Warehousing Systems Design

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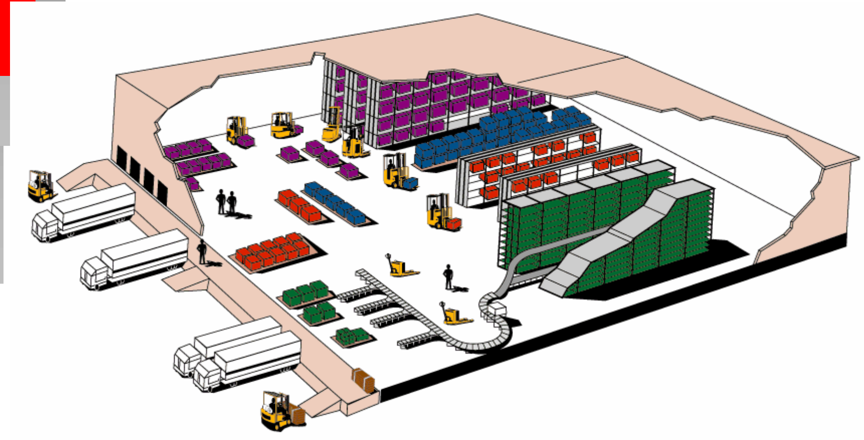
Credits

- Faculty
  - L. McGinnis, D. Bodner, T. Govindaraj, M. Goetschalckx, G. Sharp
- Graduate students
  - L. Tian and K. Huang
- Sponsors
  - Keck foundation, NSF, Ford Motor, UPS WWL,

Distribution Warehouse: Functional Areas Illustration



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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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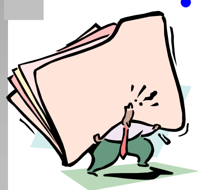
Warehousing Design: Current Characteristics

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



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Warehousing Design Methodology Needs

- Integration of isolated research and methods
- Rich empirical data sets
- Rigorous mathematical models
- Synthesis and design tools

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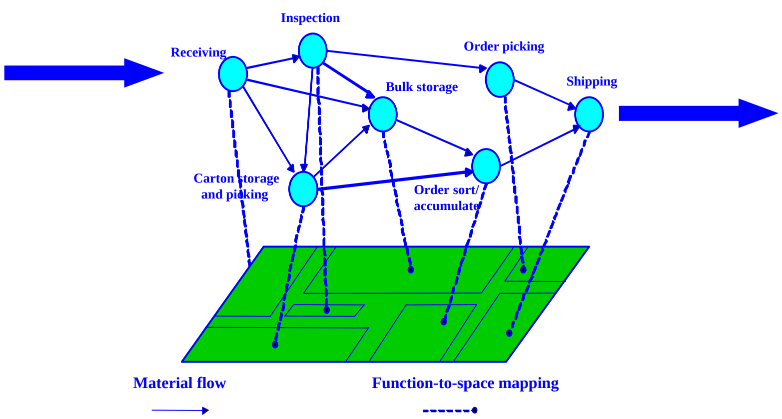
Functional Flow Network for Basic Warehousing Functions



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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*

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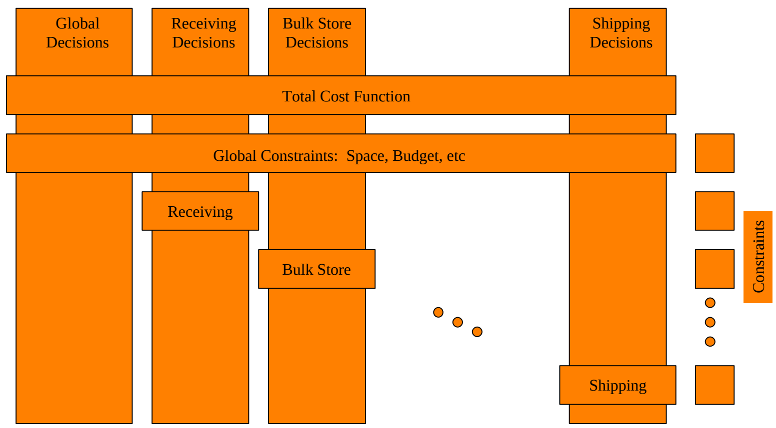
Capacitated Warehouse Flow Model (CMF)



