FORECASTING FLUCTUATIONS OF ASPHALT CEMENT PRICE INDEX IN GEORGIA

Mohammad Ilbeigi, Baabak Ashuri, Ph.D., and Yang Hui
Economics of the Sustainable Built Environment (ESBE) Lab,
School of Building Construction
Georgia Institute of Technology
Overview

• Introduction
  - Asphalt cement price index
  - Problems related to asphalt cement price variation

• Research Objective

• Research Background

• Research Approach
  - Univariate time series forecasting models

• Summary of Results
  - In sample fitting models
  - Out of sample forecasting

• Conclusion

• Limitations and Future Works
Introduction
Asphalt Cement Price Index in Georgia from 1995 to 2012
Research Motivation

**Overall Problem**
Significant volatility in the cost of Asphalt Cement leads to uncertainty about transportation project cost

- **Price Volatility** → **Uncertain Estimation**
- **Uncertain Estimation** → **Problems for Owners**
- **Uncertain Estimation** → **Problem for Contractors**
Research Motivation

- **Related Issues to Owner Organizations**
  - Hidden price contingencies
  - Very short-term price guarantees
  - Not enough bidders

- **Related Issues to Contractors**
  - Bid loss due to cost overestimation
  - Profit loss due to cost underestimation
Research Objective

Objective
Create appropriate univariate time series models for estimating and forecasting fluctuations in asphalt cement price index.
Research Background

Forecasting Models

Causal Methods
- Predicted variable is determined by independent explanatory variables
  - Regression Models

Pattern Analysis Methods
- Predicted variable is determined by its historical behaviors
  - Time Series Models
Research Approach: Time Series Models

1. Time Series Data Set
2. Time Series Analysis
3. In-Sample Model Fitting
4. Error Measurement
5. Out of Sample Forecasting
6. Error Measurement
A time series is a set of data points which are recorded at uniform time intervals.

In this research, our time series data set consists of monthly asphalt cement price index in the state of Georgia from Sep 1995 to June 2012.

GDOT determines the index based on the average of prices from around 20 different suppliers after removing the minimum and maximum prices.
Time Series Forecasting Process

- Time Series Data Set
- Time Series Analysis
- In-Sample Model Fitting
- Error Measurement
- Out of Sample Forecasting
- Error Measurement

Time series analysis methods are used to extract meaningful characteristics of a time series data set.
A time series is stationary if its statistical properties do not depend on time.
Time Series Forecasting Process

- Time Series Data Set
- Time Series Analysis
- In-Sample Model Fitting
- Error Measurement
- Out of Sample Forecasting
- Error Measurement

Stationary: ❌

Auto Correlation Function Plot:
Seasonality displays certain cyclical or periodic behaviors during the time.
Time Series Forecasting Process

- Time Series Data Set
- Time Series Analysis
- In-Sample Model Fitting
- Error Measurement
- Out of Sample Forecasting
- Error Measurement

First Difference Auto Correlation Function Plot:

Seasonality: ✓

Series: diff(AC_monthly_price)

Lag

ACF

0 20 40 60 80 100
-0.2 0.0 0.2 0.4 0.6 0.8 1.0

Lag
In-sample model fitting uses historical data set to estimate parameters of the model and fit the model with actual data.
Time Series Forecasting Process

- Time Series Data Set
- Time Series Analysis
  - In-Sample Model Fitting
  - Error Measurement
- Out of Sample Forecasting
  - Error Measurement

- In Sample Period: Sep 1995 to June 2011
- Out of Sample Period: July 2011 to June 2012
**Time Series Forecasting Process**

1. **Time Series Data Set**
2. **Time Series Analysis**
3. **In-Sample Model Fitting**
4. **Error Measurement**
5. **Out of Sample Forecasting**
6. **Error Measurement**

**Models:**
- Simple Moving Average (SMA)
- Holt Exponential Smoothing
- Holt-Winters Exponential Smoothing
- ARIMA
- Seasonal ARIMA
# Time Series Models

