A “Real” Design Problem

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The LPPD Exchange – Ann Arbor, MI

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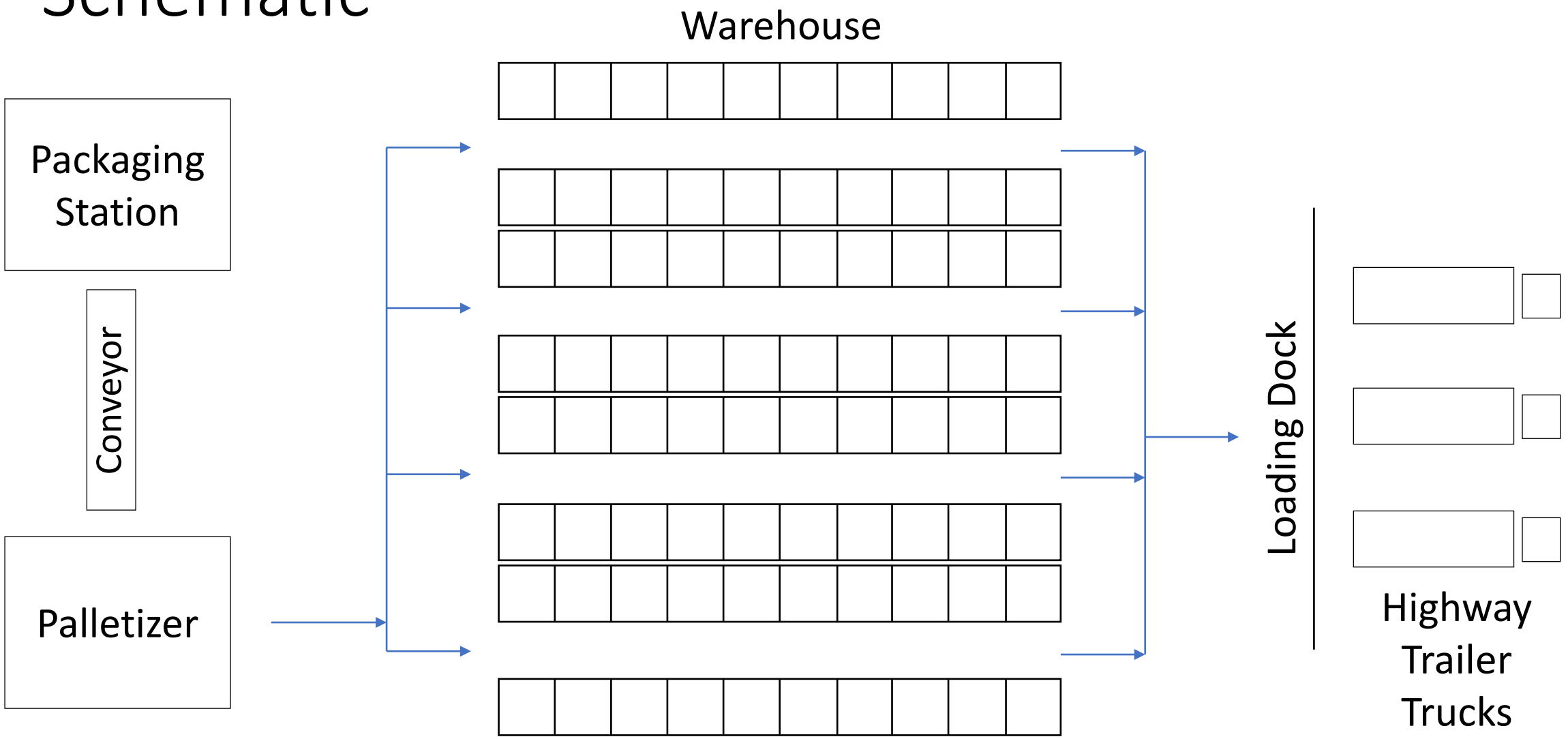
A Logistics Design Problem: Context

- Finished goods are packaged into cardboard cartons
- Cartons transported to a palletizer via belt conveyor, where pallet loads are formed
- Full pallet loads stored in finished goods warehouse using a powered lift truck
- Pallet loads transferred from warehouse to loading dock via lift truck, then loaded onto highway trailer truck for delivery to customers.

Adapted from Tanchoco and Agee, “Plan Unit Loads to Interact with All Components of Warehouse System,” *Industrial Engineering*, pp. 36-48, June 1981.

Schematic


Warehouse
Packaging Station
Conveyor
Palletizer
Loading Dock
Highway Trailer Trucks

Objectives

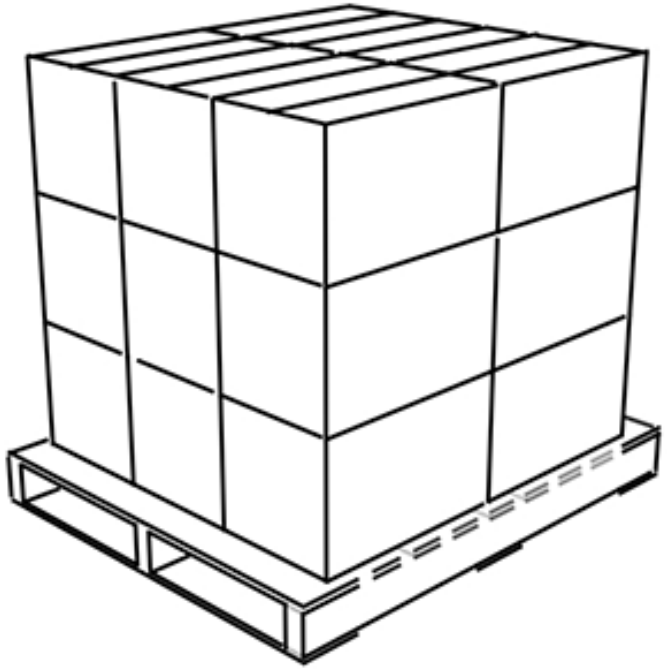
- Minimize the warehouse area required to store 500,000 parts