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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

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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

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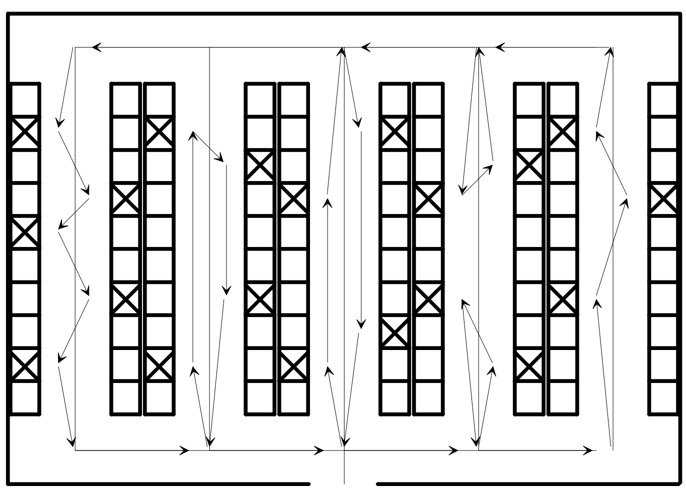
Schematic of Warehouse Ladder Structure



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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

Selected Formulas

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

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

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

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

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

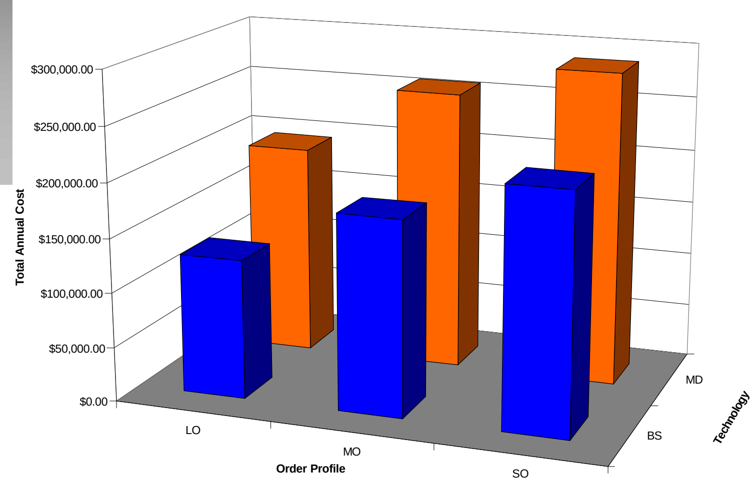
Preliminary Numerical Experiments

- 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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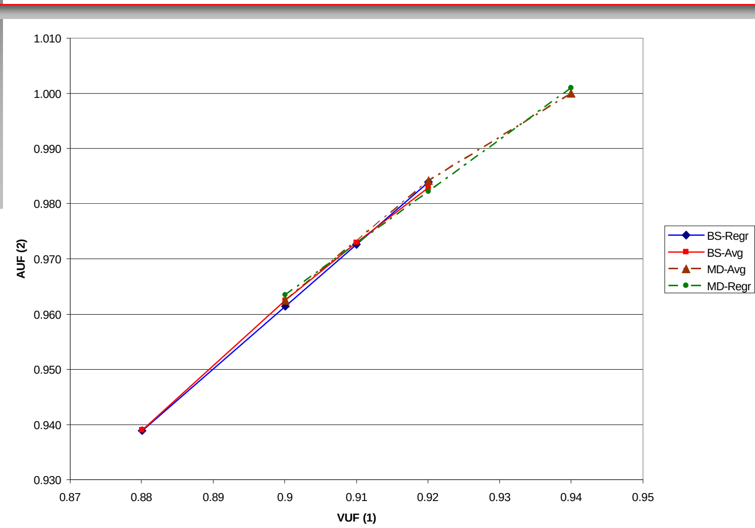
VUF and AUF Linear Relations Graph



