Forecasting Workshop:
Intermittent Demand Forecasting

Recent Advances in Intermittent Demand Forecasting

John Boylan
j.boylan@lancaster.ac.uk
Professor of Business Analytics
Recent Advances
by John Boylan (Lancaster Centre for Forecasting)

Practical Issues
by Roy Johnston (Formerly Euro car Parts)

Assessing Performance
by Steve Morlidge (Product Director, CatchBull)

Software and Freeware
by Nikolaos Kourentzes (Lancaster Centre for Forecasting)

Panel Discussion

Networking Reception
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• Knowledge-transfer partnerships
• Systems auditing and tuning
• MSc summer projects
• PhD research partnerships

Forecasting for...
• FMCG
• Electricity and Utilities
• Call-centres
• Government
• Pharmaceutical products
• Spare parts
• Promotional effects

Prof Robert Fildes
Prof John Boylan
Dr Sven Crone
Dr Nikolaos Kourentzes
Dr Nicos Pavlidis
Dr. Gokhan Yildirim
Agenda

1. Context
2. Definitions of Intermittent Demand
3. Croston-Based Methods
4. Temporal Aggregation
5. Bootstrapping Approaches
6. Performance Measures
The fate of Edmunds Walker

- Ailing company acquired by Unipart in 1984
- Over 100 branches in UK
- “Our aim is to supply all the day to day parts our customers will require direct from the branch stocks”
- Branch managers had free rein on ordering policy
- Punitive excess stock-holding & obsolescence
- Divested by Unipart in early 1990s
- Liquidated in 2001
Changes in the **business context**: 

1. Service becoming ever more critical.
2. Greater emphasis on environmental costs of obsolescence.
3. More granularity of data giving rise to more intermittence.
4. ERP systems not fully geared up for intermittence.
5. Performance management ever more crucial.
Research Developments:

• Very slow advances from 70s to 90s.
• Then, from 2000, improvements in the standard methods.
• Also, suggestions made for alternative approaches based on temporal aggregation and bootstrapping.
• In recent years, debate on most appropriate measures of performance.
Changes in the research context:

1. Emphasis on ‘impact’ of research.
2. Universities’ research assessed accordingly.
3. REF: Scale from 1* (national significance) to 4* (world class).
4. Lancaster’s Forecasting Case-Study rated as 4*.

*We want impact for its own sake - not just for ratings.*
Intermittent Demand Advances
Software Context

Software Developments:

• Slowly, major packages have implemented Croston’s method.
• Limited uptake of advances beyond that:
  • Syncron (SBA method)
  • JDA (Demand Classification)
• Overall, commercial software is lagging behind research developments, BUT freeware now available.
Some Definitions

**Intermittent Demand**
Demand is non-deterministic, with some periods having no demand.

**Lumpy Demand**
Intermittent demand, which also has highly variable demand sizes.
Intermittent Demand Advances

Definitions

![Chart showing intermittent and lumpy demand]

- **Intermittent Demand:** Occurs when demand is sporadic and unpredictable.
- **Lumpy Demand:** Characterized by irregular, unpredictable peaks in demand.

The chart illustrates the demand distribution over a year, with distinct peaks in May and August for intermittent demand and a significant peak in August for lumpy demand.
Intermittent Demand Advances

Definitions

- Mean inter-demand interval
  - High → Intermittent
  - Low → Non-intermittent

- Mean demand size
  - Low → Slow

- Coefficient of variation of demand sizes
  - High → Erratic
  - Low → Non-erratic

AND/OR

AND

AND

- AND

- OR

- Lumpy

- Clumped

Audited stock control system, which used Exponential Smoothing for all slow demand items.

For some slow demand items, stock levels were excessive.

Errors were associated with intermittent and lumpy demand items.
Croston’s Basic Finding

If used immediately after a demand occurrence, then Exponential Smoothing is upwardly biased for intermittent demand.
Croston’s Method (1972)

If demand occurs

1. Re-estimate mean demand size (S1) using Exponential Smoothing
2. Re-Estimate mean demand interval (I1) using Exponential Smoothing (same smoothing constant)
3. Re-estimate mean demand : \( D1 = \frac{S1}{I1} \)

Else if demand does not occur

Do not re-estimate
**Poisson Distribution:**

Input Forecasted Mean to get whole Lead-Time Distribution

\[ \lambda = D_1 = \text{Forecasted Mean} \]

\[ k = D = \text{Potential Demand Value} \]
Compound Poisson Distribution

- Assumes Demand Incidence (number of occurrences of demand) is Poisson.
- Size of Demand, when demand occurs, is taken to follow a different distribution (e.g., lognormal, geometric).
- Need estimate of demand variance too.