  and

- Minimize the number of truckloads required to deliver 500,000 parts

Design Decisions

1. Select carton size:
   - 12”L x 10”W x 10”H -- holds 17 parts, weighs 27.2 lbs.
   - 10”L x 8”W x 8”H -- holds 9 parts, weighs 15.7 lbs.
2. Select pallet size:
   - 36”L x 36”W four-way
   - 40”L x 48”W two-way
   - 48”L x 40”W two-way
3. Determine the number of layers in pallet load.



Assumptions / Givens

- Pallet height = 6 in.
- Pallet weight = 25 lbs.
- Palletizer max height = 70 in.
- Lift truck capacity = 3,000 lbs.
- Lift truck max height = 106 in.
- Warehouse clear height = 20 ft.
- Number of warehouse aisles = 4
- Warehouse aisle width = 10 ft.
- Block storage with 6” spacing between stacks
- Truck trailer interior = 40’(L) x 7.5’(W) x 11’(H)

How would you approach this design problem?

- *Say "hello" to someone nearby and introduce yourself.*

- *Discuss with them how to approach the problem.*
    - *Do some calculations, if possible.*

- How long do you estimate it will take you to get an answer?
- How much iteration do you estimate will happen?

Book Solution

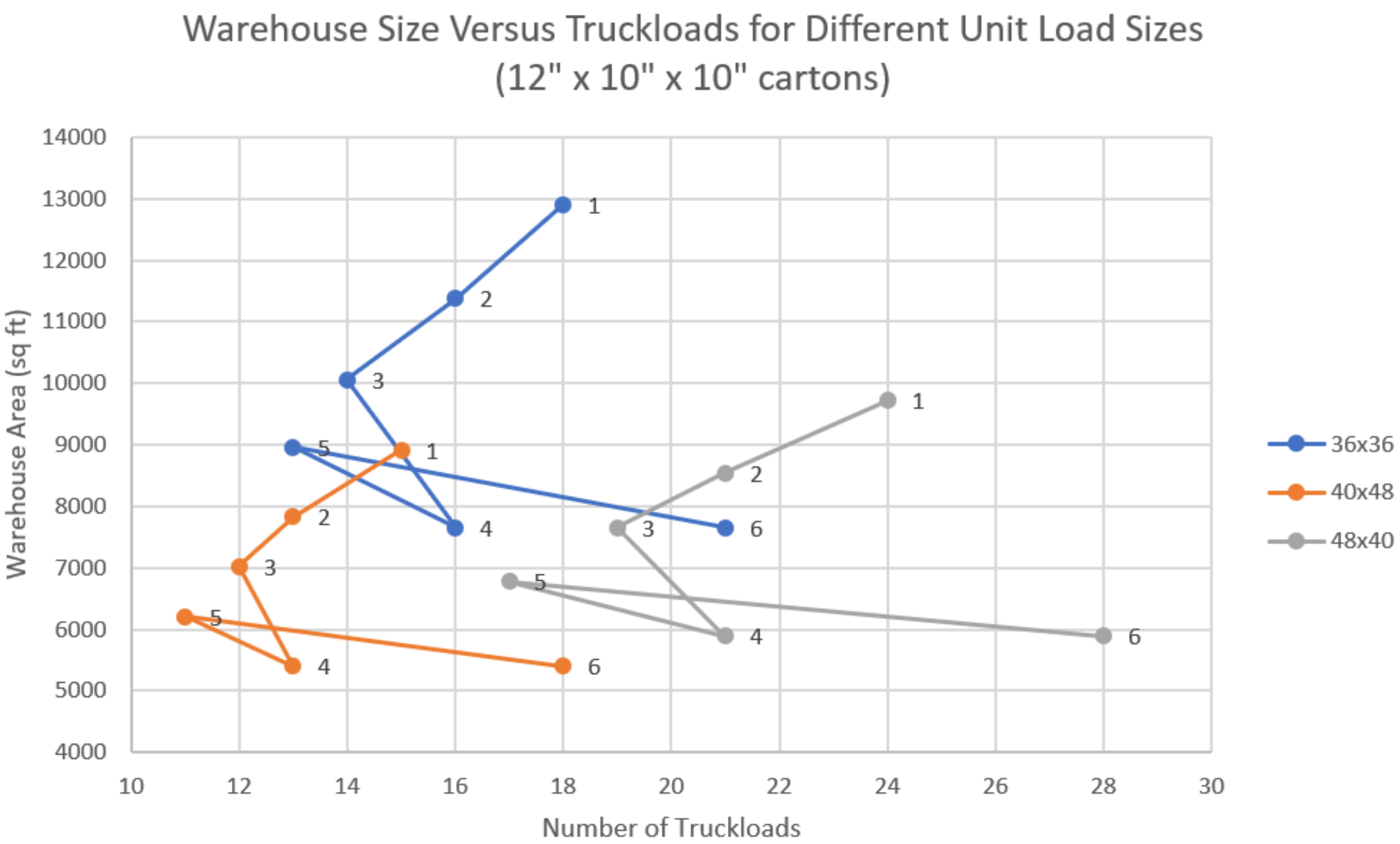
Carton	Pallet	Cartons/ Layer	# of Layers	Total # of Unit Loads	Warehouse Area	# of Truckloads
12”x10”x10”	36” x 36”	9	4	817	7394	18
	40” x 48”	16	4	460	5426	13
	48” x 40”	16	4	460	5781	21
10”x8”x8”	36” x 36”	16	5	695	6283	15
	40” x 48”	24	5	463	5462	13
	48” x 40”	24	5	463	5819	22

