Prioritizing Inbound Transportation

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MIT SCM Research FEST

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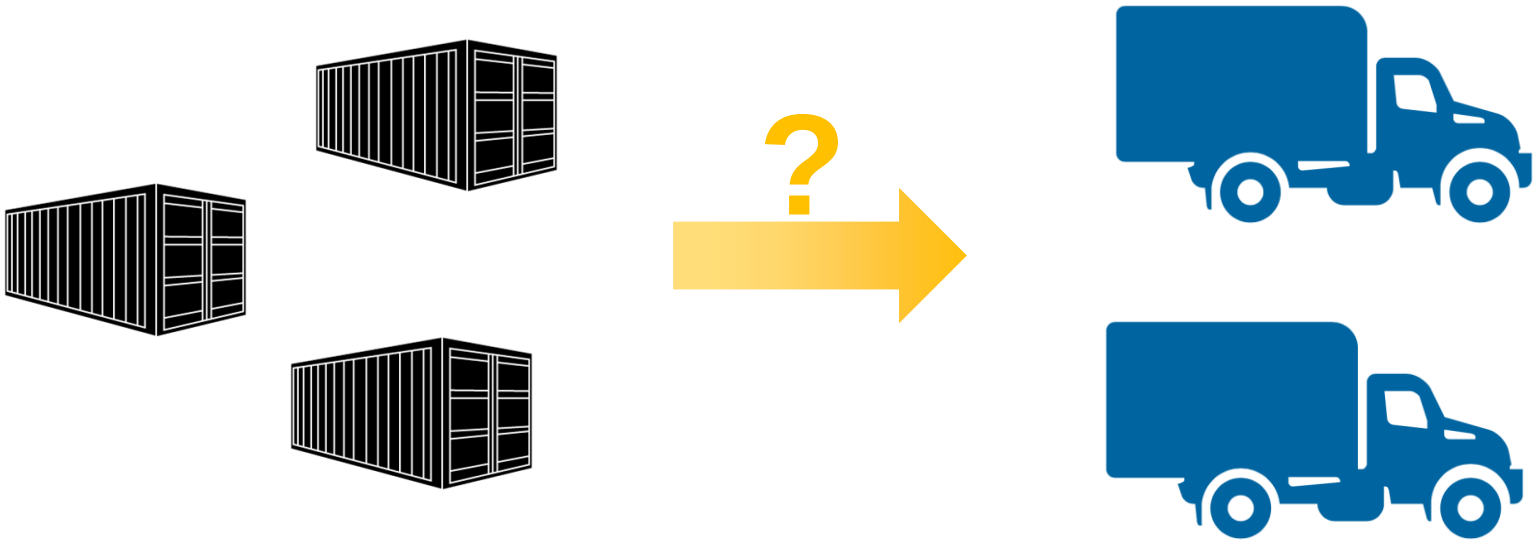
MIT Supply Chain MANAGEMENT

Agenda

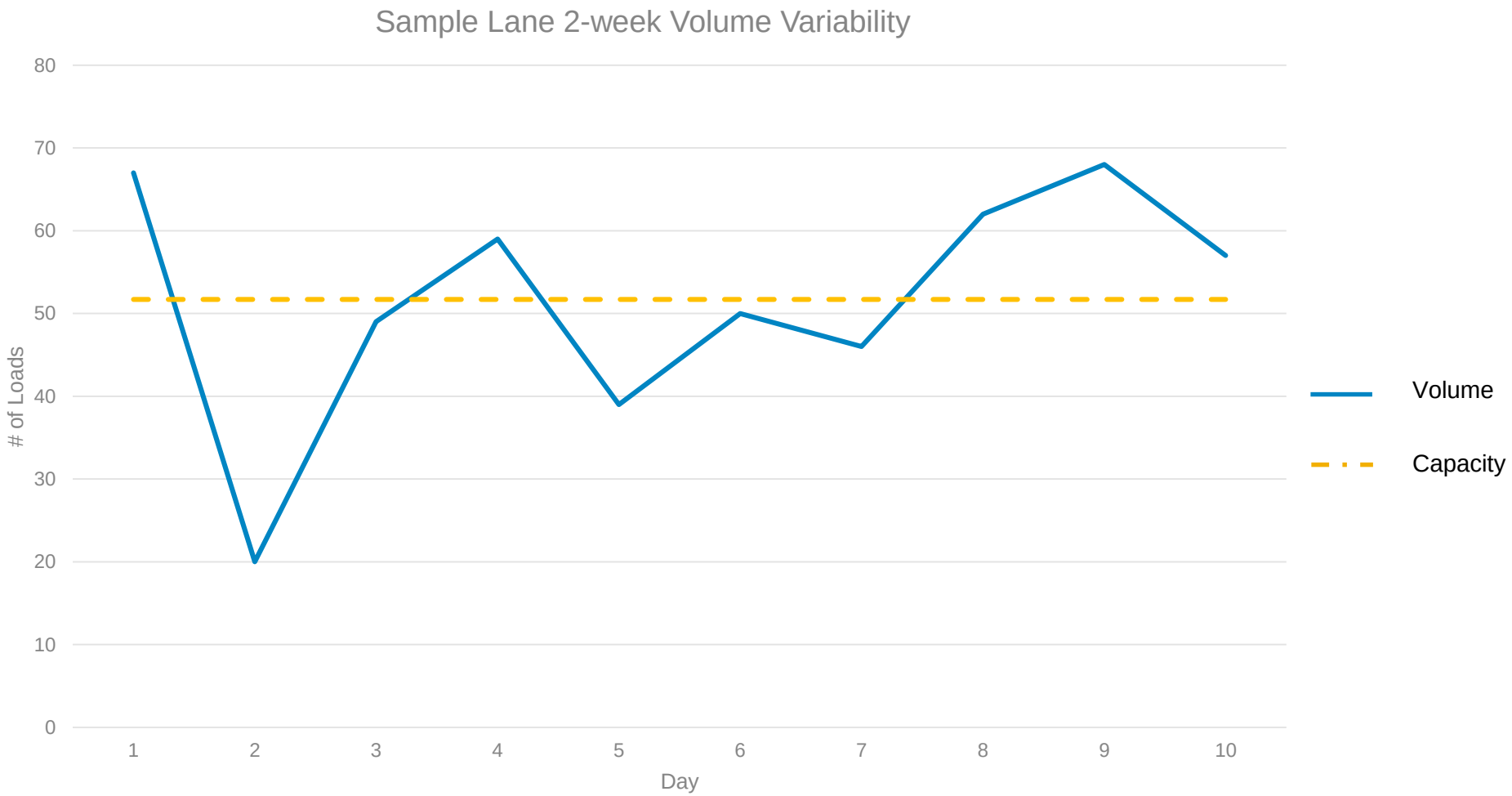
- Context
- Prioritization Method
- Optimization
- Key Takeaways

3 Loads vs. 2 Trucks

Research question: How to determine which loads to pick up when capacity is constrained?