## Modeling Assumptions:

<table>
<thead>
<tr>
<th>Time Series Methodologies</th>
<th>Modeling Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple Moving-Average (SMA)</td>
<td>N.A.</td>
</tr>
<tr>
<td>Holt Exponential Smoothing (Holt ES)</td>
<td>Underlying data show trends</td>
</tr>
<tr>
<td>Holt-Winters Exponential Smoothing (Holt-Winters ES)</td>
<td>Underlying data show trends &amp; seasonality</td>
</tr>
<tr>
<td>Auto-Regressive Integrated Moving-Average (ARIMA)</td>
<td>Underlying data are nonstationary Model residuals are white noise</td>
</tr>
<tr>
<td>Seasonal ARIMA</td>
<td>Underlying data are nonstationary &amp; seasonal Model residuals are white noise</td>
</tr>
</tbody>
</table>
# Time Series Models

## Modeling Parameters:

<table>
<thead>
<tr>
<th>Time Series Methodologies</th>
<th>Modeling Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple Moving-Average (SMA)</td>
<td>N.A.</td>
</tr>
<tr>
<td>Holt Exponential Smoothing (Holt ES)</td>
<td>$\alpha$ $\beta$</td>
</tr>
<tr>
<td>Holt-Winters Exponential Smoothing (Holt-Winters ES)</td>
<td>$\alpha$ $\beta$ $\gamma$</td>
</tr>
<tr>
<td>Auto-Regressive Integrated Moving-Average (ARIMA)</td>
<td>$p$ $d$ $q$</td>
</tr>
<tr>
<td>Seasonal ARIMA</td>
<td>$p$ $d$ $q$ $P$ $D$ $Q$</td>
</tr>
</tbody>
</table>
Time Series Forecasting Process

- Time Series Data Set
- Time Series Analysis
- In-Sample Model Fitting
- Error Measurement
- Out of Sample Forecasting
- Error Measurement

HoltWinterES model and forecast values

Asphalt Cement Index ($/ton)

- real value
- fitted value
- forecasted value

Time

2000 2005 2010

100 200 300 400 500 600 700
Time Series Forecasting Process

- Time Series Data Set
- Time Series Analysis
- In-Sample Model Fitting
- Error Measurement
- Out of Sample Forecasting
- Error Measurement

**Error Measures:**

- Mean Absolute Percentage Error (MAPE)

\[
MAPE = \frac{1}{N} \sum_{t=1}^{N} \left| \frac{\hat{Y}(t) - \tilde{Y}(t)}{\tilde{Y}(t)} \right| \times 100\%
\]
Time Series Forecasting Process

- Time Series Data Set
- Time Series Analysis
- In-Sample Model Fitting

Error Measures:

- Mean Absolute Percentage Error (MAPE)
- Mean Square Error (MSE)

\[
\text{MAPE} = \frac{1}{N} \sum_{t=1}^{N} \left| \frac{\hat{Y}(t) - \tilde{Y}(t)}{\tilde{Y}(t)} \right| \times 100%
\]

\[
\text{MSE} = \frac{1}{N} \sum_{t=1}^{N} \left( \hat{Y}(t) - \tilde{Y}(t) \right)^2
\]
Time Series Forecasting Process

- Time Series Data Set
- Time Series Analysis
- In-Sample Model Fitting
- Error Measurement

Out of Sample Forecasting
- Error Measurement

**Error Measures:**

- Mean Absolute Percentage Error (MAPE)
- Mean Square Error (MSE)
- Mean Absolute Error (MAE)

\[
\text{MAPE} = \frac{1}{N} \sum_{t=1}^{N} \left( \frac{\hat{Y}(t) - \tilde{Y}(t)}{\tilde{Y}(t)} \right) \times 100\%
\]

\[
\text{MSE} = \frac{1}{N} \sum_{t=1}^{N} (\hat{Y}(t) - \tilde{Y}(t))^2
\]

\[
\text{MAE} = \frac{1}{N} \sum_{t=1}^{N} |\hat{Y}(t) - \tilde{Y}(t)|
\]
Time Series Forecasting Process

- Time Series Data Set
- Time Series Analysis
- In-Sample Model Fitting
  - Error Measurement
  - Out of Sample Forecasting
  - Error Measurement

<table>
<thead>
<tr>
<th>In Sample Model Fitting Error:</th>
<th>SMA</th>
<th>ARIMA</th>
<th>Seasonal ARIMA</th>
<th>Holt ES</th>
<th>Holt Winters ES</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAPE</td>
<td>6.97%</td>
<td>6.91%</td>
<td>7.06%</td>
<td>8.24%</td>
<td>10.53%</td>
</tr>
<tr>
<td>MSE</td>
<td>744.91</td>
<td>671.15</td>
<td>615.75</td>
<td>850.38</td>
<td>1080.70</td>
</tr>
</tbody>
</table>
Out-of-sample forecasting attempts to forecast future values of a variable by using the time series models and their parameters that were determined via in-sample model fitting based on the historical data.
Time Series Forecasting Process