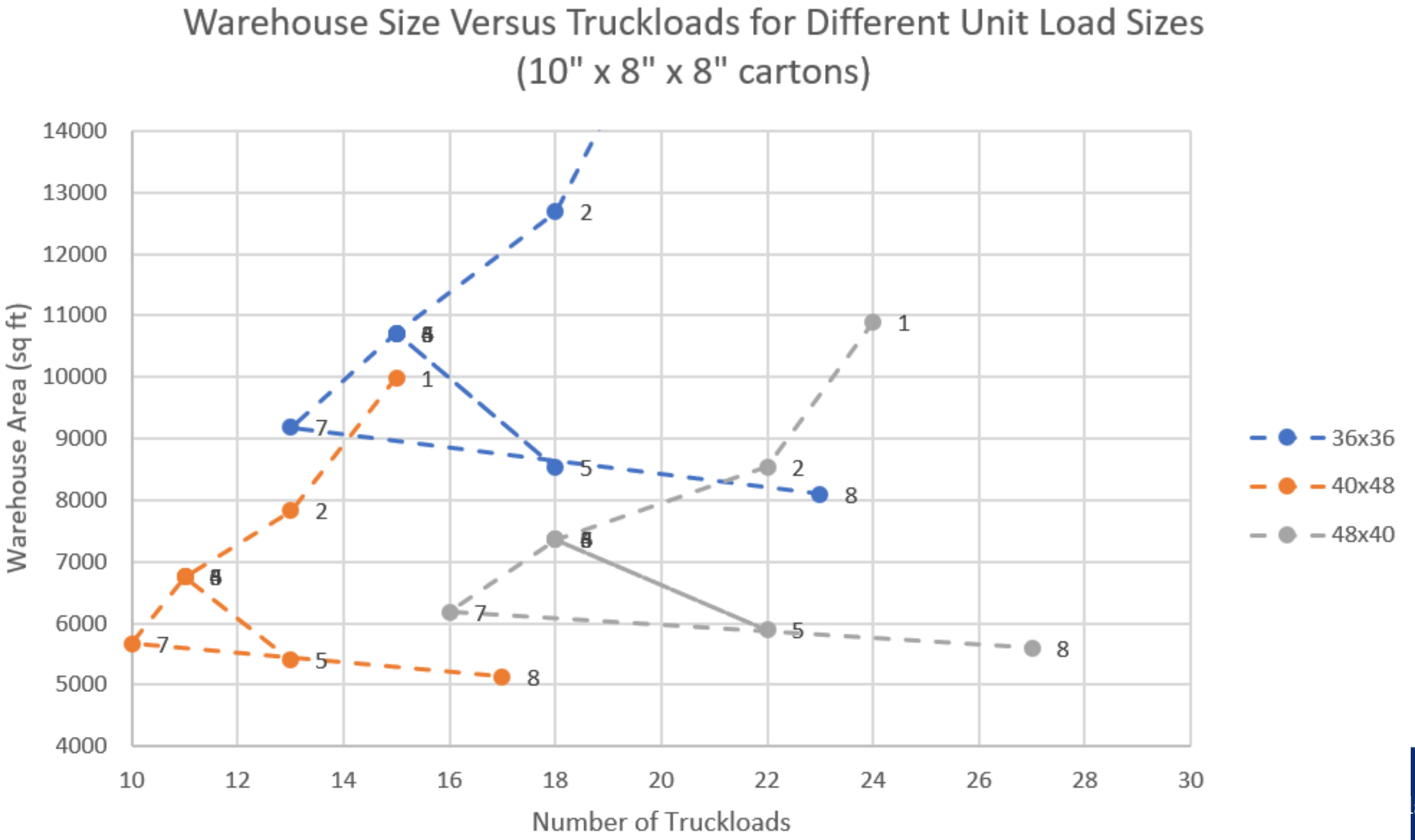
From Tanchoco and Agee, “Plan Unit Loads to Interact with All Components of Warehouse System,” *Industrial Engineering*, pp. 36-48, June 1981.

