Warehousing Systems Design

Marc Goetschalckx, Doug Bodner, T. Govindaraj, Leon McGinnis, Gunter Sharp, Lei Tian

Industrial and Systems Engineering
Georgia Institute of Technology
Atlanta, GA 30332-0205
marc.goetschalckx@isye.gatech.edu

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Marc Goetschalckx

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.*

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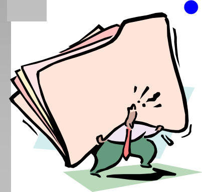
Warehousing Design: Current Characteristics

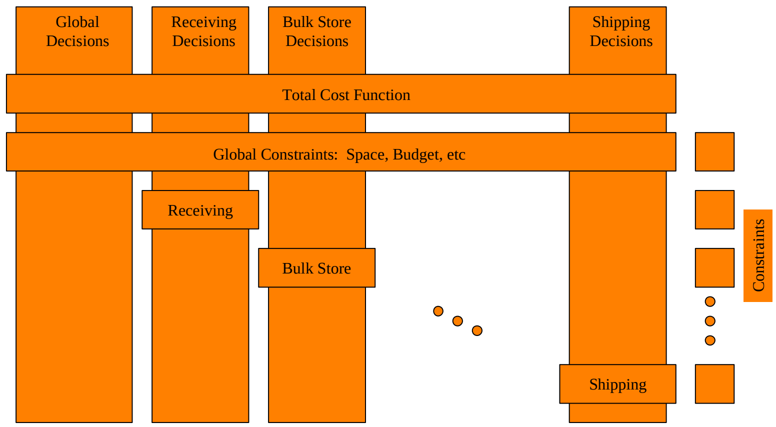
- Overwhelming complexity and variety
  - No monolithic model
  - Hierarchical, iterative models
  - Approximate analytical models
    - Dramatically limit number of alternatives
  - Final choice based on detailed simulation



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)

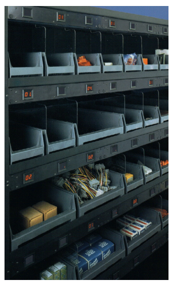


Warehouse Type 1: Small Parts Storage and Order Picking

- 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

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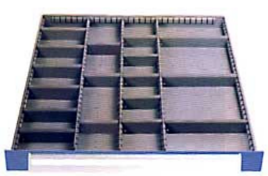
Modular Drawers Illustrations



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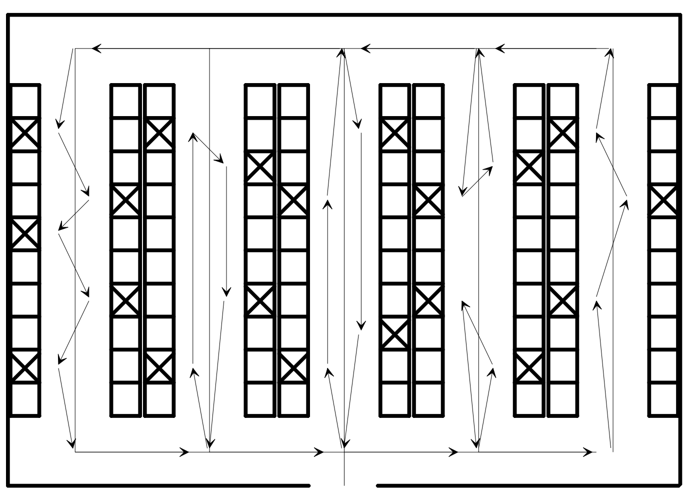
Single Technology Optimization Model

- 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

Schematic of Warehouse Ladder Structure



Model Hierarch 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

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Selected Formulas

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

$$OTT = \frac{1}{WS}\left[\begin{array}{l} NA \cdot AL(1-(1-1/NA)^{NL}) + 2 \cdot AW(NA - \sum_{j=1}^{NA-1}(j/NA)^{NL}) + \\ AL(1/2 + 1/2\sum_{j=1}^{NA}(j/NA)^{NL}\binom{NA}{j}(-1)^{j-1}2^{(NA-j)}) \end{array}\right]$$

$$\sum_m NCU_m \cdot CD_{mw} \leq 2 \cdot NA \cdot AL$$

$$AREA = \left[2 \cdot CAW + AL\right]\left[NA \cdot \left(2 \cdot CD_{md} + AW\right)\right]$$

$$NE \geq NO \cdot \left(OTT + ET \cdot NL\right)$$

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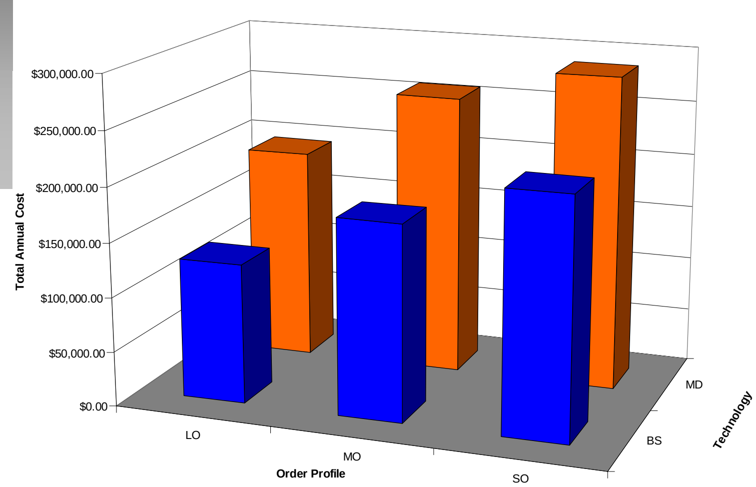
Preliminary Numerical Experiments