- Time Series Data Set
- Time Series Analysis
- In-Sample Model Fitting
- Error Measurement
- Out of Sample Forecasting
- Error Measurement

**Models:**
- Simple Moving Average (SMA)
- Holt Exponential Smoothing
- Holt-Winters Exponential Smoothing
- ARIMA
- Seasonal ARIMA
Time Series Forecasting Process

- Time Series Data Set
- Time Series Analysis
- In-Sample Model Fitting
- Error Measurement
- Out of Sample Forecasting
- Error Measurement

HoltWinterES model and forecast values

Asphalt Cement Index ($/ton)

<table>
<thead>
<tr>
<th>Year</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>100</td>
</tr>
<tr>
<td>2005</td>
<td>200</td>
</tr>
<tr>
<td>2010</td>
<td>300</td>
</tr>
</tbody>
</table>

real value
fitted value
forecasted value

Time

2000 2005 2010

100 200 300 400 500 600 700

Asphalt Cement Index ($/ton)

real value
fitted value
forecasted value

Time
Time Series Forecasting Process

- Time Series Data Set
- Time Series Analysis
- In-Sample Model Fitting
- Error Measurement
- Out of Sample Forecasting

Forecasting Error

<table>
<thead>
<tr>
<th>Error Measures</th>
<th>SMA</th>
<th>ARIMA</th>
<th>Seasonal ARIMA</th>
<th>Holt ES</th>
<th>Holt Winters ES</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAPE</td>
<td>4.73%</td>
<td>6.52%</td>
<td>10.03%</td>
<td>35.15%</td>
<td>5.3%</td>
</tr>
<tr>
<td>MSE</td>
<td>1091.75</td>
<td>2029.44</td>
<td>5845.04</td>
<td>51364.11</td>
<td>1157.18</td>
</tr>
<tr>
<td>MAE</td>
<td>28.90</td>
<td>37.97</td>
<td>65.65</td>
<td>255.75</td>
<td>34.47</td>
</tr>
</tbody>
</table>
Results: Forecasted Values

Asphalt Cement Price Index ($/ton)

Time

RealValue

Georgia Institute of Technology

NCTSPM
Results: Forecasted Values

Asphalt Cement Price Index ($/ton)

- RealValue
- SMA

Time

1 2 3 4 5 6 7 8 9 10 11 12
Results: Forecasted Values

Asphalt Cement Price Index ($/ton)

Time

RealValue

Arima
Results: Forecasted Values

Asphalt Cement Price Index ($/ton) vs Time

- RealValue
- Seasonal Arima
Results: Forecasted Values

Asphalt Cement Price Index ($/ton)

Time

RealValue
HoltES
Results: Forecasted Values

Asphalt Cement Price Index ($/ton)

Time

RealValue
Holtwinter ES
Results: Forecasted Values

Asphalt Cement Price Index ($/ton)

Time

RealValue
SMA
Arima
Seasonal Arima
HoltES
Holtwinter ES
Results: Forecasted Confidence Intervals

Confidence Intervals:
Conclusion

• Accurate forecasting of asphalt cement price index is possible by Time Series models

Accurate forecasting of material price can help:

• Contractors to submit more accurate and competitive bids

• State DOTs to consider more accurate budget

• Contractors and State DOTs to measure their risks and develop appropriate risk management strategies

• State DOTs to examine financial implications of offering Price Adjustment Clause (PAC) for asphalt cement
Limitations and Future Works

• Limitations:
  1. Not appropriate for long term forecasting
  2. Unable to perform well when a discrete jump occurs

• Measuring the value of Price Adjustment Clause (PAC)

• Develop procedure to determine risk contingencies

• Multivariate time series forecasting models
Acknowledgment

• Georgia Tech University Transportation Center
• Georgia Department of Transportation (GDOT)
• Dr. Peter Wu
• Ms. Georgene Geary
• Ms. Supriya Kamatkar
• Mr. David Jared
Thank you for your attention!