Bikeshare and Traffic Fatalities - A Case Study in Bayesian Time Series

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Introduction and Theoretical Approach

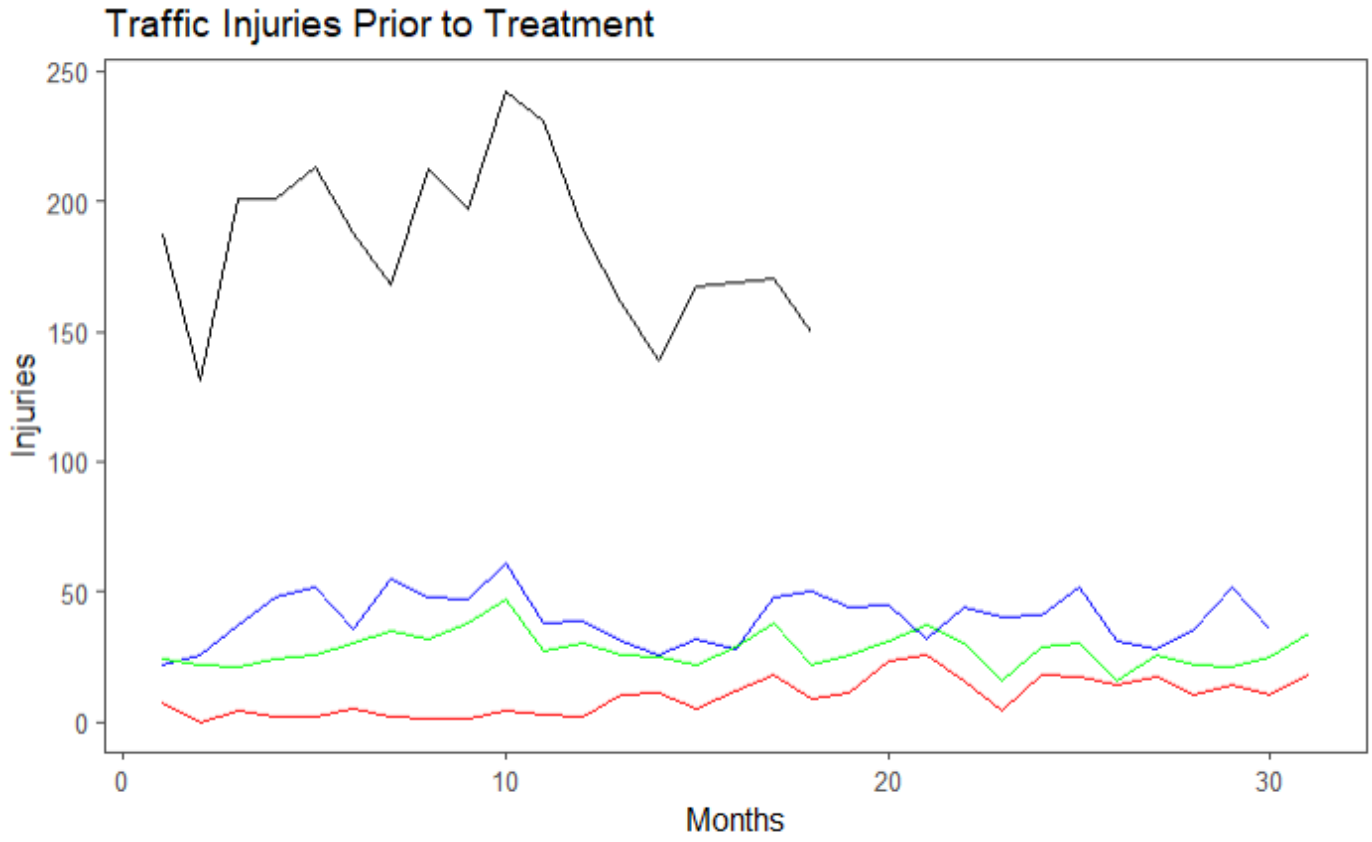

Figure 1: City-level Injury Trends

A Note on Causal Interpretations

- Prior goal: Interpret the forecast error $\bar{\epsilon} = \frac{1}{T}\sum_{t=1}^{T} \epsilon_t$ as the causal effect of bikeshare on traffic injuries