Motivation
Why prioritize?



Source: ShopCo

Analytic Hierarchy Process (AHP)
Prioritization Technique

- **Widely used in multi-criteria decision making**
  - Allocate funds across research projects
  - Develop criteria to rate and select vendors

- **Fits ShopCo's problem**
  - Multiple criteria and stakeholders
  - Consistency check
  - Ratio-scaled

Leveraged AHP to define prioritization logic

AHP – Key Steps

1. Define problem
2. Develop hierarchical framework
3. Construct pairwise comparison matrices
4. Perform judgment of pairwise comparison matrices
5. Synthesize pairwise comparison matrices
6. Perform consistency check
7. Repeat steps 3-6 for all levels of the hierarchy
8. Develop final priority values
9. Prioritize loads

*Adapted from Ariff et al., 2012

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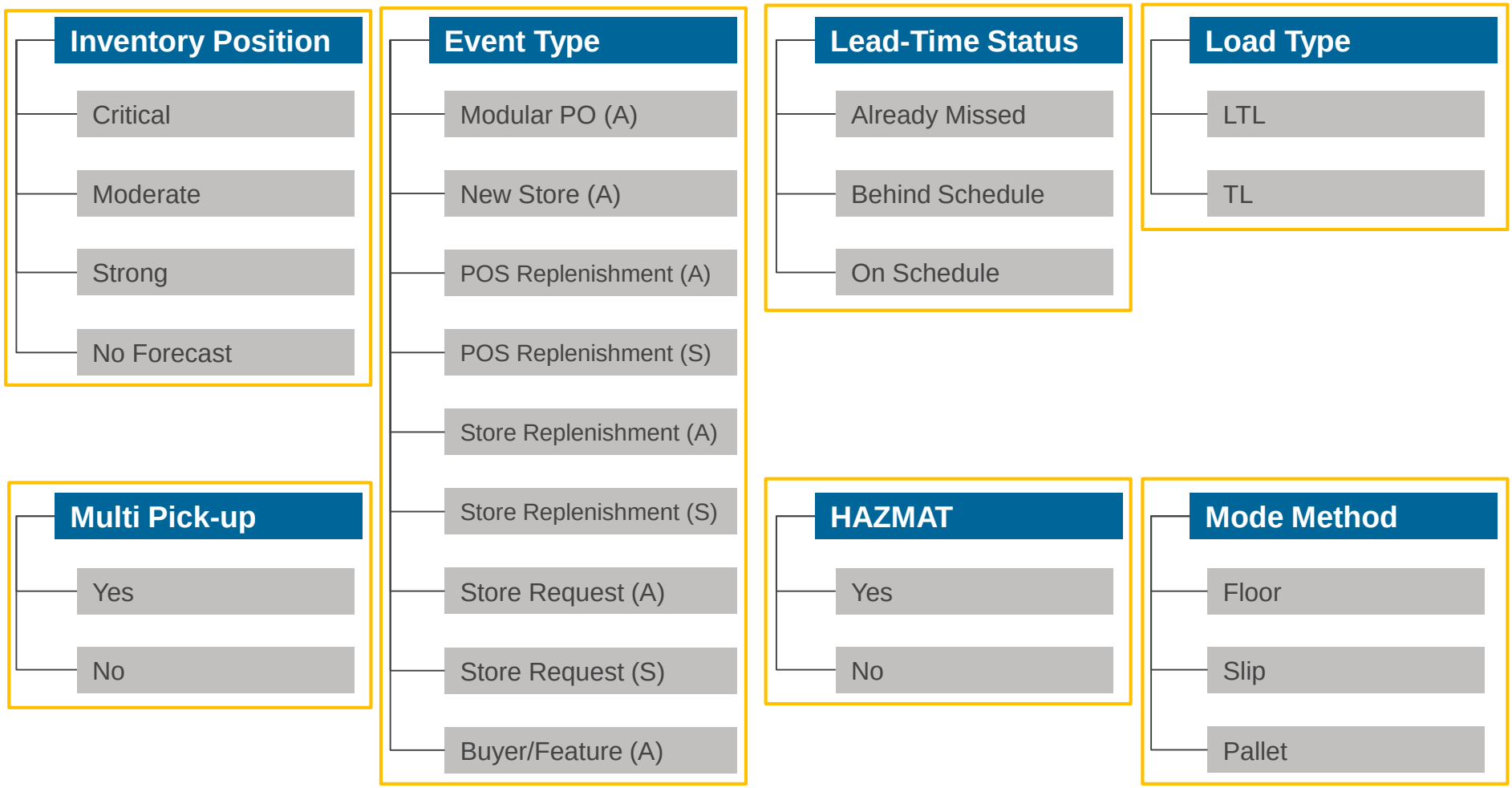
Defining Decision Criteria

