The Chained Fisher
ODOT Construction Cost Index

November 8, 2013
Office of Estimating
Bid Analysis and Review Team
Ohio Department of Transportation
Objectives

- To discuss the current methods used to compute the ODOT construction cost index
- To explain the benefits of a chained Fisher approach
- To describe other improvements that have been made to the ODOT construction cost index
Tracking Construction Costs

- Various index forms used at state and national levels
- Choice of index form depends on many factors
  - Data availability
  - Purpose/usage of index (e.g. budgeting)
  - Importance of comparability across agencies
- Cost indices are used to measure inflation—how prices have changed over time
Examples of Current Index Methods

- Index forms used by state departments of transportation
  - Laspeyres Index*
    - Ohio
    - Texas
  - Fisher Index
    - California
    - Florida
  - Chained Fisher Index
    - Colorado

- The Federal Highway Administration (FHWA) uses a chained Fisher approach\(^1\)

*Modified Laspeyres
ODOT’s Current Index Method

- **Modified Laspeyres**: compares 12-month rolling, weighted-average prices
- **Base period FY04–FY05**
- **Reported monthly**
- **Fixed basket of items representing 10 item classes**
- **Fixed weights**
  - Weights used to indicate the relative importance of items are not allowed to change between the chosen base period and the current period
  - Weights are computed using base period expenditure shares
ODOT’s Current Index Method

- **Item Index**

\[
I_i = \left[ \frac{\sum m q_m p_{m,t}}{12} \right] \div \left[ \frac{\sum m q_{m,0} p_{m,0}}{12} \right], \quad \text{for } m=1,\ldots,12
\]

\[
= \left[ \frac{\sum m q_{m,t} p_{m,t}}{12} \right] \div \left[ \frac{\sum m q_{m,0} p_{m,0}}{12} \right]
\]

\[
= \frac{\tilde{p}_t}{\tilde{p}_0}, \text{ a ratio of weighted-average, per unit prices}
\]

- **Class Index**

\[
I_j = \sum_i I_i \omega_i , \text{ where } \omega_i \text{ is the weight for item } i
\]

- **Composite Index**

\[
CCI = \sum_j I_j \omega_j , \text{ where } \omega_j \text{ is the weight for class } j
\]
Proposed Index Method

- Chained Fisher approach
- Computed and reported quarterly
- More comprehensive basket of items
Key Traits of Fixed–Weight Indices

- Relatively easy to compute
- Uses fixed base year
  - Base year becomes less relevant over time
  - Requires periodic changes of base year, which changes entire index series (re-writing history)
- Assumes fixed weights—allows no change in the relative importance of items
- Requires a fixed basket of items
  - Assumes no change in items purchased over time
  - Results in substitution bias
Key Traits of Chained Indices

- Accounts for changes in basket and weights of items\(^2\)
- Eliminates issue of updating the base period
- Performs better than fixed-weight indices when prices and quantities are volatile\(^3\)
- Not additive: expenditure share does not equal contribution to growth\(^4\)
- Potential for chain drift (bias) increases with chaining frequency
Computing the Fisher Price Index

- **Laspeyres**: measures the change in cost of purchasing the same basket of goods in the current period as was purchased in a specified base period

  $$L(p) = \frac{\sum_i p_{it} q_{i0}}{\sum_i p_{i0} q_{i0}}$$

- **Paasche**: compares the cost of purchasing the current basket of goods with the cost of purchasing the same basket in an earlier period

  $$P(p) = \frac{\sum_i p_{it} q_{it}}{\sum_i p_{i0} q_{it}}$$

- **Fisher**: geometric mean of Laspeyres and Paasche Indices

  $$F(p) = \sqrt{L(p) \times P(p)}$$
So, what is chaining?

Relative Indices
- Compute index for every pair of adjacent periods

Index Series
- Chain, or multiply, the relative indices to form the series
Step-by-step: Chained Fisher

- **Compute item-level price ratios**, \( \frac{p_{i, t}}{p_{i, t-1}} \) → Item Relatives
  - Use annual-rolling, weighted-average prices
  - Compute for every pair of adjacent quarters
- **First Stage Aggregation** → Class Relatives
  - Insert item relatives into Fisher index formula
  - **Restrict weights** to selected items for which a price trend may be established
- **Second Stage Aggregation** → Composite Relatives
  - Insert class relatives into Fisher index formula
  - **Scale up class weights** to include non-standard items (i.e. as-per-plan, lump sum, and miscellaneous items)
- **Chain composite relatives** → Index Series
Two–Stage Fisher Aggregation

- **Stage 1**: Use Fisher index formula to aggregate from the item level to the class level

\[ R_{j,t-1}^t = \sqrt{\left( \sum_i \omega_{i,t-1} \frac{p_{i,t}}{p_{i,t-1}} \right)} \times \left( \frac{1}{\sum_i \omega_{i,t} \frac{p_{i,t-1}}{p_{i,t}}} \right) \]