Questions…

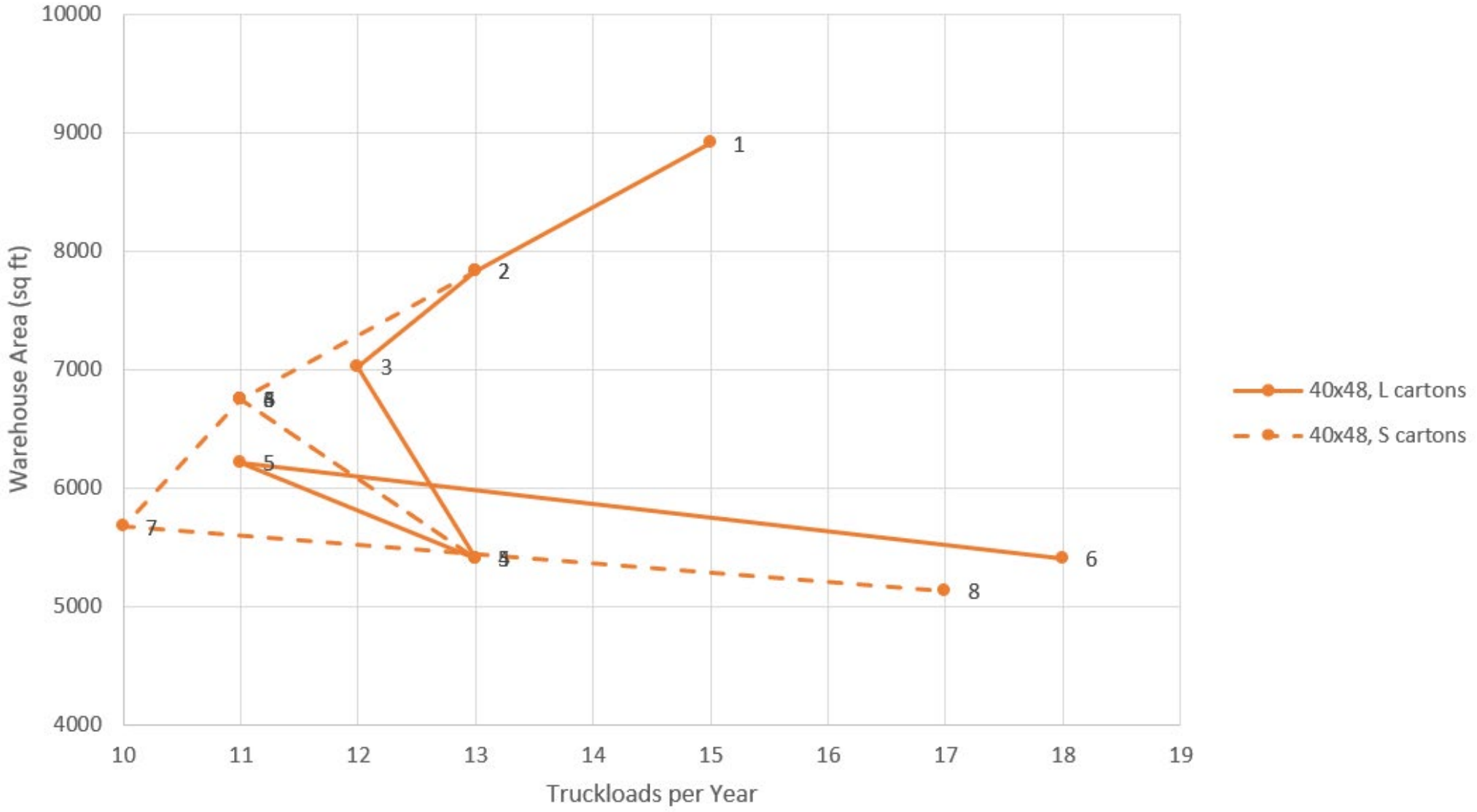
1. How quickly can you identify the best solution in the set?
2. How confident are you that this is the best solution?
3. What trade-offs did the designers make in their analysis?
4. How much reusable knowledge was produced?

What if we had “visible knowledge” for this problem…?


Warehouse Size Versus Truckloads for Different Unit Load Sizes
(12" x 10" x 10" cartons)
Warehouse Area (sq ft)
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
10
12
14
16
18
20
22
24
26
28
30
Number of Truckloads
36x36
40x48
48x40


Warehouse Size Versus Truckloads for Different Unit Load Sizes
(10" x 8" x 8" cartons)
Warehouse Area (sq ft)
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
10
12
14
16
18
20
22
24
26
28
30
Number of Truckloads
36x36
40x48
48x40

Top Two Contenders



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1. How quickly can you identify the best solution in the set?
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How to Develop Visible Knowledge

Allen Ward Procedure

1. State the issue
2. Draw a picture
3. Create a causal diagram
4. Find data and create curves
5. Develop countermeasures

Let's try this together….

Issue:

Picture of System:

Causal Diagram:

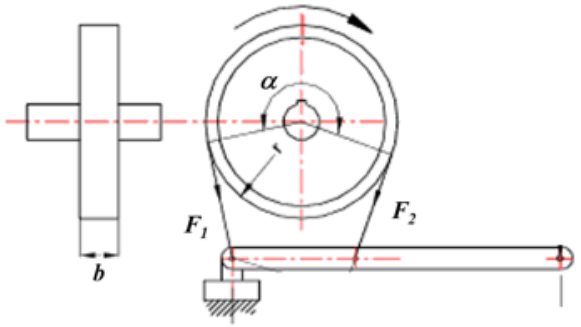
Hypothesized Relationships and Equations:

By: D. Sobek, dsobek@montana.edu Date: 19 June 2018

Issue:

Band brake design for specific braking torque requirement

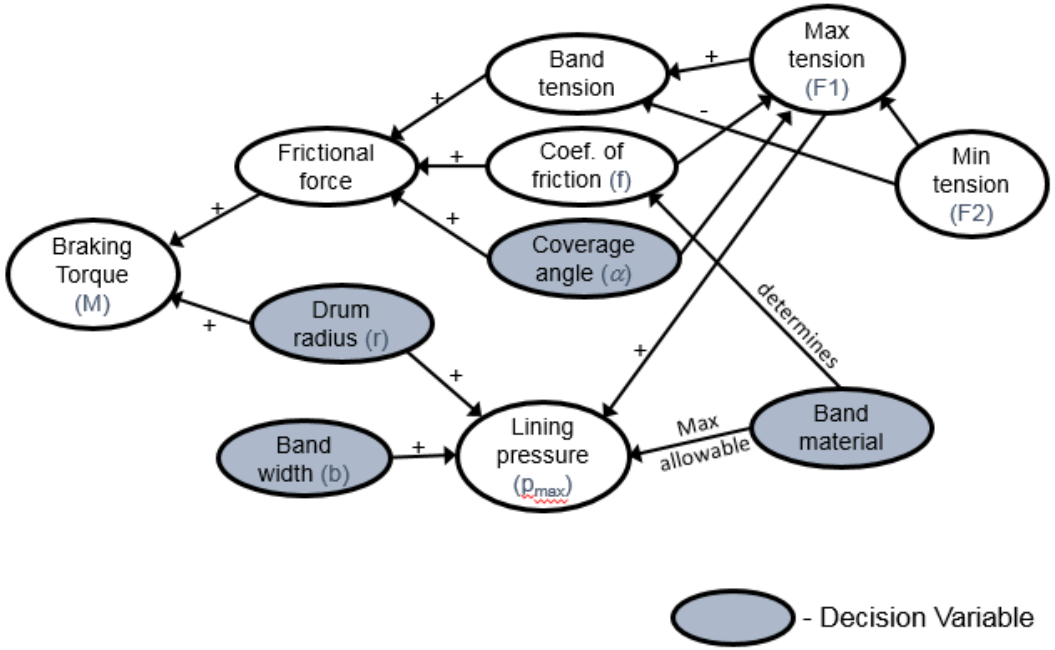
Picture of System:



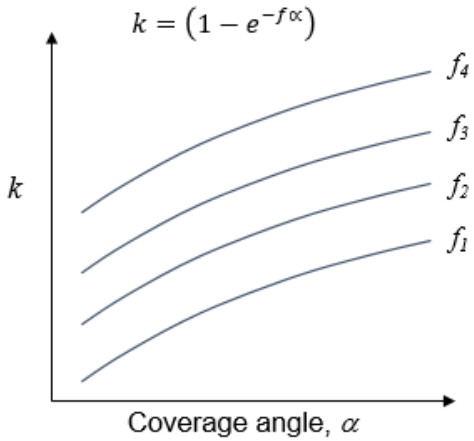
Variables:

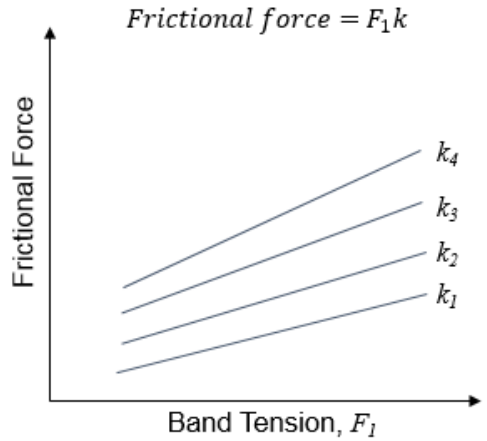
r = drum radius (m)
α = coverage angle (rad)
F_1 = max. band tension (N)
F_2 = min. band tension (N)
b = band width (m)
f = band coef. of friction

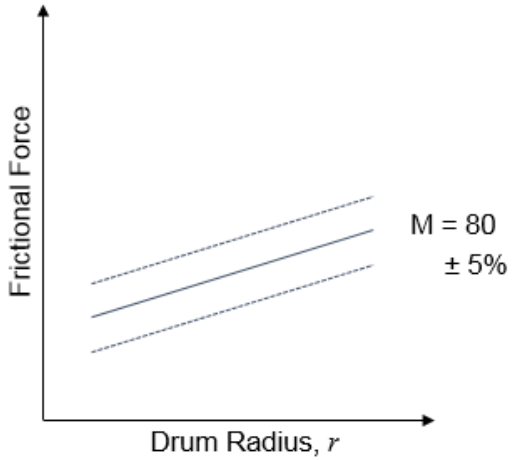
Causal Diagram:



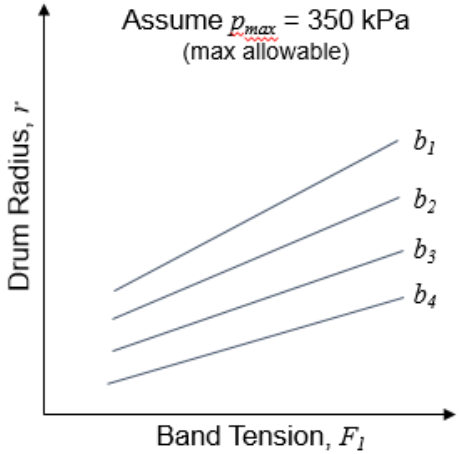
Hypothesized Relationships and Equations:







M = 80
± 5%



1. With a partner, state the issue.

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Which of these do you like best?

a. Improved pallet loads.
b. Pallet load design to minimize storage space and shipping frequency.
c. Logistics trade-offs.
d. 40” wide pallets maximize space utilization.