…with inputs from key stakeholders at ShopCo



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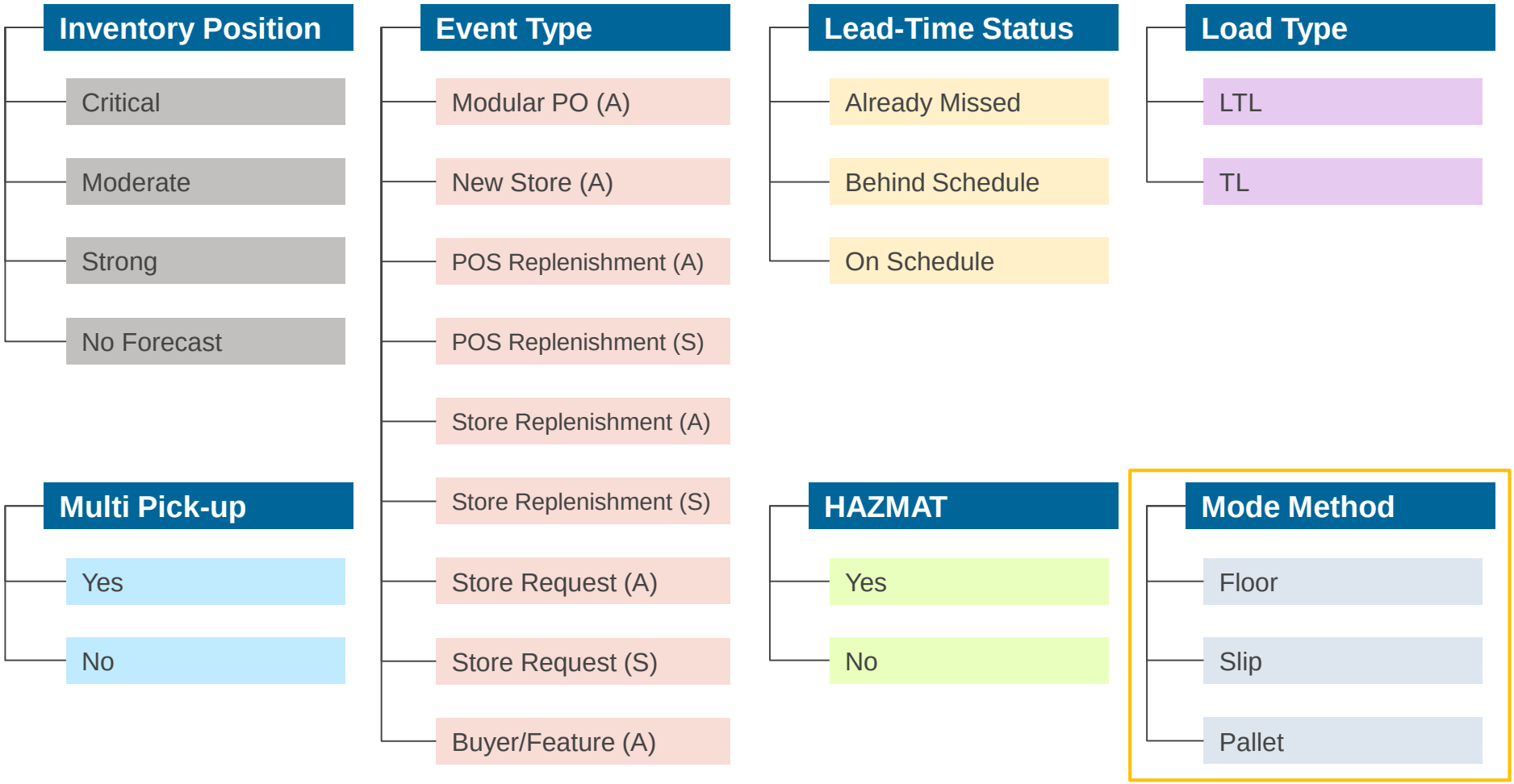
Pairwise Comparisons



Pairwise Comparison – Matrix

- Example: Mode Method pairwise comparison

	Slip	Floor	Pallet
Slip	1.000	-	-
Floor	-	1.000	-
Pallet	-	-	1.000

Pairwise comparison judgments

Inverse

The Fundamental Scale for Pairwise Comparison

Intensity of Importance	Definition	Explanation
1	Equal importance	Two elements contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one element over another
5	Strong importance	Experience and judgment strongly favor one element over another
7	Very strong importance	One element is favored very strongly over another, its dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one element over another is of the highest possible order of affirmation

Intensities of 2, 4, 6, and 8 can be used to express intermediate values. Intensities 1.1, 1.2, 1.3, etc. can be used for elements that are very close in importance

Pairwise Comparison – Matrix

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	Slip	Floor	Pallet
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Pairwise Comparison – Matrix

- Example: Mode Method pairwise comparison

	Slip	Floor	Pallet
Slip	1.000	**3.000**	-
Floor	-	1.000	-
Pallet	-	-	1.000

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Pairwise Comparison – Matrix

- Example: Mode Method pairwise comparison

	Slip	Floor	Pallet
Slip	1.000	-	-
Floor	-	1.000	-
Pallet	-	-	1.000

Use reciprocal!

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Pairwise Comparison – Matrix

- Example: Mode Method pairwise comparison

	Slip	Floor	Pallet
Slip	1.000	**0.333**	**-**
Floor	-	1.000	**-**
Pallet	-	-	1.000

The Fundamental Scale for Pairwise Comparison

Intensity of Importance	Definition	Explanation
1	Equal importance	Two elements contribute equally to the objective
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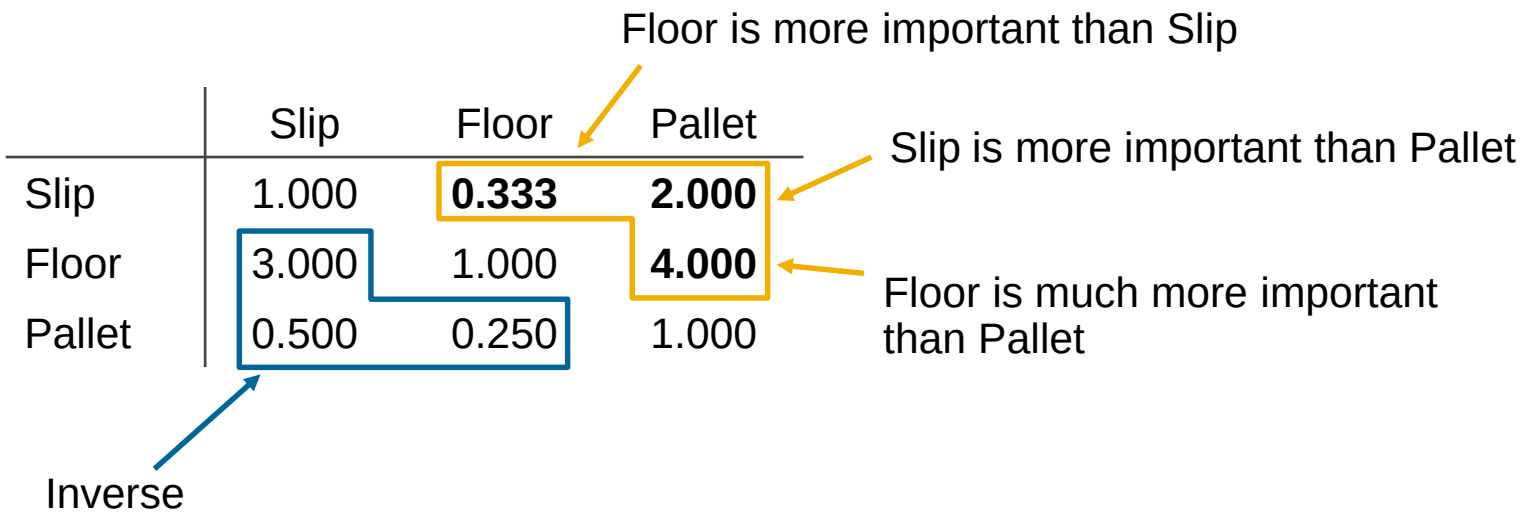
Pairwise Comparison – Mode Method Results