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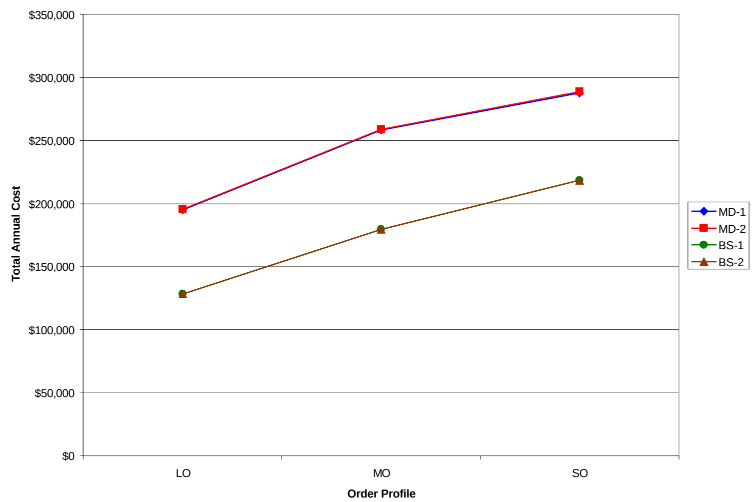
Comparison of Total Cost for Different Models & Technologies



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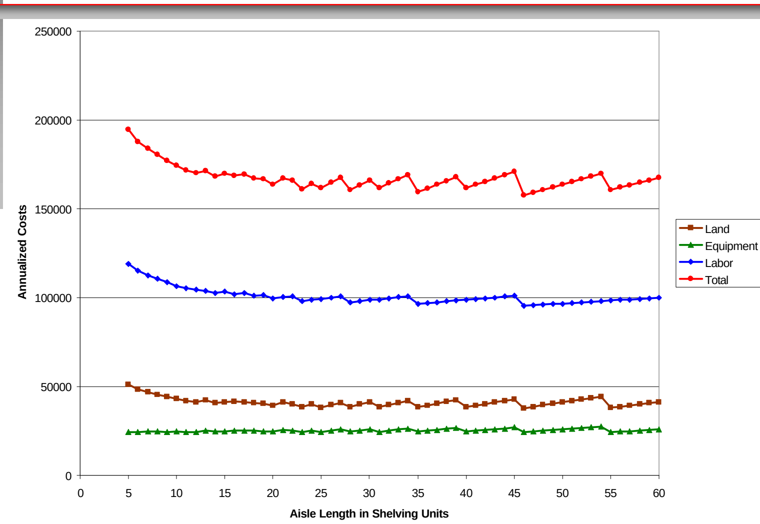
Summary of Cost Impact of Aisle Configuration (BS-LO)



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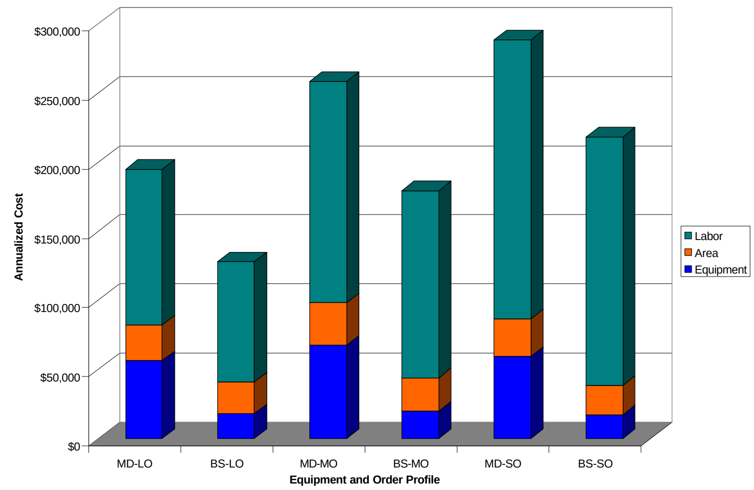
Summary of Technology and Category Cost Comparison



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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?