Matching Supply and Demand via 2-Phase Delayed Distribution at Yedioth Group: Models, Algorithms and IT

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Distribution Networks

» Distribution networks are central to many supply chains

» **Design:** Topology, shipping modes, inventory (pooling), IT & coordination

» **Operations:** Production & shipment decisions

» **Today:**

- New concept – **2-Phase Delayed Distribution** --- enabled by new models and algorithms, process redesign and IT changes

- Field implementation in the print industry with significant financial impact! Another implementation in the food industry (specialty bread)
‘Old’ Distribution Model

Distribution-Cycle Decisions Timeline

Production level $Q^0$: per-unit cost $c$

Shipments $y_i$

Demand per-unit lost sales cost $b$

Scraping of returns: per-unit cost $h$

Retailers

1. $h(y_1 - D_1)^+$

2. $b(D_1 - y_1)^+$

3. $h(y_i - D_i)^+$

i. $b(D_i - y_i)^+$

n. $b(D_n - y_n)^+$

$y_i$, $y_n$, $D_1$, $D_i$, $D_n$
New Distribution Concept

» **Main Ideas:**

- Each sales agent holds pooled inventory and deliver in-cycle (mid-week) shipment to respective retailers

- Mid-week shipment will be based on demand information from the first half of the week

- How to obtain information? – EDI and RFID systems
2-Phase Delayed Distribution

Production
\[ \sum_i y_i^1 + Q^1 = Q^0 \]

Sales Agent
\[ \sum_i Q_i^2 \leq Q^1 \]

Scraping

Retailers
1
2
3

Distribution-Cycle Decisions Timeline

\[ h(Q_i^2 + (y_i^1 - D_i^1)^+ - D_i^2)^+ \]

2nd Shipments based on sales information

Initial Shipments
\[ y_i^1 \text{ and } Q^1 \]

2nd period demand
\[ b(Q_i^2 + (y_i^1 - D_i^1)^+ - D_i^2)^+ \]

Retailers
1

b(Q_i^2 + (y_i^1 - D_i^1)^+ - D_i^2)^+

b(Q_i^2 + (y_i^1 - D_i^1)^+ - D_i^2)^+

b(Q_i^2 + (y_i^1 - D_i^1)^+ - D_i^2)^+

b(Q_i^2 + (y_i^1 - D_i^1)^+ - D_i^2)^+

2nd period demand per-unit lost sales cost \( b \)
Mathematical Formulation

Two-stage stochastic program with recourse:

\[
P_{01} = \text{Minimize} \quad cQ_0 + E \left[ P_2 \left( Q_1, y_1^1 - D_1, \ldots, y_n^1 - D_n^1 \right) \right]
\]

s.t.

\[
Q^1 + \sum_i y_i^1 = Q^0 
\]

\[
Q^1, y_i^1 \geq 0, \text{ for each } i
\]

\[
P_2 \left( Q_1, y_1^1 - d_1^1, \ldots, y_n^1 - d_n^1 \right) = \text{Minimize} \quad \sum_i E \left[ b (D_i^2 - y_i^2)^+ + h \left( y_i^2 - D_i^2 \right)^+ + bL_i \right]
\]

s.t.

\[
\sum_i Q_i^2 = Q^1 \quad \text{Total 2^{nd} shipments}
\]

\[
L_i \geq d_i^1 - y_i^1, \text{ for each } i 
\]

\[
y_i^2 = y_i^1 - d_i^1 + Q_i^2 + L_i, \text{ for each } i
\]

\[
L_i, Q_i^2 \geq 0, \text{ for each } i
\]
Model Analysis

**Theorem** (Avrahami, Herer, L. ['13]):

- $P_2()$ is jointly convex in $(Q^1, x_1, \ldots, x_n)$ and so is $E[P_2(Q^1, y_i - D_i, \ldots, y_n - D_n)]$ in $(Q^1, y_1, \ldots, y_n)$
- $P_{01}$ is jointly convex in $(Q^0, Q^1, y_1, \ldots, y_n)$
Literature Review

» The value of information in supply chains (special focus on RFID)

Lee et al ['00,'04], Liu & Miao ['06], Aykut et al ['06], Lee & Ozer ['07], Doukidis ['07], and more!

» Pooling strategies (inventory pooling, delayed differentiation, postponement, transshipment...)

Eppen ['79], Eppen&Schrage ['81], Jackson&Muckstadt ['89], Netessine et al ['02], Corbett&Rajaram ['04], Dong&Rudi ['04], Ho&Tang ['98], Garg&Lee ['99]. Groenevelt&Rudi ['00], Rudi ['00], Raman at al ['97],.....and more!

