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

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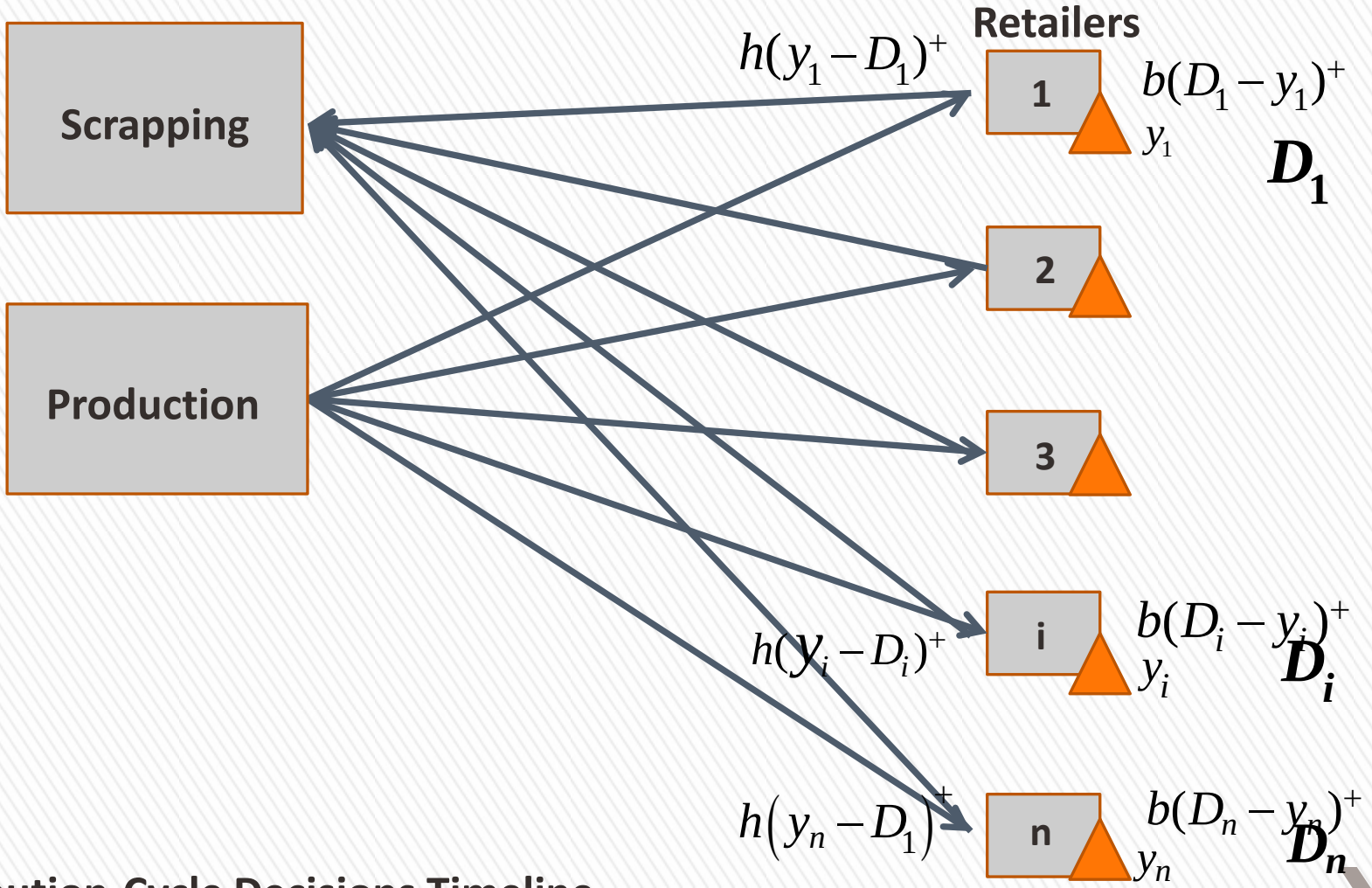
Distribution Networks

- 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	Scrapping of returns: per-unit cost h