2. Sketch a diagram of the issue.

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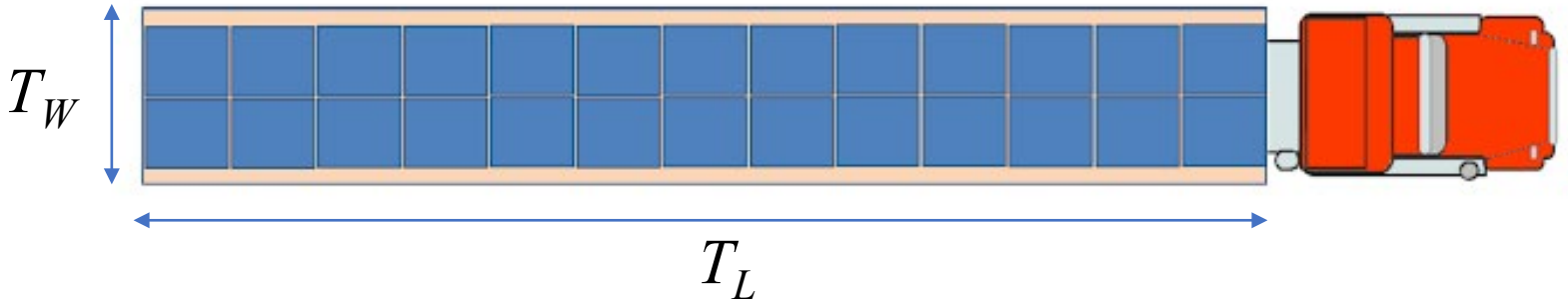
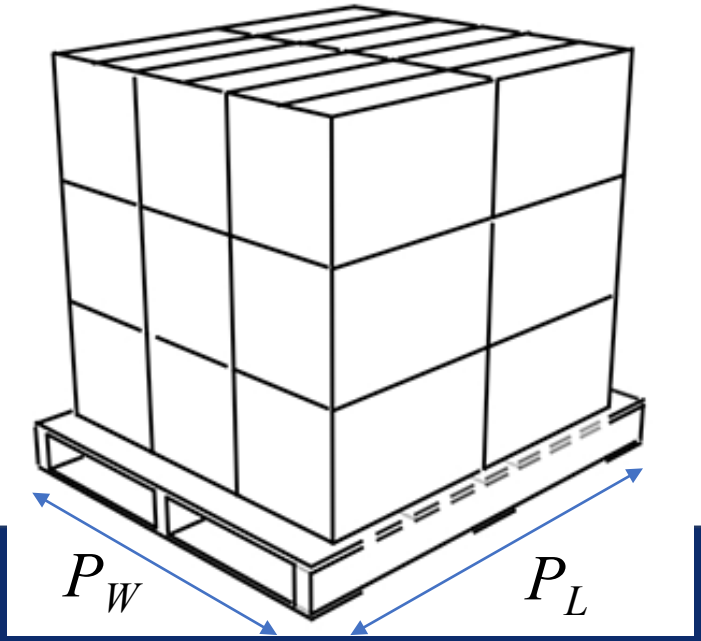
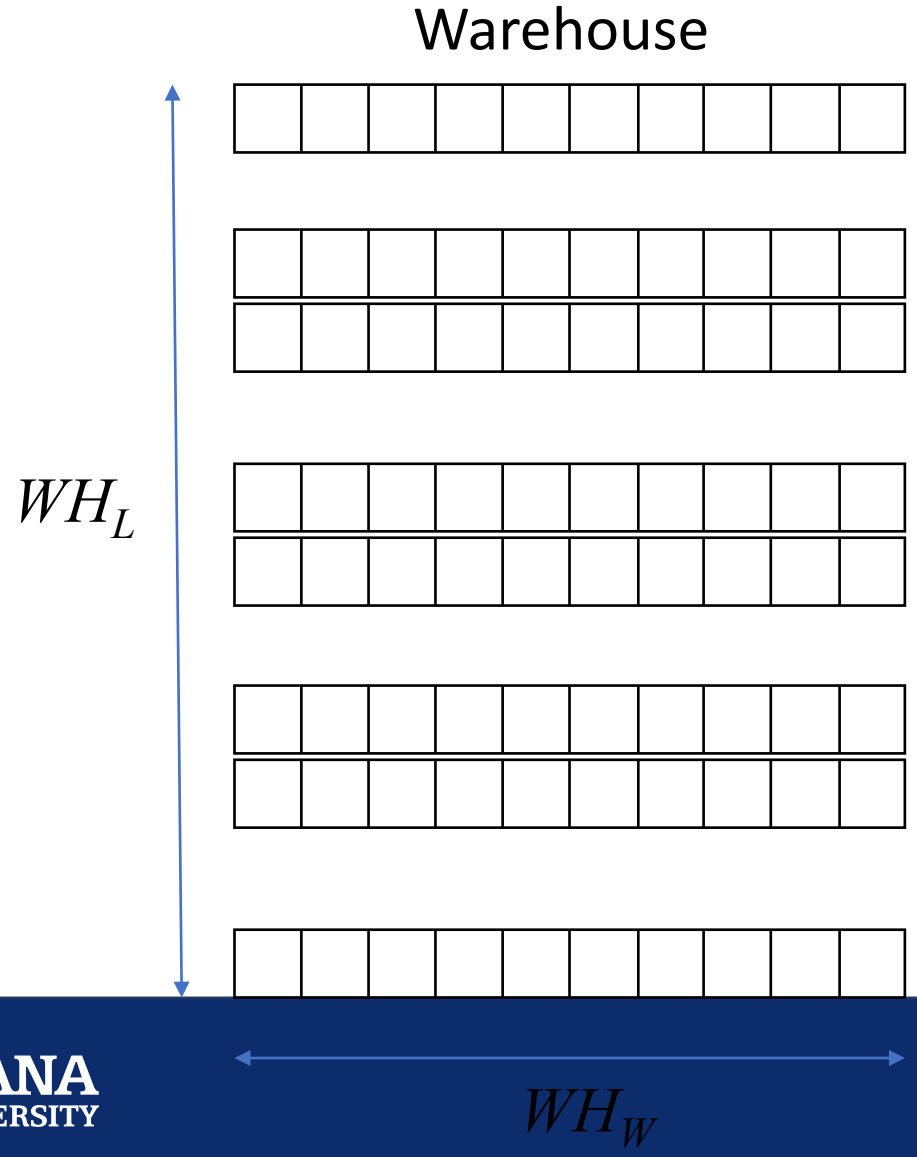