» Few papers on replenishment interval optimization

Allen ['58], McGavin at al ['93, ‘97], Shang ['10]

» Rich literature on the One-Warehouse-Multi-Retailer problem

Eppen ['81], Zipkin ['82]
Solution Approach

» Use stochastic gradient descent method:

\[ P_{01} = \text{Minimize} \quad cQ_0 + E\left[ P_2\left(Q^1, y^1_i - D^1_i, \ldots, y^n_i - D^n_i\right)\right] \]

» Need to obtain unbiased estimator of subgradient of:

\[ E\left[ P_2\left(Q^1, y^1_i - D^1_i, \ldots, y^n_i - D^n_i\right)\right] \text{ at any point } \left(Q^0, Q^1, y^1_1, \ldots, y^n_1\right) \]

» For discrete and finite support demands \(D_i^2\), the second stage cost function

\[ P_2\left(Q^1, y^1_i - d^1_i, \ldots, y^n_i - d^n_i\right) = \text{Totally unimodular linear program (LP)} \]

for each realization

» Solve dual to obtain unbiased estimate of subgradient
Solution Procedure - Overview

Optimize $P_{01}$ via subgradient optimization:

1. Start with any solution

2. Estimate subgradient at current point:
   - Samples from distributions $D_i$
   - Solve dual of $P_2(\phi)$, for each sample
   - Average respective dual solutions to estimate subgradient

3. Step in correct direction

4. If not done, update step size and go to 2
Pilot Implementation - Why?

» Research department skeptical:
  > How can less be better?

» Sales agents suspicious:
  > How can less be better?
  > Salary dependent on sales

» Proof of concept in real world is required

» 5 week pilot!
Pilot Implementation Scope

» One magazine: L’isha
  > Weekly (not daily)
  > High volume

» 50 selected retailers

» 10 sales agents:
  > Each serving 5 retailers for the pilot
  > Holds the undistributed magazines

  > Supplementary distribution during regular midweek visit. No added cost!

> Document in-week demand
**Pilot Implementation Results**

<table>
<thead>
<tr>
<th>Total</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Order quantity</td>
<td>7438</td>
<td>6764</td>
</tr>
<tr>
<td>Returns</td>
<td>1908</td>
<td>1174</td>
</tr>
<tr>
<td>Sales</td>
<td>5530</td>
<td>5590</td>
</tr>
<tr>
<td>Stockouts</td>
<td>62</td>
<td>35</td>
</tr>
</tbody>
</table>

- **Down ~ 9%**
- **Down ~ 38%**
- **Up ~ 1%**
- **Down ~ 42%**

Savings from printing, other savings from freeing printing capacity

**Delayed 2-Phase Distribution works!**
Large Scale Implementation Details

» After pilot decision support tool was implemented for over 15 magazines!

» Model is solved on a weekly basis. Recommendations modified manually.

» Currently implemented in 400 EDI enabled (mostly larger) retailers (POS data once a day)

» Sales agents compensated for sales and returns
Large Scale Implementation Results

» Results similar to pilot

» 10–15% reduction in production levels:
  > Research department no longer interfering

» ~ 35% reduction in returns

» Sales levels unaffected/slightly higher
Optimizing Review Epochs

What is the **best timing** for the review/distribution epoch?

- In simulations, single optimal location = 42% - 96% of the benefits of full pooling!
- Optimal location is rarely (never) in the middle – changed replenishment day to Thursday!
- **Estimated total savings:** $250K from 400 retailers, projected $1M from entire network
Scaling - RFID Pilot

» Pilot RFID technology to enable implementation throughout entire network

» 5 RFID stands with tags on magazine (plastic bag)

» Model proven, technology being piloted:
  > Same operational and optimization model
  > Technology is being evaluated
Magazine with RFID Tag
Smart Stand
Smart Stand with Magazines
Weekend (Daily) Newspaper Pilot

» Most costly and profitable product

» Timescale reduced from 1 week to ~6 hours

» Ten retailers, two sales agents:
  - Subperiod 1: 8:00 – 11:00
  - Subperiod 2: 11:00 – 14:00

» Similar savings – Huge potential impact!

» Added visit with additional costs
Specialty Bread Products

» Same model implemented by 3ID for a bakery enabled by RFID solution

» Similar characteristics: weekly distribution, perishable, full refund

* Pictures provided by 3ID
Some Thoughts on RFID Research

» RFID costs real money

» Much RFID research can be termed “MORE OF THE SAME”

» Is RFID just a better barcode?

» The money is in changing the operational paradigm

» Models (like ours) can answer the question: “Is RFID worth the investment?”
Summary

» New pooling concept: Delayed 2-Phase Distribution

» Applicable to print industry (documented significant impact)

» Applicable to other industries (food)

» Models for
  > Day-to-day operational decisions
  > Strategic decisions: investment in IT

» One additional distribution close to full pooling
Questions
Comments
Remarks
Observations
Suggestions
Criticisms

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