New Distribution Concept

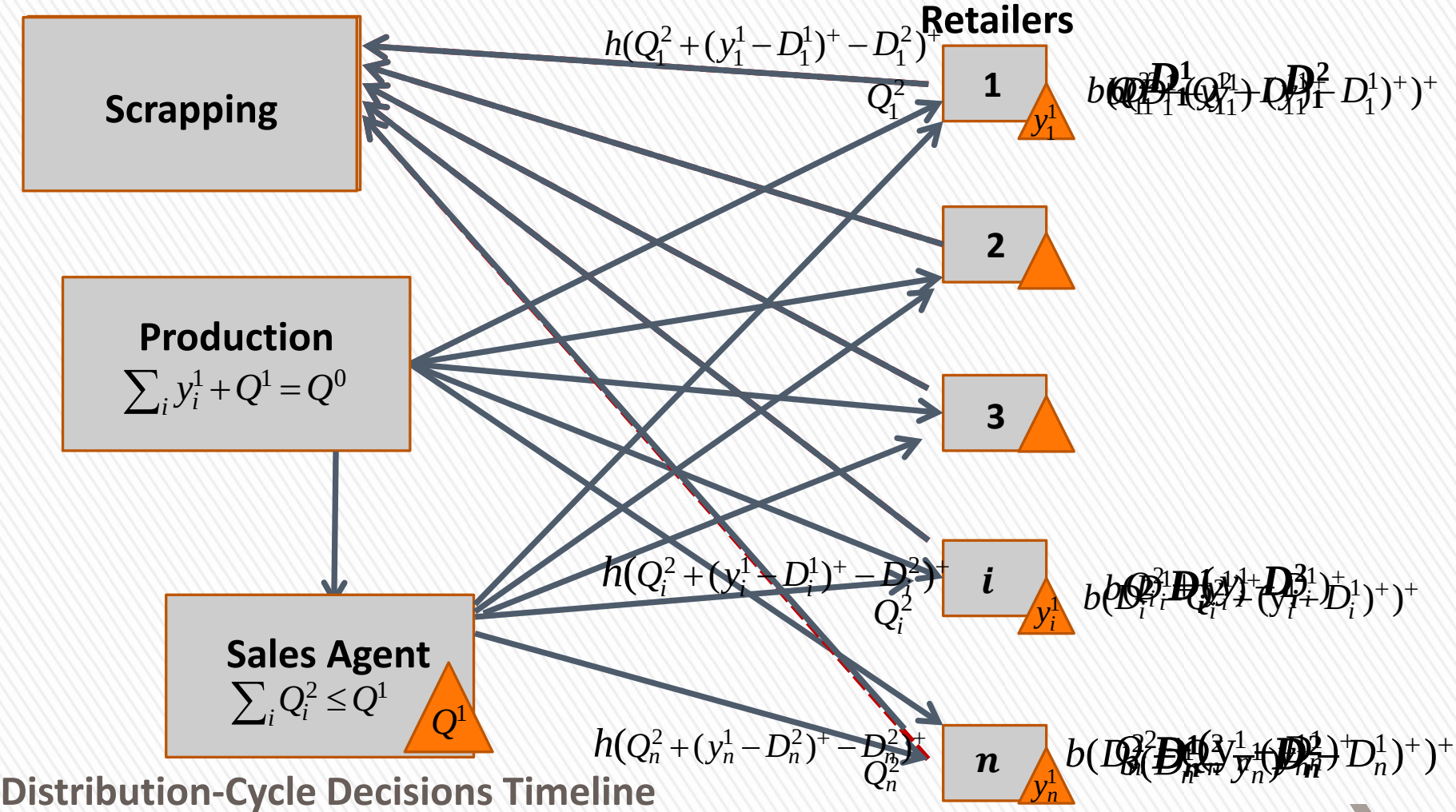
» **Main Ideas:**

- 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



Distribution-Cycle Decisions Timeline

2nd Shipments y_i^1 based on sales information	2nd period demand Initial Shipments y_i^1 and Q^1	b period demand per-unit lost sales cost b

Mathematical Formulation

» Two-stage stochastic program with recourse:

$$P_{01} = \underset{Q^0, Q^1, y_1^1, \ldots, y_n^1}{\text{Minimize}} \; cQ_0 + E\left[P_2\left(Q^1, y_1^1 - D_1^1, \ldots\ldots, y_n^1 - D_n^1 \right) \right]$$

Production cost

Cost to go

s.t.

$$Q^1 + \sum_1 y_i^1 = Q^0$$

Total production

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

Production level = Q^0

Initial Shipments = y_i^1

Undistributed quantity = Q^1

$$P_2\left(Q^1, y_1^1 - d_1^1, \ldots\ldots, y_n^1 - d_n^1 \right) = \underset{L_i, Q_i^2, y_i^2}{\text{Minimize}} \; \sum_i E\left[b\left(D_i^2 - y_i^2 \right)^+ + h\left(y_i^2 - D_i^2 \right)^+ + bL_i \right]$$

s.t.

$$\sum_i Q_i^2 = Q^1$$

Total 2nd shipments

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

Lost Sales

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

Flow

$$L_i, Q_i^2 \geq 0, \text{ for each } i$$

Lost sales of retailer i in first period = L_i

2nd Shipments = Q_i^2

Inventory level at the beginning of period 2 after 2nd shipment = y_i^2

Model Analysis

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

» P_2 () is jointly convex in $\left(Q^1, x_1, \ldots, x_n\right)$ and so is $E\left[P_2\left(Q^1, y_1^1 - D_1^1, \ldots\ldots, y_n^1 - D_n^1\right)\right]$ in $\left(Q^1, y_1^1, \ldots, y_n^1\right)$