Compound Bernoulli Distribution

- Assumes Demand Occurrence is a yes/no variable with a constant probability of being ‘yes’.
- Size of Demand treated as in Compound Poisson.
Croston’s method is itself biased (2001)

- Arises because estimate of Mean Demand Interval is inverted.
- Eg  Average \((1/4, 1/6, 1/8) = (0.25 + 0.167 + 0.125) / 3 = 0.181\)
  BUT:  \(1 / \text{Average (4, 6, 8)} = 1 / 6 = 0.167\)

<table>
<thead>
<tr>
<th>Bias of Croston</th>
<th>Percentage of periods with demand occurrences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smooth 0.1</td>
<td>5% 4% 3% 2% 1%</td>
</tr>
<tr>
<td>Constant 0.2</td>
<td>10% 8% 6% 3% 1%</td>
</tr>
</tbody>
</table>
Syntetos-Boylan Approximation (2005)

- Assumes Demand Incidence is Bernoulli.

\[
\text{Forecast of Mean Demand} = (1 - \alpha/2) \frac{S_1_{SES}}{I_1_{SES}}
\]

- \(\alpha\) = Smoothing constant for Demand Interval (can use different smoothing factors for Size and Interval)


- Assumes Demand Incidence is Poisson

\[
\text{Forecast of Mean Demand} = (1 - \alpha/(2-\alpha)) \frac{S_1_{SES}}{I_1_{SES}}
\]

- \(\alpha\) as before.
Teunter-Syntetos-Babai (2011)  
Allows re-estimation when no demand 

If demand occurs 

1. Re-estimate mean demand size (S1) using Exponential Smoothing 
2. Re-Estimate probability of demand occurrence (P1) using Exponential Smoothing 
3. Re-estimate mean demand: \( D_1 = S_1 \times P_1 \) 

Else if demand does not occur 

1. Do not re-estimate S1 
2. Re-estimate P1 
3. Re-estimate mean demand: \( D_1 = S_1 \times P_1 \)
Aggregate-Disaggregate Intermittent Demand Approach (ADIDA)
(A self-improvement approach - Nikolopoulos et al, 2011)
What level of temporal aggregation?
ADIDA (2011, 2012)

Especially useful for aggregation level = Lead Time:

1. No need to disaggregate
2. Produces more stable estimates of mean and standard deviation
3. Can be plugged into standard distributions (eg Poisson, Negative Binomial)

What if SKUs are highly ‘lumpy’ and do not follow any standard distribution?
Empirical Methods

<table>
<thead>
<tr>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
<th>P6</th>
<th>P7</th>
<th>P8</th>
<th>P9</th>
<th>P10</th>
</tr>
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(History Length = 10)

Suppose LT = 3 and Block-Size (m) = 3

1. Non-Overlapping Blocks
Block 1 = \{P2, P3, P4\}, Block 2 = \{P5, P6, P7\}, Block 3 = \{P8, P9, P10\}

2. Overlapping Blocks
Block 1 = \{P1, P2, P3\}, Block 2 = \{P2, P3, P4\} , ... , Block 8 = \{P8, P9, P10\}

3. Bootstrapping
Randomly drawn from all combinations (with replacement)
eg: Block 1 = \{P7, P2, P9\}, Block 2 = \{P2, P3, P3\}, ....

1. Sample h-period ahead demand from historical data (h = 1,...,L ; L=lead time)
2. Calculate total lead-time demand
3. Repeat a large number of times
4. Calculate percentiles of the lead-time demand distribution

Comments

• Method assumes that the underlying distribution – although unknown – is not changing over time.
• May be little non-zero data to sample from
Direct Percentile Estimation
Cluster Based Processing (2013)

1. Identify a cluster of series from historical demand data (based on a ‘cluster driver’)
2. Determine of there is an ‘association’ between an item
3. If no
   • Use non-cluster based approach
   If yes
   • Use cluster-based approach
4. Generate Lead-Time Distribution (as in previous slide)
5. Determine percentile of interest
Accuracy Measurement

Do not use:

• Mean Absolute Percentage Error (MAPE): problem of dividing by zeros!
• Symmetric MAPE (sMAPE): always 200% for zero demand!

General problem for Absolute Error Measures (Morlidge, 2015)

Alternative measures discussed in later presentation.
Forecasting not an end in itself

- Forecasting Method
- Inventory Rules
- Stock Management System
- Stock-holding Costs
- Service Level

Need accuracy metrics that relate to stock performance
Conclusions

• Significant developments of methods in the last 15 years
• Many not yet adopted in software or by organisations
• Testing on real data consistently showing improvement in stock performance
• Freeware now available (Kourentzes, 2014)

• More applied research needed
• Please approach a member of Lancaster Centre for Forecasting if you would be interested in collaborating on research focused on your own organisation.
Thank you for your attention!

Questions?

John Boylan

Lancaster University Management School
Lancaster Centre for Forecasting - Lancaster, LA1 4YX
email: j.boylan@lancaster.ac.uk

www.forecasting-centre.com/