Warehousing Design Objective

The goal of warehouse design is to

- Minimize the discounted present value of the costs of
- Establishing and operating the warehouse over some horizon specified by the decision-maker
- Subject to a number of resource and performance constraints.
### Warehousing Design: Current Characteristics

- **Overwhelming complexity and variety**
  - No monolithic model
  - Hierarchical, iterative models
  - Approximate analytical models
    - Dramatically limit number of alternatives
  - Final choice based on detailed simulation

### Iterative Warehouse Design Algorithm

- **Solve capacitated warehouse flow model (CMF)**
  - MIP
  - Determines flows, technologies and areas

- **Solve conceptual block layout (WBL)**
  - Block layout heuristics or MIP
  - Determines location, transportation costs

- **Iterate**
Capacitated Warehouse Flow Model (CMF)

Global Decisions
Receiving Decisions
Bulk Store Decisions
Shipping Decisions

Total Cost Function
Global Constraints: Space, Budget, etc.

Receiving
Bulk Store
Shipping

Warehouse Type 1: Small Parts Storage and Order Picking

- **Availability of analytical models**
- **Wide range of technologies**
  - Bin shelving, modular drawers, gravity flow rack, carousels
- **Variety of policy decisions**
  - Storage, order picking, aisle configuration
**Bin Shelving Illustrations**

**Modular Drawers Illustrations**
**Single Technology Optimization Model**

- Minimize sum of area, equipment, labor cost
- Subject to
  - Picking throughput requirements
  - Inventory storage requirements
- Incorporates
  - Travel time, extract time, picking policy
  - Equipment counts
  - Aisles configuration, storage policy

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**Schematic of Warehouse Ladder Structure**
**Model Hierarchy by Increasing Level of Detail**

- **Level 1**
  - Volume only, no individual dimensions, number of cabinets
  - Fast optimization and round-up

- **Level 2**
  - Explicit vertical dimension, cabinets and drawer types
  - Bin packing MIP

**Selected Formulas**

- Travel time in function of number of aisles visited (Chew, 1999)

\[
OTT = \frac{1}{WS} \left[ NA \cdot AL \left( 1 - \left( 1 - \frac{1}{NA} \right)^{NL} \right) + 2 \cdot AW \left( NA - \sum_{j=1}^{NA-1} \left( \frac{j}{NA} \right)^{NL} \right) \right] \\
\sum_{m} NCU_m \cdot CD_{mw} \leq 2 \cdot NA \cdot AL \\
AREA = \left[ 2 \cdot CAW + AL \right] \left[ NA \cdot \left( 2 \cdot CD_{md} + AW \right) \right] \\
NE \geq NO \cdot (OTT + ET \cdot NL)
\]
Preliminary Numerical Experiments

Three scenarios

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Parameters

- 250 shifts/year (250 days, 1 shift/day)
- $12 / labor hour

Total Annual Cost Comparison Based on Level 1 Models
**Volume versus Area Utilization Factor**

- Fill Ratio of volume (Level 1) or area (level 2)
- Determined based on three data sets
- Validated based on three other data sets
- Consistent and stable ratios
- Physical validation still required

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**VUF and AUF Linear Relations Graph**

![Graph showing linear relationships between VUF and AUF]
Comparison of Total Cost for Different Models & Technologies

Summary of Cost Impact of Aisle Configuration (BS-LO)
Summary of Technology and Category Cost Comparison

Cost Comparison Observations and Conclusions

- Overriding influence of labor costs (travel and extract times)
- Level 1 models are sufficiently accurate to reject many technologies and rank cost impacts
- Model validation necessary
  - Perturbation, face, model consistency
- Cost parameters are a localized input
Future Research

- Need for more level 1 models
  - Different technologies, storage policies, order picking policies
- Model validation of all levels
- All departments on functional flow path (receiving, shipping)
- Master model experiments

Thank You
Can I Answer Any Questions?