Warehousing Systems

Topics for 3 classes
- Introduction to warehousing
- Activity profiling
- Design of a fastpick area
- Zoning/slotting and layout issues

Why Have a Warehouse?
- Warehouses require many expensive resources:
  - capital
  - labor
  - facilities
  - management systems
  - etc.

Product Consolidation
- There is a cost associated with each product movement
- Distributor can consolidate shipments for downstream customers
  - can reduce transportation costs
  - can facilitate downstream receiving

Product Positioning
- Position product close to the customer
- Speed!

Economies of Scale
- To realize economies of scale from price breaks (purchasing)
- To realize economies of scale in storage (equipment, space)
**Product Buffer**
- Can provide an inventory buffer for:
  - Variability in demand
  - Seasonality of demand

**Value Adding**
- Some warehouses are used to add value to the product
  - Packaging
  - Assembly
  - Postponement

**Postponement**
- Postponement types - form (labeling, packaging, assembly, manufacturing,) and time
- A favored strategy under following conditions:
  - *Technology & process characteristics* - modular design, limited complexity, feasible to decouple
  - *Product characteristics* - high commonality of modules, specific peripherals
  - *Market characteristics* - short product life cycles, price competition, varied markets and customers

**Warehousing Functions**
- **Receiving Function**
  - Unload
  - Inspect
  - Put Away

- **Cross Dock**

- **Shipping Function**
  - Load
  - Pack
  - Order Pick

- **Storage Function**

**Warehousing Evolution**
- The role of warehousing has evolved over the years:
  - 1950-1970 - primary role of the warehouse was the storage function
  - 1970-1990 - the rise of distribution centers (DC) which included order assembly as a key component
  - 1990-present - the rise of the logistics center which included value added services on top of the DC functions
- Storage (though still important!) is not the key driver that it once was.

**Current Key Warehousing Issues**
- Increased use of cross docking
- Increased use of “fast-pick”
- Increased use of value adding services and customization
- Need to deal with reverse logistics (e.g. returns)
- Increase in complexity (e.g. SKU proliferation)
- Increased accuracy requirements
Warehousing Objective

- Minimize the set of costs:
  - labor
  - space
  - capital
  - IT, etc.
- Subject to constraints from customer
  - fill rate
  - response time
  - accuracy

![Hard Problem!]

What is activity profiling?

- A systematic analysis of the activity of order (and item) activity during warehousing operations
- It helps us to identify
  - Policy improvement opportunities
  - Equipment selection/use changes
  - Layout redesign opportunities
  - Key SKUs

![The data is key!]

Basics of profiling

- Important to realize that there is a tradeoff between:
  - Simple (aggregate) statistical description
  - Complex description
- Simple statistics can give a quick (albeit rough) description of the warehouse. However, looking at averages can hide complexity (including correlation, confounding, etc.)

Example

- For our warehouse, the average lines per order is 10
- If we look at the actual distribution of lines per order we see the following:
  - 50% of the time the lines per order is 1
  - 50% of the time the lines per order is 19

Example statistics

- Average number of shipments per day
- Average number of SKUs in the warehouse
- Average number of orders shipped per day
- Average number of lines per order
- Average number of units (pieces, cases) per line
- Number of order-pickers devoted to pallet movement, case-picking, and to broken-case picking
- Seasonalities
- etc.
What Do These Statistics Tell Us?

In a warehouse, “20% of the SKUs account for 80% of the activity.”

ABC classification

Common ABC rankings

There are several different ways in which SKUs can be “ordered”

- based on dollar annual volume
- based on case movements
- based on number of times picked
- based on weight moved
- etc.