- Three scenarios

	# SKUs	# Orders	# Lines/Order	# Lines/Year
LO	1,000	75	200	3,750,000
MO	1,000	500	30	3,750,000
SO	1,000	3,000	5	3,750,000

- 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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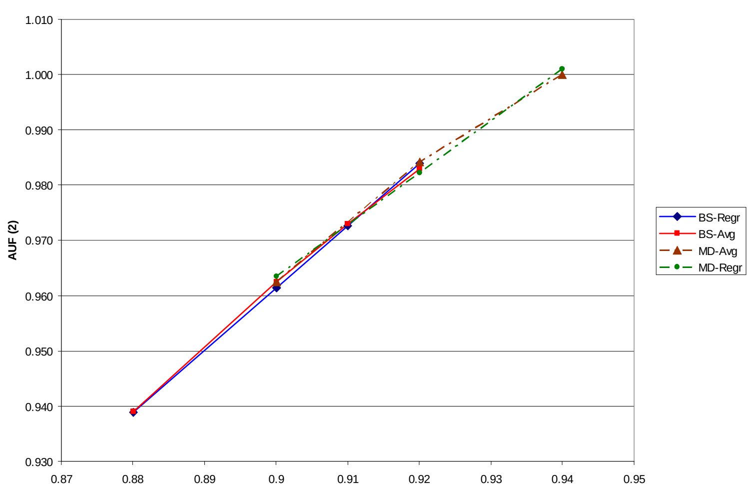
VUF and AUF Linear Relations Graph



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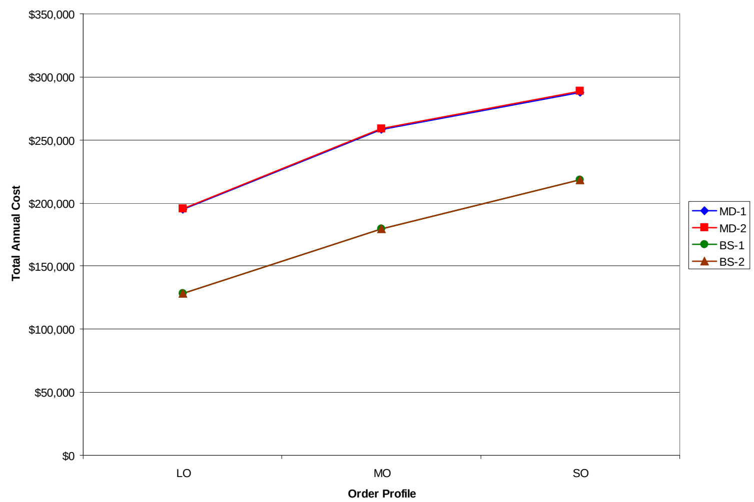
Comparison of Total Cost for Different Models & Technologies



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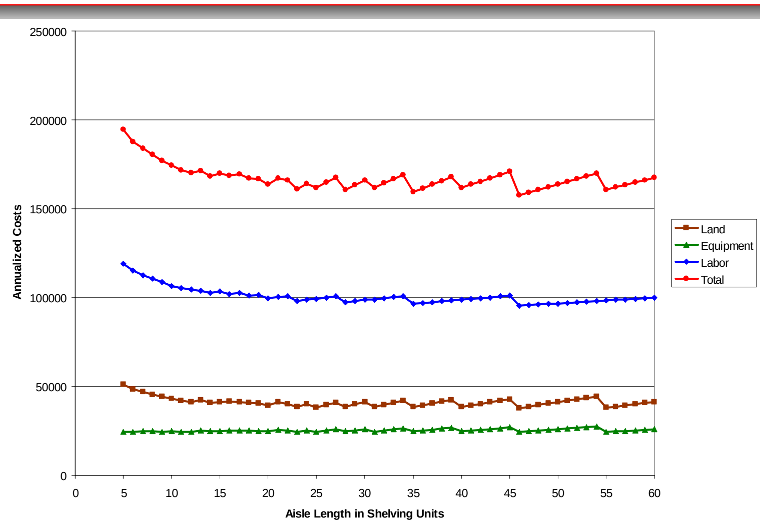
Summary of Cost Impact of Aisle Configuration (BS-LO)



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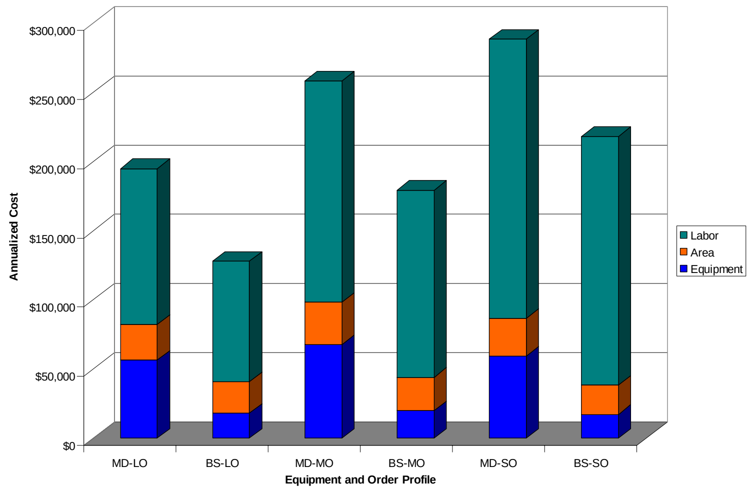
Summary of Technology and Category Cost Comparison



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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

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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?