and the ensemble model to generate base forecasts. These forecasting models collectively account for i) the spline trend, ii) multiple seasonalities, iii) holiday effects, and iv) serial dependencies in the time series. Our study is fully reproducible and we provide data and code through a Github repository enabling reproduction and refinement of the proposed approach and benchmarks. The proposed approach could also be generalised to forecast requirements in other healthcare services, such as admissions in Emergency Department, 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.

Yours sincerely

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