Initial Approach

- Goal: Estimate a simplistic ARMA(1,1) model for each city independently

$$\nu_t = \mu + \phi * y_{t-1} + \theta * \epsilon_{t-1}$$

$$\epsilon_t = y_t - \nu_t$$

$$\mu \sim \mathcal{N}(0, 10)$$

$$\phi \sim \mathcal{N}(0, 100)$$

$$\theta \sim \mathcal{N}(0, 100)$$

$$\sigma \sim \text{Student-t}(3, 0, 29.7)$$

$$\epsilon_t \sim \mathcal{N}(0, \sigma)$$

Initial Model Results

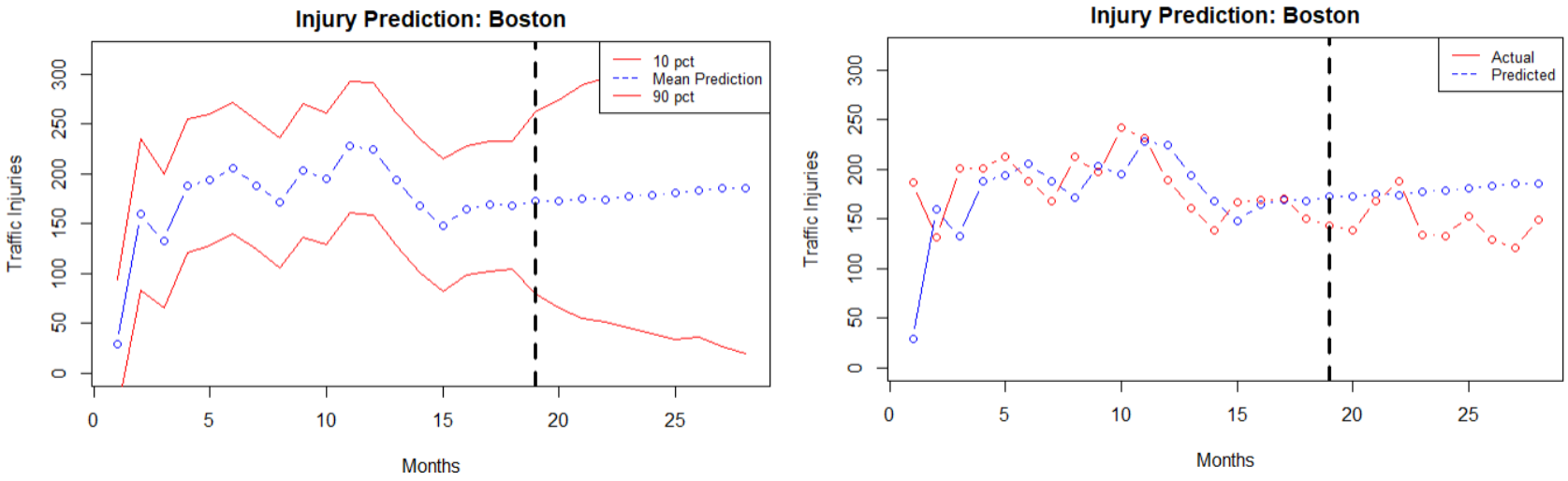

Figure 2: Boston ARMA(1,1)

Initial Model Results (ctd)

Period	Boston	Cambridge	Brookline	Summerville
Before	31.11	7.35	4.10	4.94
After	35.56	8.94	4.10	4.88

Figure 3: MAE by City

Issues with this Approach

- Fails to reduce the significant uncertainty associated with sample autocorrelation
- Significant computational errors indicate the model is poorly parameterized