Each of these can give a very different picture of warehouse operations

Top 10 items by # cases

<table>
<thead>
<tr>
<th>SKU</th>
<th>Pcs/Case</th>
<th>Pieces</th>
<th>Cases</th>
<th>Picks</th>
</tr>
</thead>
<tbody>
<tr>
<td>UL Slimfast Bonus Choc Royale</td>
<td>6</td>
<td>3085</td>
<td>514</td>
<td>525</td>
</tr>
<tr>
<td>Standard Family ‘Tom’ pack</td>
<td>12</td>
<td>4488</td>
<td>374</td>
<td>374</td>
</tr>
<tr>
<td>Sahners Pay Stix</td>
<td>12</td>
<td>4232</td>
<td>360</td>
<td>360</td>
</tr>
<tr>
<td>Gemini Video Tape 1.2L</td>
<td>24</td>
<td>7200</td>
<td>303</td>
<td>471</td>
</tr>
<tr>
<td>House Brand Aspirin 50G</td>
<td>12</td>
<td>3144</td>
<td>262</td>
<td>365</td>
</tr>
<tr>
<td>House Brand Complete Alergy Caps</td>
<td>24</td>
<td>5850</td>
<td>254</td>
<td>354</td>
</tr>
<tr>
<td>Act II Micro Butter</td>
<td>144</td>
<td>34362</td>
<td>239</td>
<td>806</td>
</tr>
<tr>
<td>House Brand Pain Rel Caps 30/50MG</td>
<td>24</td>
<td>5804</td>
<td>234</td>
<td>360</td>
</tr>
<tr>
<td>House Brand Caps 500MG</td>
<td>24</td>
<td>5560</td>
<td>231</td>
<td>485</td>
</tr>
<tr>
<td>Sahners S/F Ass mix</td>
<td>12</td>
<td>2520</td>
<td>210</td>
<td>206</td>
</tr>
</tbody>
</table>

Top 10 items by # customer requests (picks)

<table>
<thead>
<tr>
<th>SKU</th>
<th>Pcs/Case</th>
<th>Pieces</th>
<th>Cases</th>
<th>Picks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Act II Micro Butter</td>
<td>144</td>
<td>34362</td>
<td>239</td>
<td>806</td>
</tr>
<tr>
<td>Beach Bag Sea</td>
<td>6</td>
<td>815</td>
<td>136</td>
<td>780</td>
</tr>
<tr>
<td>Act II Micro Life Butter</td>
<td>144</td>
<td>21276</td>
<td>140</td>
<td>511</td>
</tr>
<tr>
<td>House Brand Pain Rel Caps 30/50MG</td>
<td>24</td>
<td>5804</td>
<td>234</td>
<td>360</td>
</tr>
<tr>
<td>Act II Micro White Cheddar</td>
<td>120</td>
<td>15810</td>
<td>132</td>
<td>595</td>
</tr>
<tr>
<td>House Brand Complete Alergy Caps</td>
<td>24</td>
<td>5850</td>
<td>254</td>
<td>354</td>
</tr>
<tr>
<td>House Brand Echinacea</td>
<td>144</td>
<td>4175</td>
<td>33</td>
<td>534</td>
</tr>
<tr>
<td>Wrigley Plen-T-Pak Big Red</td>
<td>192</td>
<td>12702</td>
<td>87</td>
<td>534</td>
</tr>
<tr>
<td>Wrigley Plen-T-Pak Coulteri</td>
<td>192</td>
<td>14136</td>
<td>77</td>
<td>526</td>
</tr>
<tr>
<td>UL Slimfast Bonus Choc Royal</td>
<td>6</td>
<td>3085</td>
<td>314</td>
<td>525</td>
</tr>
</tbody>
</table>
### Top 10 items by # pieces sold

<table>
<thead>
<tr>
<th>SKU</th>
<th>Pcs/Case</th>
<th>Pieces</th>
<th>Cases</th>
<th>Picks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Deck Baseball Low #</td>
<td>432</td>
<td>25452</td>
<td>163</td>
<td>423</td>
</tr>
<tr>
<td>Act II Micro Butter</td>
<td>144</td>
<td>2050</td>
<td>239</td>
<td>806</td>
</tr>
<tr>
<td>Score Baseball Series II</td>
<td>720</td>
<td>23544</td>
<td>35</td>
<td>348</td>
</tr>
<tr>
<td>Act II Micro Lite Butter</td>
<td>144</td>
<td>21718</td>
<td>144</td>
<td>570</td>
</tr>
<tr>
<td>Tropic Wax Pack Baseball</td>
<td>720</td>
<td>18864</td>
<td>25</td>
<td>279</td>
</tr>
<tr>
<td>Act II Micro White Cheddar</td>
<td>139</td>
<td>16871</td>
<td>133</td>
<td>563</td>
</tr>
<tr>
<td>Wrigley Plent-Pak Distillment</td>
<td>192</td>
<td>13736</td>
<td>177</td>
<td>526</td>
</tr>
<tr>
<td>Act II Micro Natural</td>
<td>144</td>
<td>13284</td>
<td>132</td>
<td>563</td>
</tr>
<tr>
<td>Wrigley Plent-Pak Big Red</td>
<td>192</td>
<td>12752</td>
<td>127</td>
<td>530</td>
</tr>
<tr>
<td>Hershey Resse Peanut Butter Cpl</td>
<td>432</td>
<td>12218</td>
<td>29</td>
<td>310</td>
</tr>
</tbody>
</table>