	Slip	Floor	Pallet
Slip	1.000	**0.333**	**2.000**
Floor	3.000	1.000	**4.000**
Pallet	0.500	0.250	1.000

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*Adapted from Ariff et al., 2012

Synthesize & Consistency Check

Convert comparison matrix (relative values) into priority values

	Slip	Floor	Pallet	**GM**	**PV**
Slip	1.000	0.333	2.000	0.874	0.238
Floor	3.000	1.000	4.000	2.289	0.625
Pallet	0.500	0.250	1.000	0.500	0.136
				3.663	

Priority Values (Raw)

Geometric Means

- Geometric Consistency Index (GCI): 0.0548
- GCI Threshold: 0.3147
- Consistent? √

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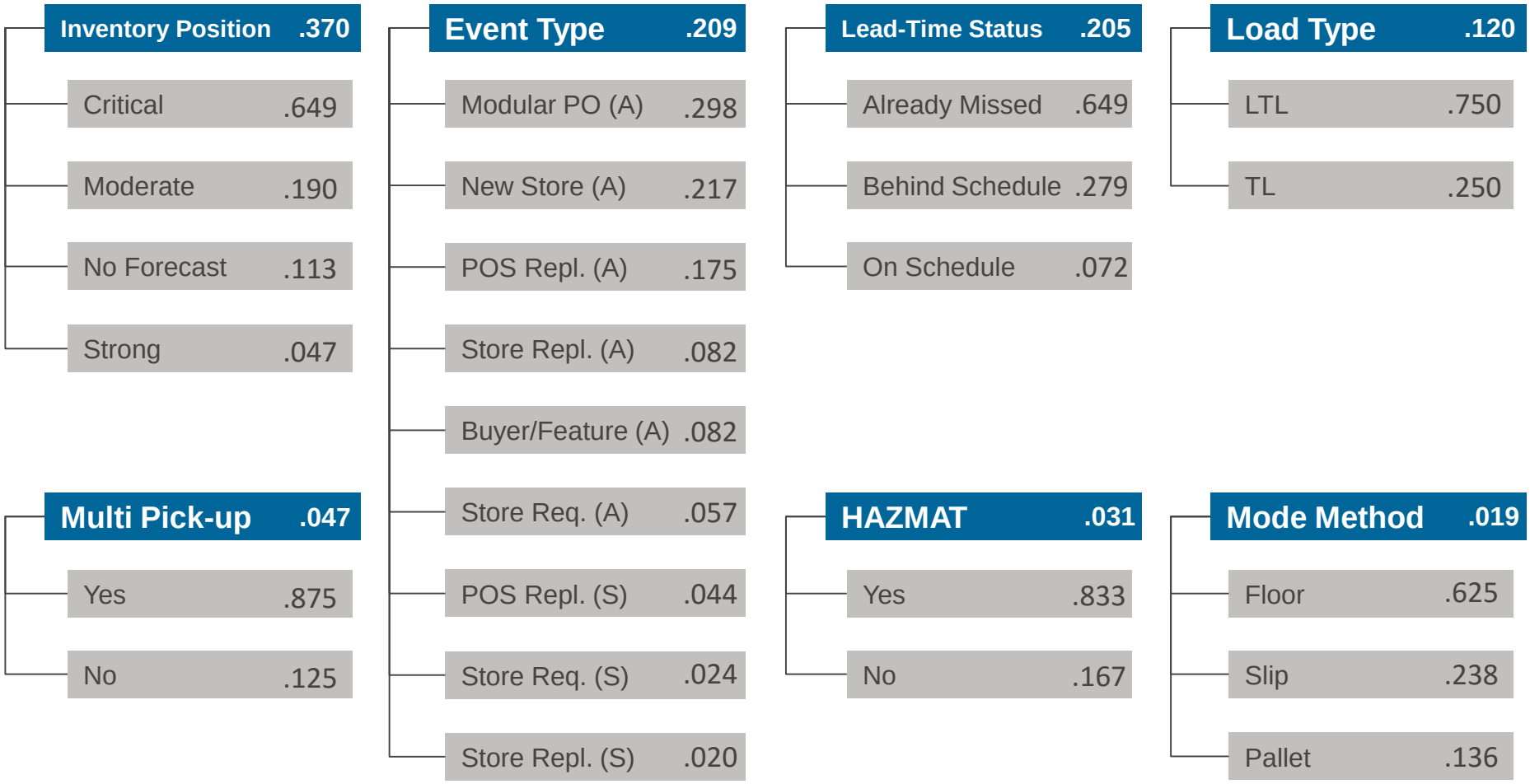
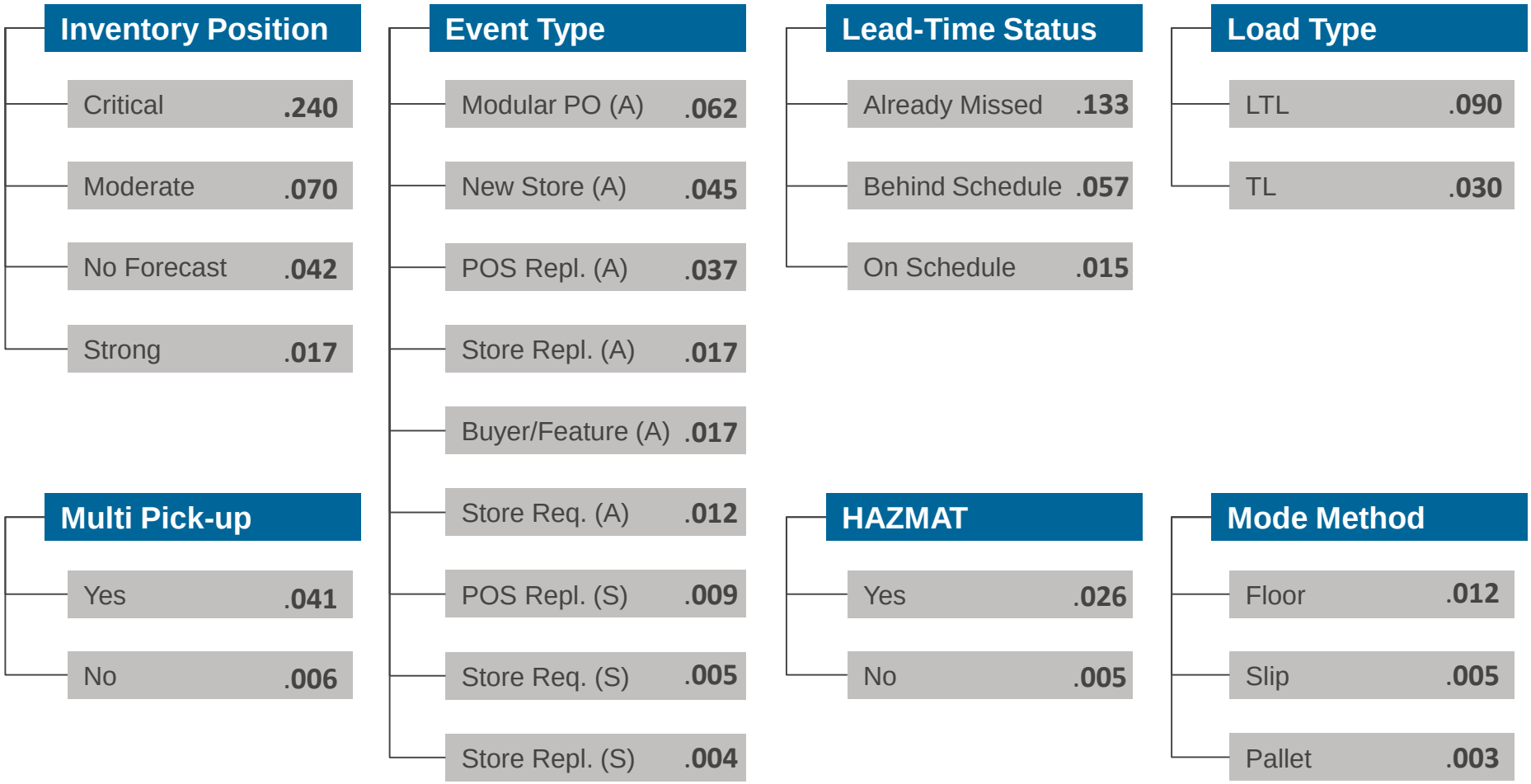
AHP Output – Raw Priority Values