Estimating the Autoregressive Term Hierarchically

- Allow the model to incorporate additional information to minimize uncertainty

Model Specification

$$y_t = a_t + b_t y_{t-1} + \epsilon_t$$

$$y_t \sim \mathcal{N}(a_t + b_t y_{t-1}, \sigma_e)$$

$$a_t \sim \mathcal{N}(a_{t-1}, \sigma_a)$$

$$b_t \sim \mathcal{N}(b_{t-1}, \sigma_a)$$

$$a_1 \sim \mathcal{N}(\mu_a, \sigma_a)$$

$$b_1 \sim \mathcal{N}(0, \sigma_a)$$

$$\mu_a \sim \mathcal{N}(0, \sigma_a)$$

Results

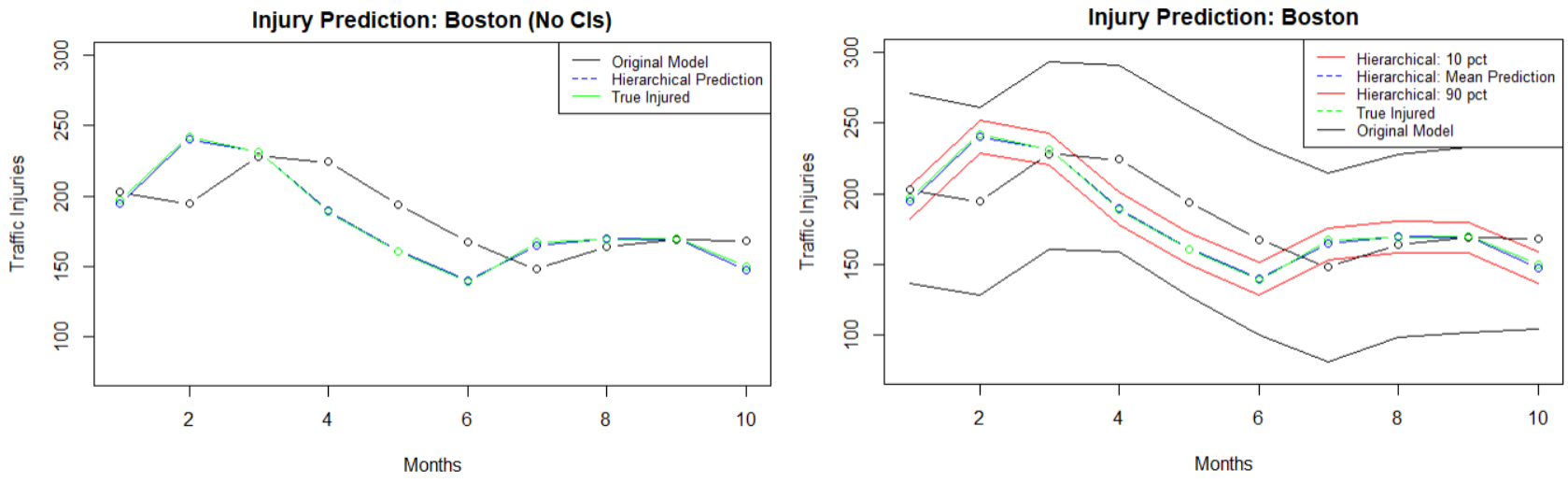

Figure 4: Boston Injury Predictions

Results (ctd)

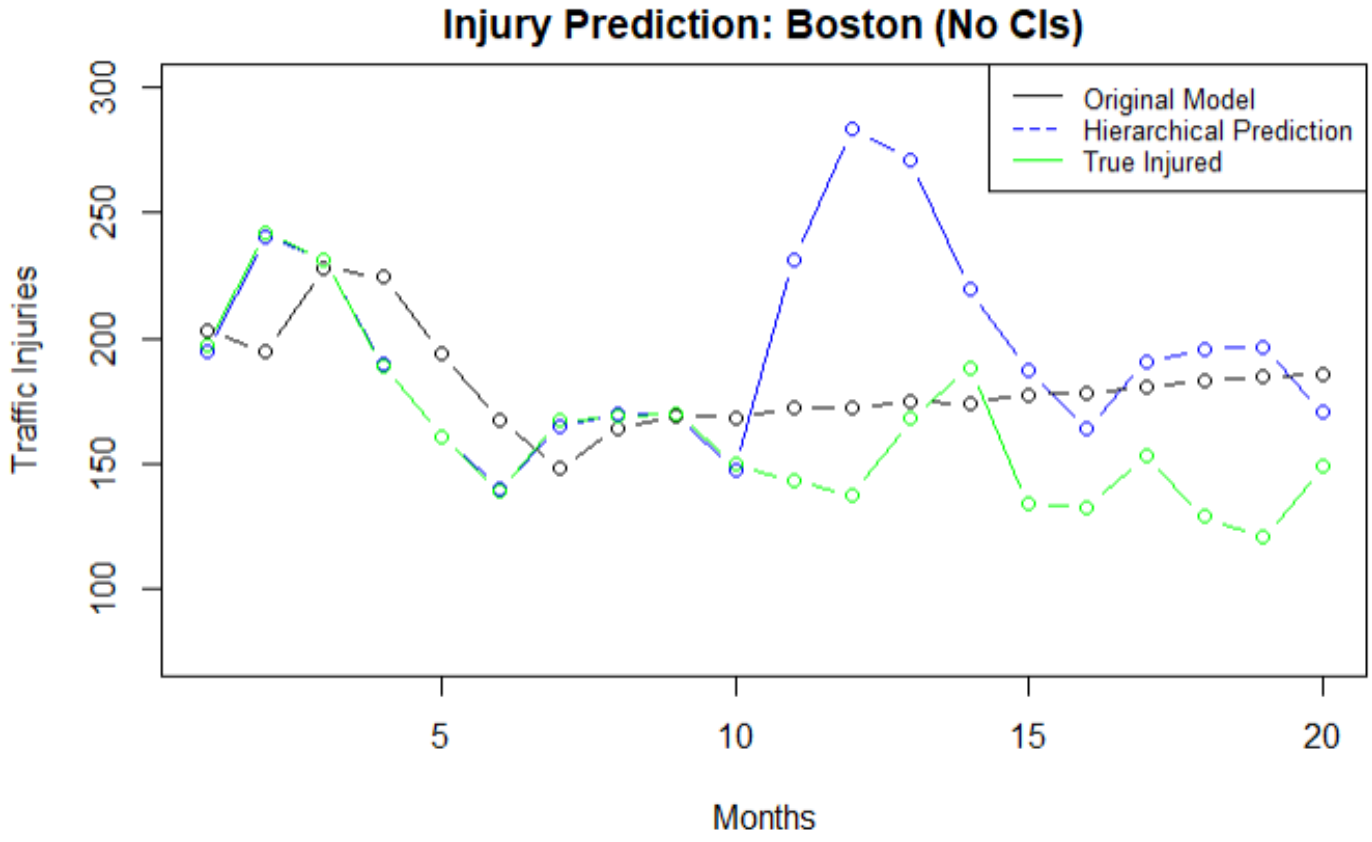

Figure 5: Boston Injury Predictions

Results (ctd)

Period	ARMA(1,1)	Hierarchical
Before	31.11	1.23
After	35.56	65.31

Figure 6: MAE by City

Conclusion

- Still work to be done (at some point)!