» P_{01} is jointly convex in $\left(Q^0, Q^1, y_1^1, \ldots, y_n^1\right)$

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} = Minimize $cQ_0 + E\left[P_2\left(Q^1, y_1^1 - D_1^1, \ldots\ldots, y_n^1 - D_n^1\right)\right]$

» Need to obtain unbiased estimator of subgradient of:

$E\left[P_2\left(Q^1, y_1^1 - D_1^1, \ldots\ldots, y_n^1 - D_n^1\right)\right]$ **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

$P_2\left(Q^1, y_1^1 - d_1^1, \ldots\ldots, y_n^1 - d_n^1\right)$ **= Totally unimodular linear program** (LP)

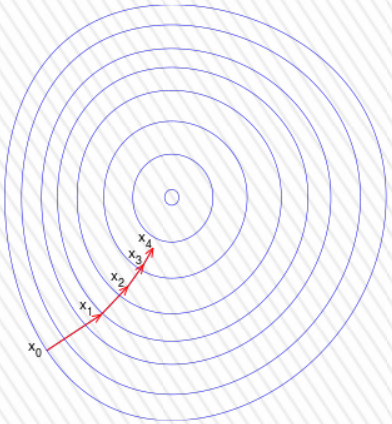
for each realization

» 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 $\boldsymbol{D}_i^1$
   - 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

Total	Before	After
Order quantity		
Returns		
Sales		
Stockouts		

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

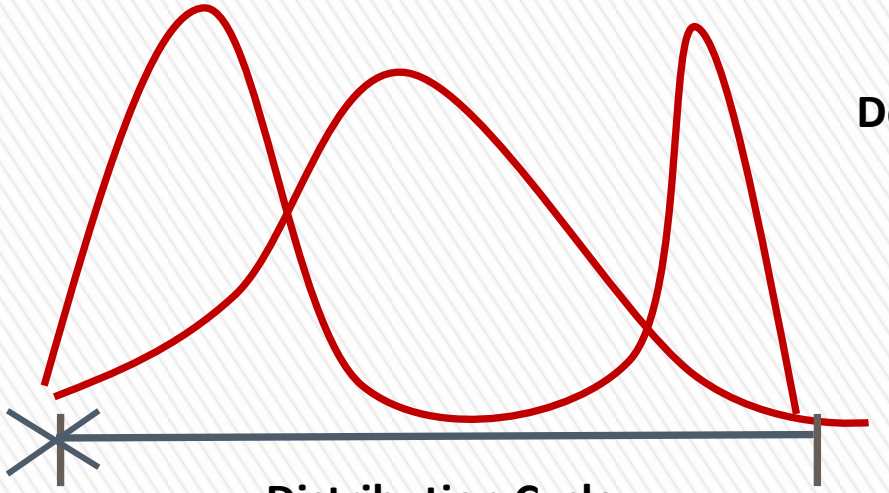
- After pilot decision support tool was implemented for over 15 magazines!
- Model is solved on a weekly basis. Recommendations modified manually.
- Currently implemented in 400 EDI enabled (mostly larger) retailers (POS data once a day)
- Sales agents compensated for sales and returns

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?

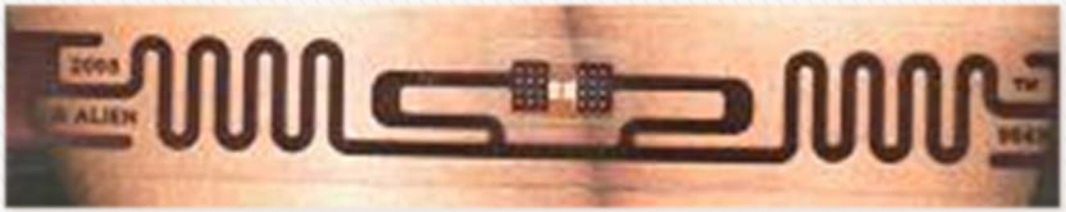


Demand density over the distribution cycle

- 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

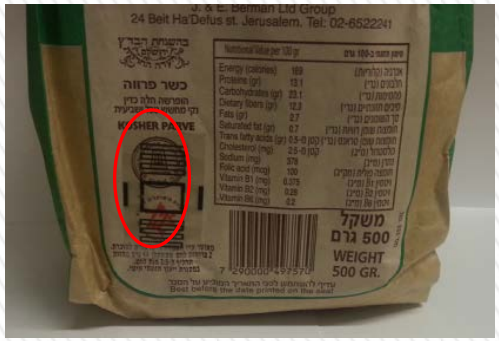
Weekend (Daily) Newspaper Pilot

- 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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