AHP Output – Final Priority Values



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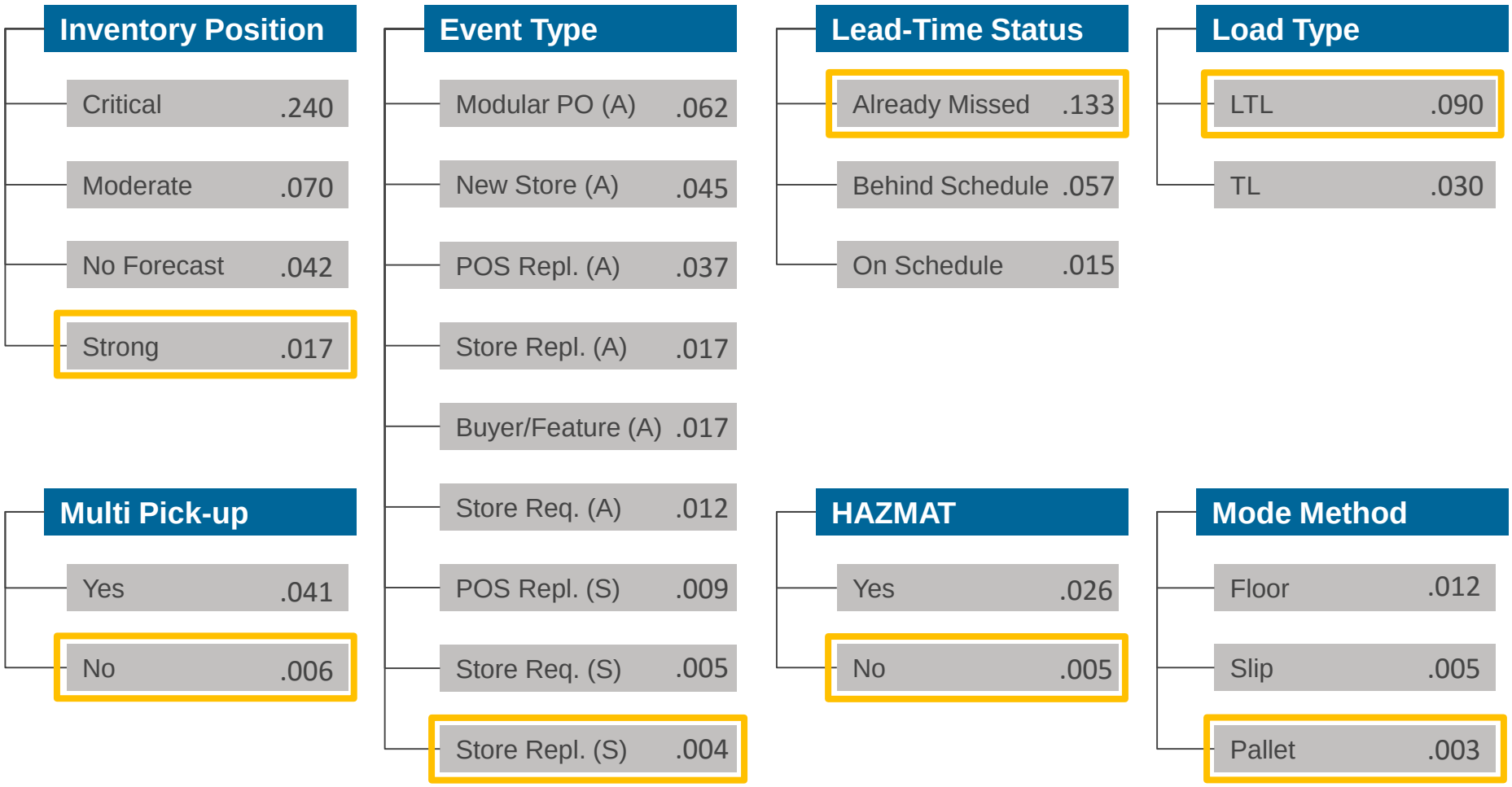
Calculate PO Priority Score– Example