  - \( R_{j,t-1}^t \) → class relative index for item class \( j \), indicating how prices have changed from the previous quarter, \( t-1 \), to the current quarter, \( t \)
  - \( \omega_i \) → the expenditure share (weight) of item \( i \) relative to selected items within item class \( j \)
Two–Stage Fisher Aggregation

- **Stage 2**: Use Fisher index formula to aggregate from the class level to the composite level

\[
R_{t-1}^t = \sqrt{\left(\sum_j \Omega_{j,t-1} R_{j,t-1}^t \right)} \times \left(\frac{1}{\sum_j \Omega_{j,t} R_{j}^{t-1}}\right)
\]

- \(R_{t-1}^t\) → relative composite index, indicating how prices have changed from the previous quarter, \(t-1\), to the current quarter, \(t\)
- \(\Omega_j\) → the expenditure share (weight) of item class \(j\), including expenditures of both selected and non-standard items

Time Reversal Property
Computing the Index Series

- **Chain composite relatives** ➔ Construction Cost Index

\[
CC_{I_{0,t}} = 1 \times R_{0,1} \times R_{1,2} \times R_{2,3} \times \cdots \times R_{t-1,t} \quad \forall t
\]

\[
= \prod_{t=1}^{T} R_{t-1,t}
\]
Pre-Estimation Adjustments to Improve Data Quality
Adjustments to Improve Data Quality

- Replacement of Outliers
  - Outliers are determined quarterly at the contract level based on distance of prices from the median
  - Prices greater than two median absolute deviations from the median are replaced with the median price
  - Median Absolute Deviation (MAD)

\[ MAD = \text{median}(|p - \tilde{p}|), \]

where \( \tilde{p} \) = median, weighted-average price
Adjustments to Improve Data Quality

- Expanded the market basket of items
- Grouped related item classes
  - Grouped asphalt concrete, liquid asphalt, and bituminous base items
  - Grouped drainage, sanitary, and water main items
  - Grouped removal, clearing & grubbing, and building demolition items
- Excluded non-standard item classes and item types
  - Excluded incidentals, lump sum mobilization, non-highway construction, and safety rest area item classes
  - Excluded lump sum*, as-per-plan, and miscellaneous item types
  - Inconsistently purchased items are also excluded

*Lump sum maintenance of traffic (MNTC) items are an exception.*
Adjustments to Improve Data Quality

- **Barriers, Earthwork, and Landscaping**
  - Weighted-average prices smoothed using a two-year moving average
  - Grouped excavation and embankment items

- **Bridge Painting**
  - Enters the index series in 2007
  - Data prior to 2007 excluded due to extreme volatility

- **Maintenance of Traffic**
  - Grouped lump sum items
  - Index for lump sum items computed using percent of contract dollars instead of weighted-average prices
Adjustments to Improve Data Quality

- **Structures**
  - Items organized into five subclasses
    - Re-bar
    - Steel and Concrete Piles
    - Structural Concrete
    - Structural Steel
    - Unclassified Structures (other)
  - Subclass relative indices are aggregated using the Fisher index form to produce the structures class index
Effects of Expanding the Market Basket

- Total dollars represented by the selected items increased from 28% (FY04-FY05) to **48%** (2012Q4) of total dollars awarded
- Total dollars represented overall increased from 74% (FY04-FY05) to **96%** (2012Q4) of total dollars awarded
Summary of Improvements

- Quarterly chained Fisher formula
- More comprehensive basket of items
- Systematic handling of outliers


Appendix
<table>
<thead>
<tr>
<th>Item Classes Represented in the Chained Fisher Construction Cost Index</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Asphalt (ASPH)</strong></td>
</tr>
<tr>
<td>- asphalt concrete (ASPH)</td>
</tr>
<tr>
<td>- bituminous base (BTMS)</td>
</tr>
<tr>
<td>- liquid asphalt (ACGL)</td>
</tr>
<tr>
<td><strong>Aggregate Base (BASE)</strong></td>
</tr>
<tr>
<td><strong>Barriers (BARR)</strong></td>
</tr>
<tr>
<td><strong>Bridge Painting (BRPT)</strong></td>
</tr>
<tr>
<td><strong>Curb (CURB)</strong></td>
</tr>
<tr>
<td><strong>Drainage (DRNG)</strong></td>
</tr>
<tr>
<td>- drainage &amp; sanitary (DRNG)</td>
</tr>
<tr>
<td>- water main (WTRM)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Earthwork (ERTH)</strong></td>
</tr>
<tr>
<td><strong>Erosion Control (EC)</strong></td>
</tr>
<tr>
<td><strong>Guardrail (GRDL)</strong></td>
</tr>
<tr>
<td><strong>Landscaping (LSCP)</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

**NOTE:** (*) denotes grouped item classes. Newly represented item classes indicated by red print.
The Chained Fisher
ODOT Construction Cost Index