Variables:

T_W = Truck width
T_L = Truck length
T_H = Truck height
P_W = Pallet width
P_L = Pallet length
UL_H = Unit Load height

2. Sketch a diagram of the issue, cont.



Variables:

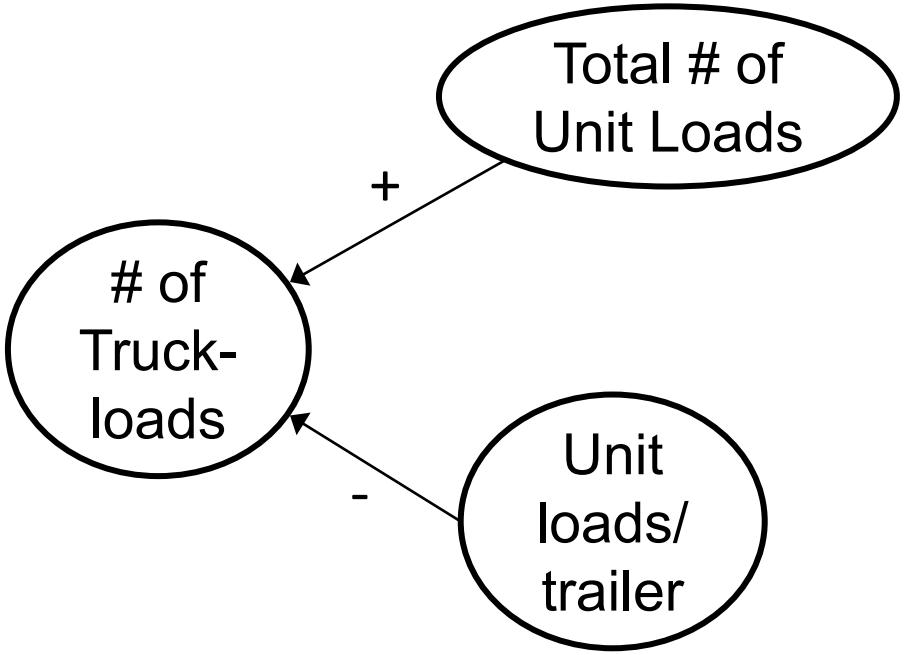
WH_W = Warehouse width

WH_L = Warehouse length

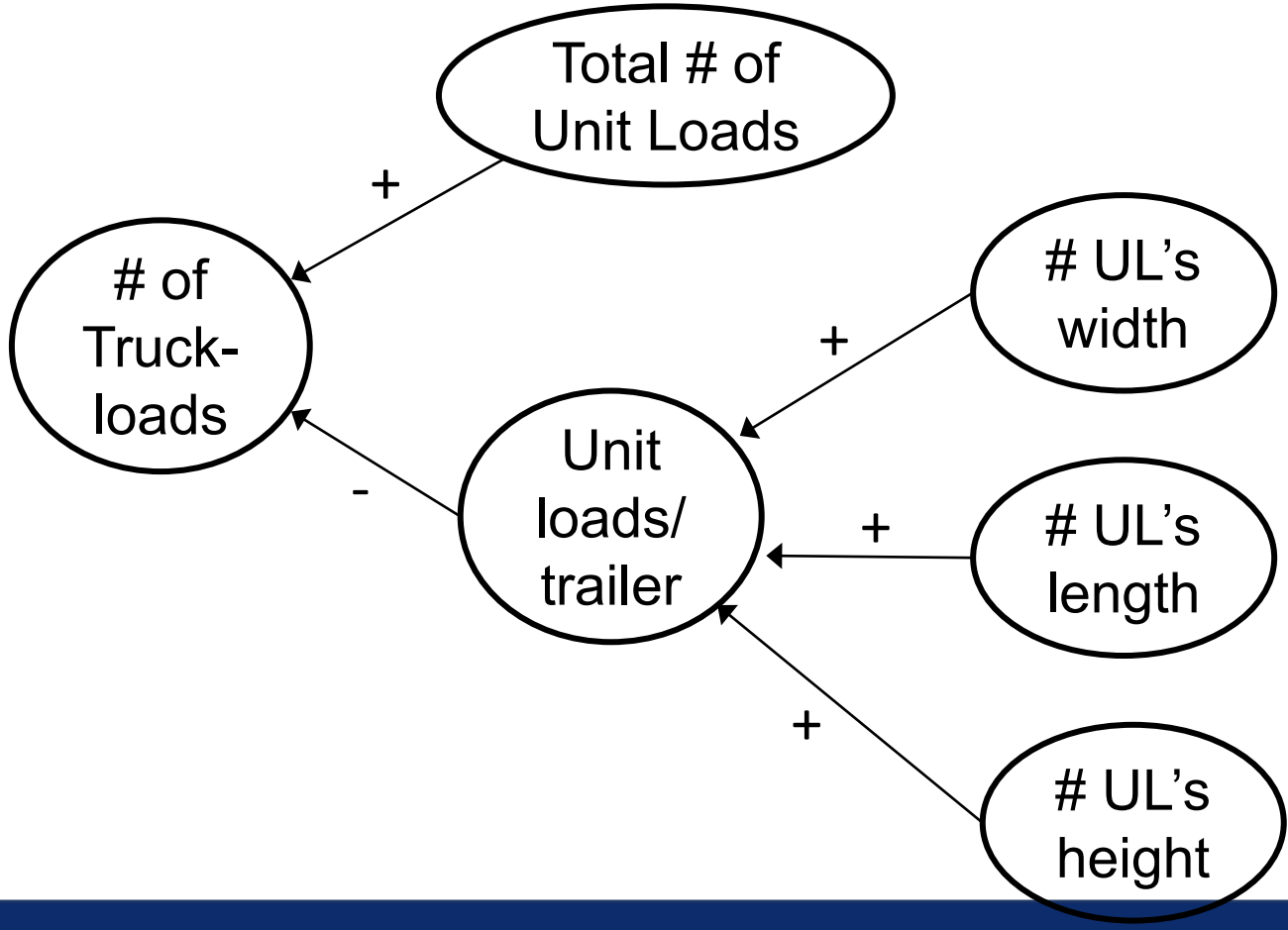
3. Create a causal diagram.