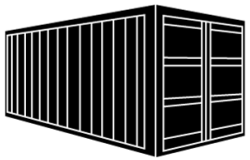
Sum up scores for decision criteria



PO Priority = .017 + .006 + .004 + .133 + .005 + .090 + .003 = .258

Roll-up to Load Priority Score

Weighting PO Priority



Load

- Load Priority (Weighted) = 0.186

$$\frac{\sum_{i=1}^{n} P_i * Q_i}{\sum_{i=1}^{n} Q_i}$$

PO 1

- PO Priority = 0.258
- Case Qty. = 220

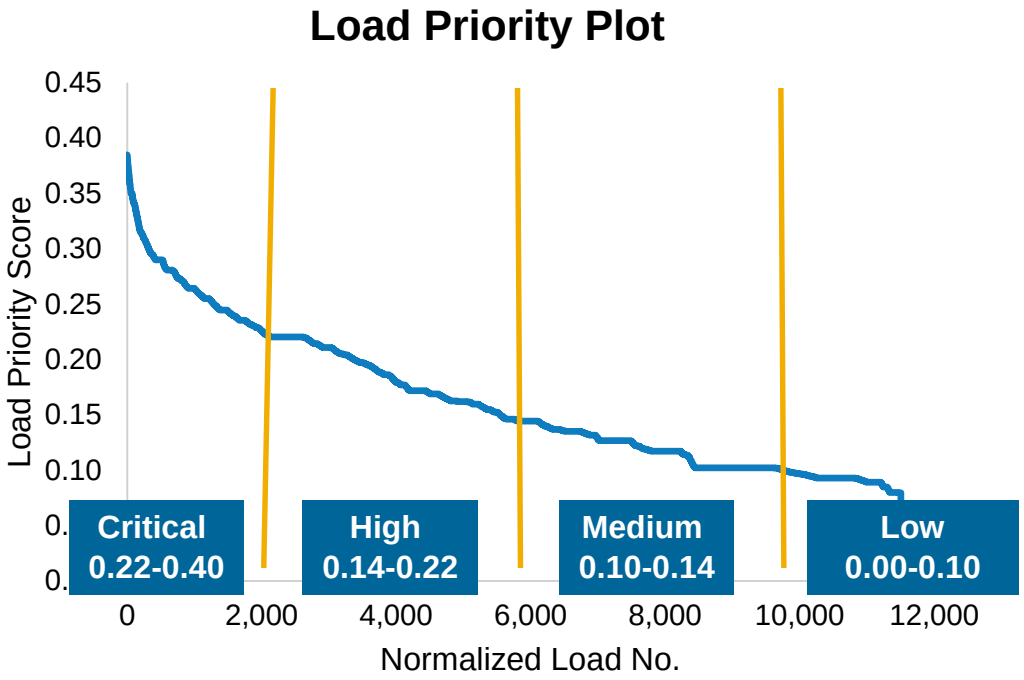
PO 2

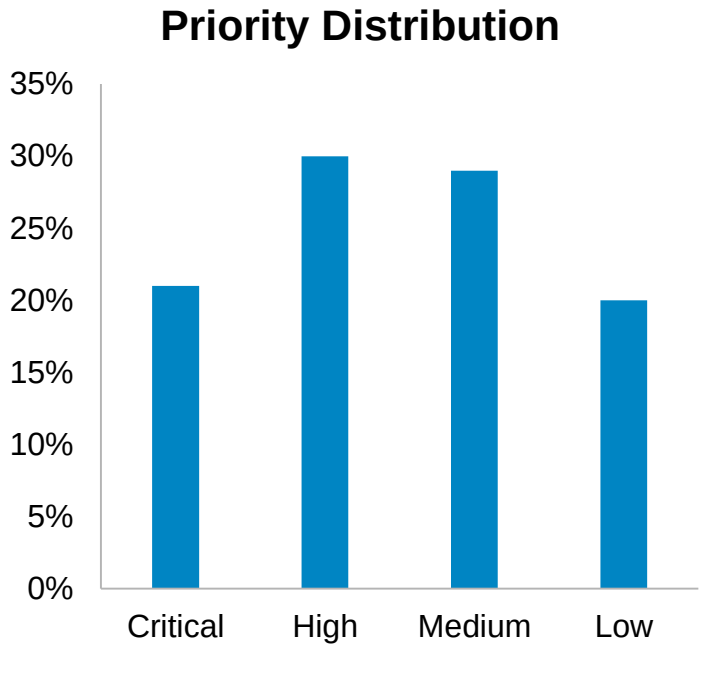
- PO Priority = 0.140
- Case Qty. = 140

PO 3

- PO Priority = 0.140
- Case Qty. = 200

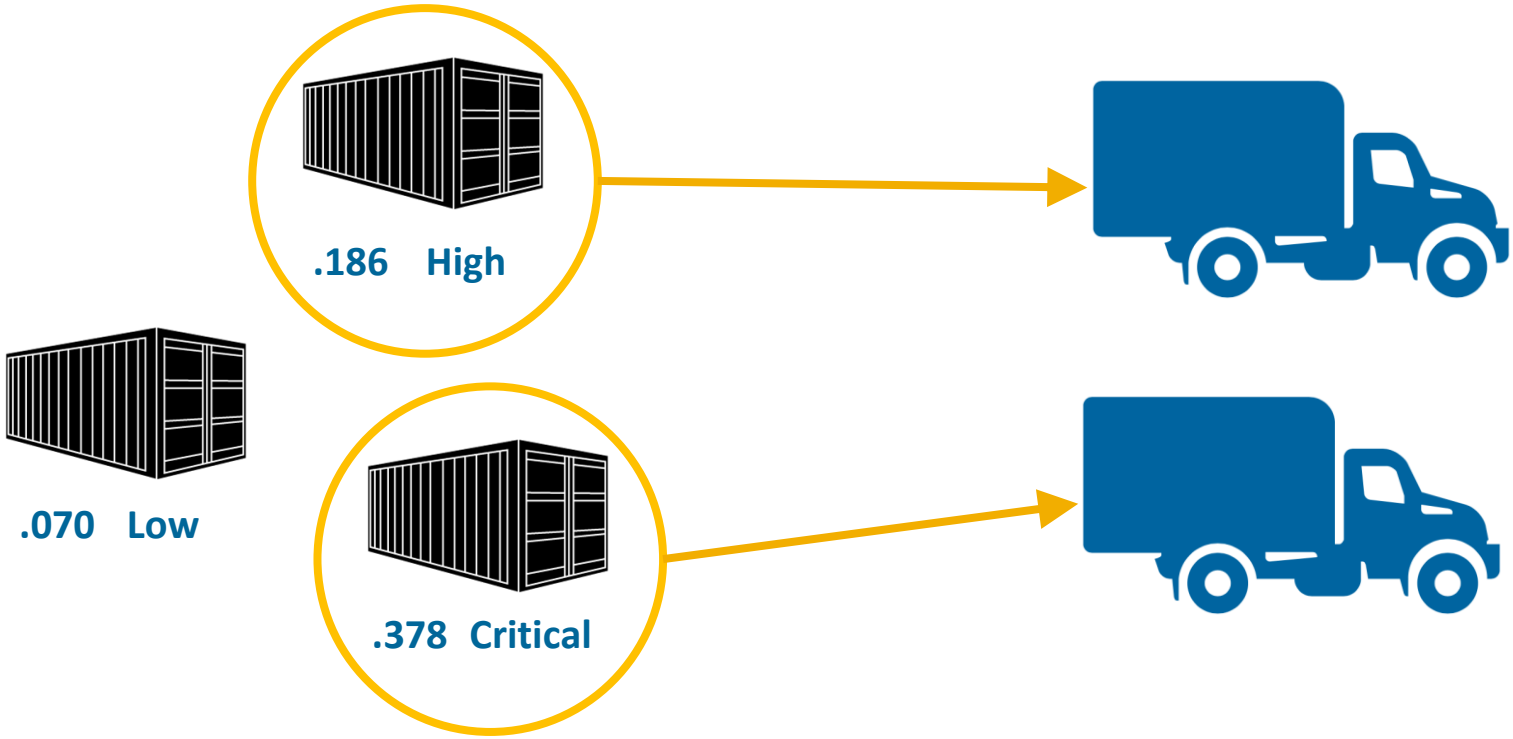
Segmentation to Facilitate Priority Management





Answer to Initial Research Question

3 Loads vs. 2 Trucks



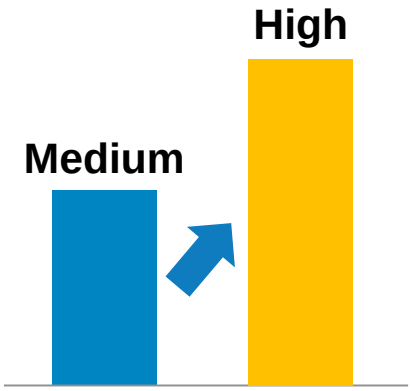
Sensitivity Analysis

Impact of holding a load – 2 Examples

- A load's priority would increase if continually skipped for shipment
  - Lead-time Status would worsen
  - Inventory Position would decrease