### Observations

- Different views tell us different things
  - Cases moved is of interest to receiving, put-away, and restocking operations because each case must be handled separately to put it on a shelf
  - Picks give us a view of which SKUs have the highest labor requirements
  - Pieces sold give us a view of sales clerk effort (notice they spend most of their time ringing up popcorn and baseball cards)

### Observations continued

- There can be some surprising issues with ABC analysis. For example, notice that the highest SKUs in terms of cases moved has very few pieces per case and hence a relatively small number of pieces moved.
- When considering mature produces (e.g. staples), they tend to not be skewed in the number of picks (i.e. it falls off slowly) compared to fashion products (e.g. the top 100 selling music CDs out of over 100000 make up 25% of all sales).

### Item profiling examples

- Profiling of customer orders
- Correlation analysis
- Time-based analysis
- Variability-based analysis
Customer order profiling questions

- Question: should we have separate areas for pallet picking and case picking?
- Question: how effective will zoning strategies be for our operations?
- Question: are there ways we can anticipate customer actions

SKU level (pallet vs case vs …)

- What if we looked at pallet versus case and case versus broken case profiles in terms of %orders:

<table>
<thead>
<tr>
<th>Form</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case</td>
<td>50%</td>
</tr>
<tr>
<td>Pallet</td>
<td>27%</td>
</tr>
<tr>
<td>Mixed</td>
<td>17%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Form</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case</td>
<td>16%</td>
</tr>
<tr>
<td>Broken Case</td>
<td>17%</td>
</tr>
<tr>
<td>Mixed</td>
<td>67%</td>
</tr>
</tbody>
</table>

What do we learn?

- The distribution of pallet and full case are such that we can separate pallet picking and zone picking operations and not pay a large penalty for mixed orders
  - warehouse within a warehouse!
- The same is not true when comparing full and broken case. The cost will probably be too high to separate these operations

Distribution of order mix of families

- Suppose we support 3 families of SKUs (F1, F2 and F3). We observe the following percentage of total orders:
  - F1 only occurs 25% of the time
  - F2 only occurs 30% of the time
  - F3 only occurs 20% of the time
  - F1 and F2 occur 2% of the time
  - F1 and F3 occur 5% of the time
  - F2 and F3 occur 13% of the time
  - F1 and F2 and F3 occur 5% of the time

What do we learn?

- Zoning by family will be a very effective strategy
- F2 and F3 should be located close to each other

- Related issue - family specification
  - by item type
  - by item form - very useful to have family types with same material handling requirements
  - Can family redesign lead to useful patterns?

Correlation

- In many cases, if one item is ordered, then there is often times a “complimentary” good ordered
Time-based analysis

- Several things change for a warehouse of time
  - weekly seasonality of SKUs
  - monthly seasonality of total demand
  - daily “seasonality” of orders
- Issue: a warehouse needs to be designed to handle the peaks not just the average!
  - (though opportunity to reduce some of these requirements by properly planning ahead)

Variability-based profiling

- Often times when we report averages, we “smooth” over the true variability of the process
- Example

<table>
<thead>
<tr>
<th>Time</th>
<th># Picks</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:00-9:00</td>
<td>110</td>
</tr>
<tr>
<td>9:00-10:00</td>
<td>40</td>
</tr>
<tr>
<td>10:00-11:00</td>
<td>33</td>
</tr>
<tr>
<td>11:00-12:00</td>
<td>35</td>
</tr>
<tr>
<td>12:00-1:00</td>
<td>29</td>
</tr>
<tr>
<td>1:00-2:00</td>
<td>180</td>
</tr>
<tr>
<td>2:00-3:00</td>
<td>140</td>
</tr>
</tbody>
</table>

Example continued

- For this example, if we staffed to the average, then we would need to be able to handle 81 picks per hour.
- However - the standard deviation for this process is very high (>61) and if we designed to the average, then for 3 of the hour periods, we would be SEVERELY under-designed.