Initial

- Priority: 0.117
- Percentile: 33.1%



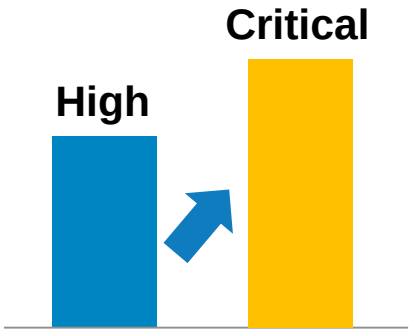
1-Day Hold

- Priority: 0.160
- Percentile: 54.9%

Load 1

Initial

- Priority: 0.195
- Percentile: 68.1%



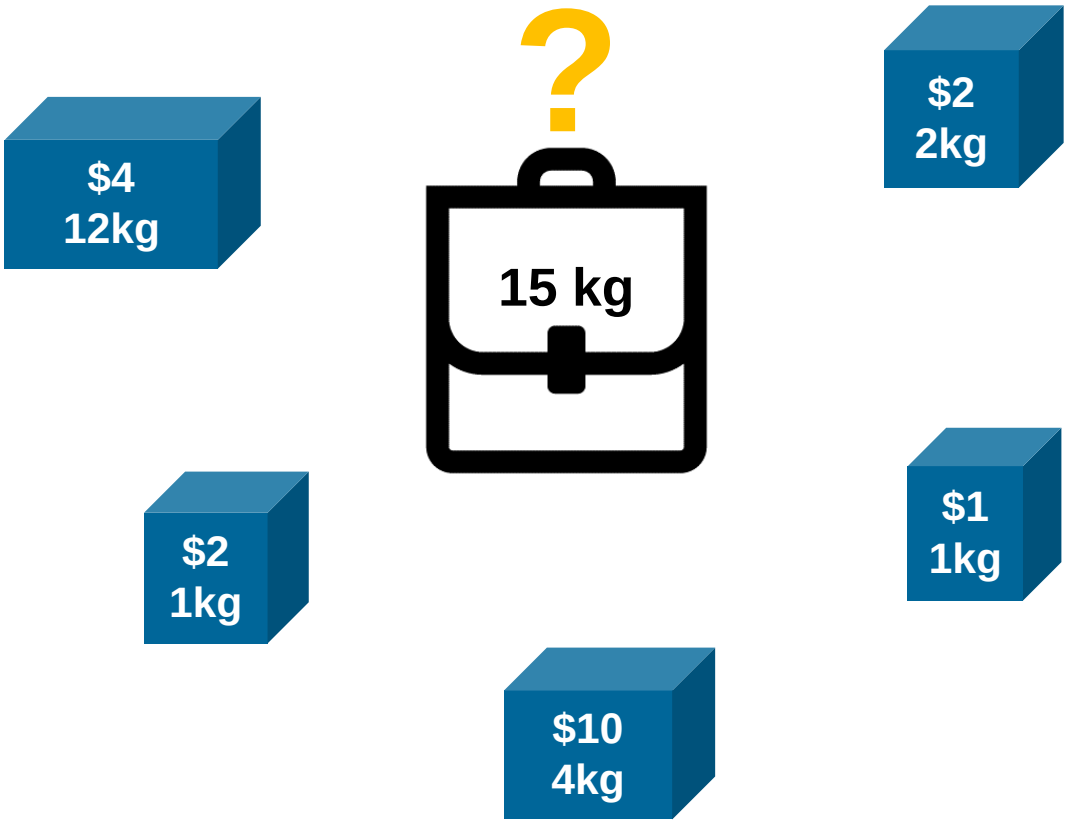
2-Day Hold

- Priority: 0.271
- Percentile: 92.8%

Load 2

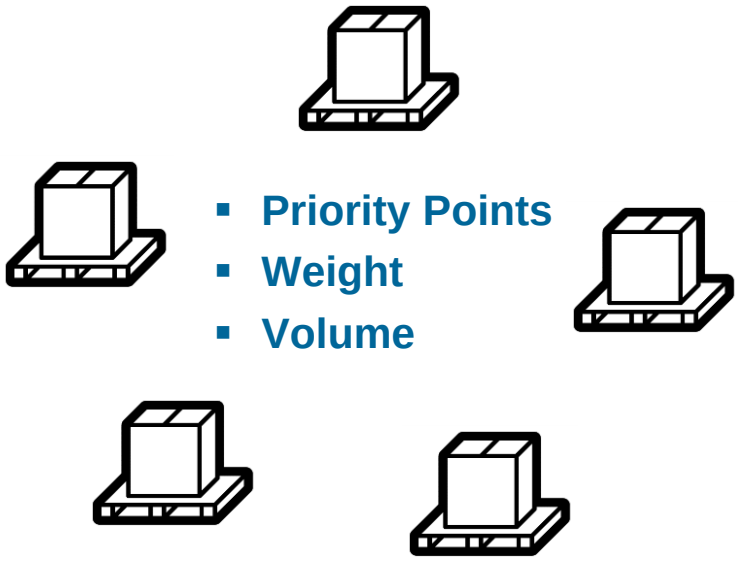
Knapsack Problem

How to fill knapsack with maximized value without exceeding weight limit?



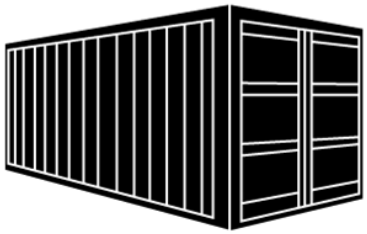
Knapsack Optimization

Could we reshuffle PO's and increase total priority points shipped?



- Priority Points
- Weight
- Volume

?



- Weight Capacity
- Volume Capacity

Knapsack Optimization

Mixed Integer Linear Programming (MILP)

Objective Function

- **Maximize** total priority points & minimize number of trucks used

Constraints

- Volume capacity
- Weight capacity
- Number of trucks available

$$Maximize:$$

$$\sum_{j=2}^{m} \sum_{i=1}^{n} X_{i,j} * P_i \; - c \; * \sum_{j=2}^{m} T_j$$

$$Subject\ to:$$

$$\sum_{i=1}^{n} X_{i,j} * \; V_i \; \leq Vmax_j \quad \forall j = 2, 3, \dots, m$$

$$\sum_{i=1}^{n} X_{i,j} * \; W_i \; \leq Wmax_j \quad \forall j = 2, 3, \dots, m$$

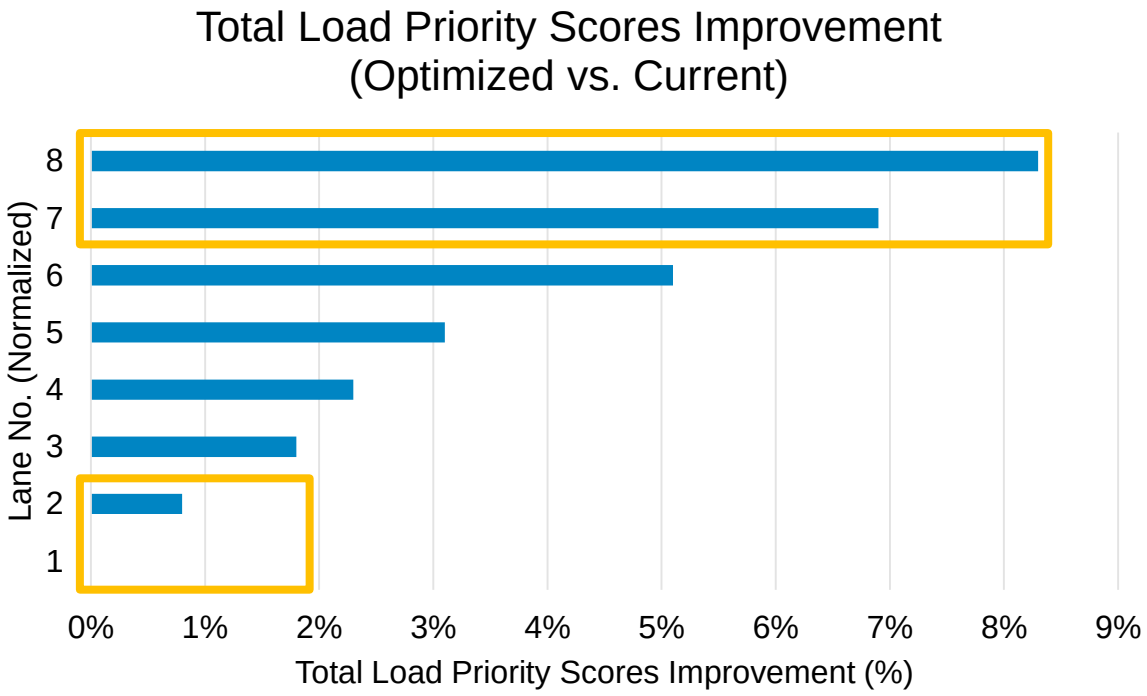
$$\sum_{j=2}^{m} T_j \leq k$$

$$\sum_{j=1}^{m} X_{i,j} = 1 \quad \forall j = 2, 3, \dots, m$$

$$\sum_{i=1}^{n} X_{i,j} \leq M * T_j \quad \forall j = 1,2, \dots, m$$

Knapsack Optimization

Test run results



- Observed opportunities to improve load priority scores by up to 8.3%

Key Takeaways

Prioritization

- Retailers often need to prioritize inbound loads when carrier capacity is constrained using systematic logic to align priorities with company objectives

AHP

- AHP can be leveraged to develop hierarchical framework that considers multiple factors and produces ratio-scaled priority scores

Optimization

- Knapsack optimization could increase total priority of loads shipped by reassigning PO's within loads on a given lane


Thank you!