How do we profile?

- Simple techniques
  - Excel spreadsheets
  - Access databases
- Software solutions
  - Data mining software

Summary

- Many opportunities in warehouse design and operations present themselves when profiling
- Activity profiling is a continuous process
- Don’t forget to look at the big picture!
E-Retail Home Delivery

Supply Chain Models

- **Supplier Direct**
- **Outsourced**
- **Integrated**
- **Flow-Through**
- **Dedicated**
- **Third-Party DC**

1. **Store**
2. **Retail Store**
3. **Current Retail DC**
4. **Current Retail DC**
5. **Dedicated DC**
6. **Third-Party DC**

Parcel Carrier or Customer Pick-up

For Home Delivery:

- **Consumer**
- **Supplier**

Potential problems:

- Out-of-stock items, late deliveries
- Multiple items from the same order arrive at different times
- Tracking, tracing and returns are more complicated

Shipping directly from the suppliers:

- **Traditional retailer**
  - Farm ➔ Importer ➔ Wholesaler ➔ Florist ➔ Customer
  - 8-12 days

- **National retailer**
  - Farm ➔ Gerald Stevens ➔ Florist ➔ Customer
  - 3-5 days

- **Direct from farms**
  - Farm ➔ Proflowers.com ➔ Customer
  - 1-2 days

Distribution from a centralized warehouse:

- **Farm**
- **Importer**
- **Wholesaler**
- **Florist**
- **Customer**

- **FedEx** dedicated e-distribution facility in Memphis

Ordered by FedEx

FedEx order processing

Inventory status

Distribution from multiple warehouses:

- **Peapod**
  - 8% to 10% of orders weren’t being shipped on time, because outside vendors were out of stock.
  - Warehouses near Chicago, San Francisco and New York City
  - Out-of-stock rate in those markets has diminished to less than 2%.

- **Webvan Group Inc.**
  - $1 billion order with Bechtel Group for giant warehouses in 26 cities across the U.S.

- **Amazon.com**
  - $300 million distribution-center initiative; giant facilities in Nevada, Kentucky and Kansas

- **eToys, Barnesandnoble.com**

Pros and cons:

- High investment costs
- Shorter delivery times

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- **Webvan Group Inc.**
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Webvan Distribution - Atlanta Market Area

Map showing 26 cities across the U.S.
Customer Orders gathered from the internet, and sent to Webvan.com marketplace for fulfillment.

Customer Orders data "crunched" to determine number of totes needed per order and optimal path of conveyor stops for each tote needed.

Empty, cleaned totes automatically introduced into conveyor systems, and conveyed to picking areas.

Picking Occurs:

- Conventional storage: Employees use RF scanners to gather totes into batches, and proceed to locate and pick items for the batch of totes. The RF scanning and optimized path helps.

- AS/RS Storage: Employees use pick-to-light technology to pick items from automatically moved AS/RS into totes conveyed in front of them.

Filled totes are conveyed through a sorting system to Shipping, where they are RF scanned to consolidate totes into groups that represent customer orders. The totes are then placed onto specialized mobile racks which are directed to specific dock doors.

Racks of filled totes are scheduled into trucks for moving to stations or directly onto courier vans for delivery to customers. Delivery occurs via a custom route planning system and GPS aided navigation.

Couriers deliver the totes to customers’ homes adhering to a detailed timeline of delivery time projections. The projections can be customized for more than 30 different variables to get courier routing optimized so the couriers are on time to meet the 30 minute window that the customer desires, and maintain high levels of productivity.

**Market Area Model**

**Equipment Related Productivity Improvement**

**Warehousing - Carousels**

**Hub and Spoke - Atlanta Market Area**