A. On the left, write the result variable we want to influence.
B. Just to the right, write the variables that directly affect that result.
C. Draw arrows that show directionally what affects what.
D. Label arrows with “+” or “-” to show positive or negative relationship.
E. Repeat substeps B-D until you reach variables that are **directly controllable**.

Start of Causal Diagram



Start of Causal Diagram



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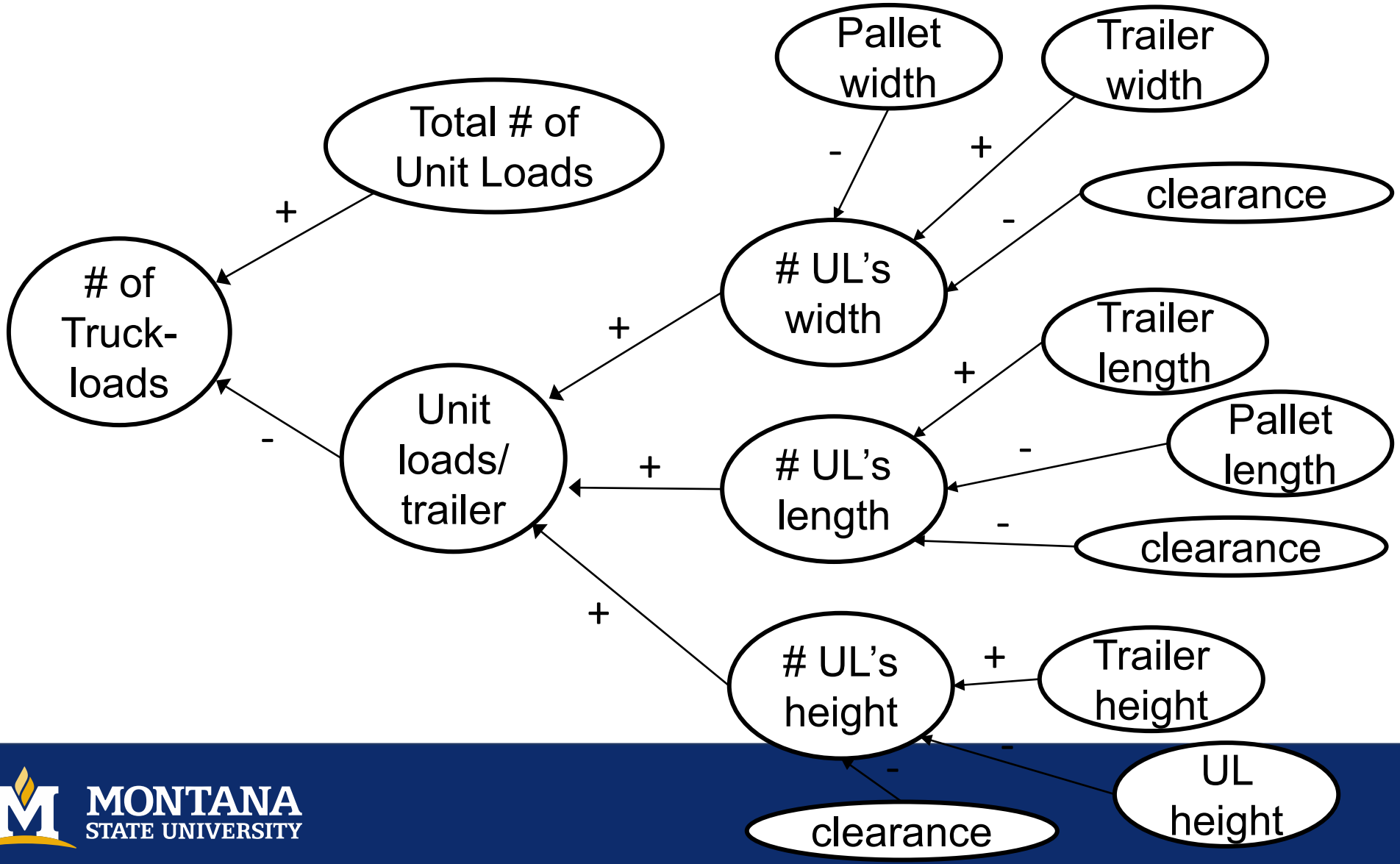
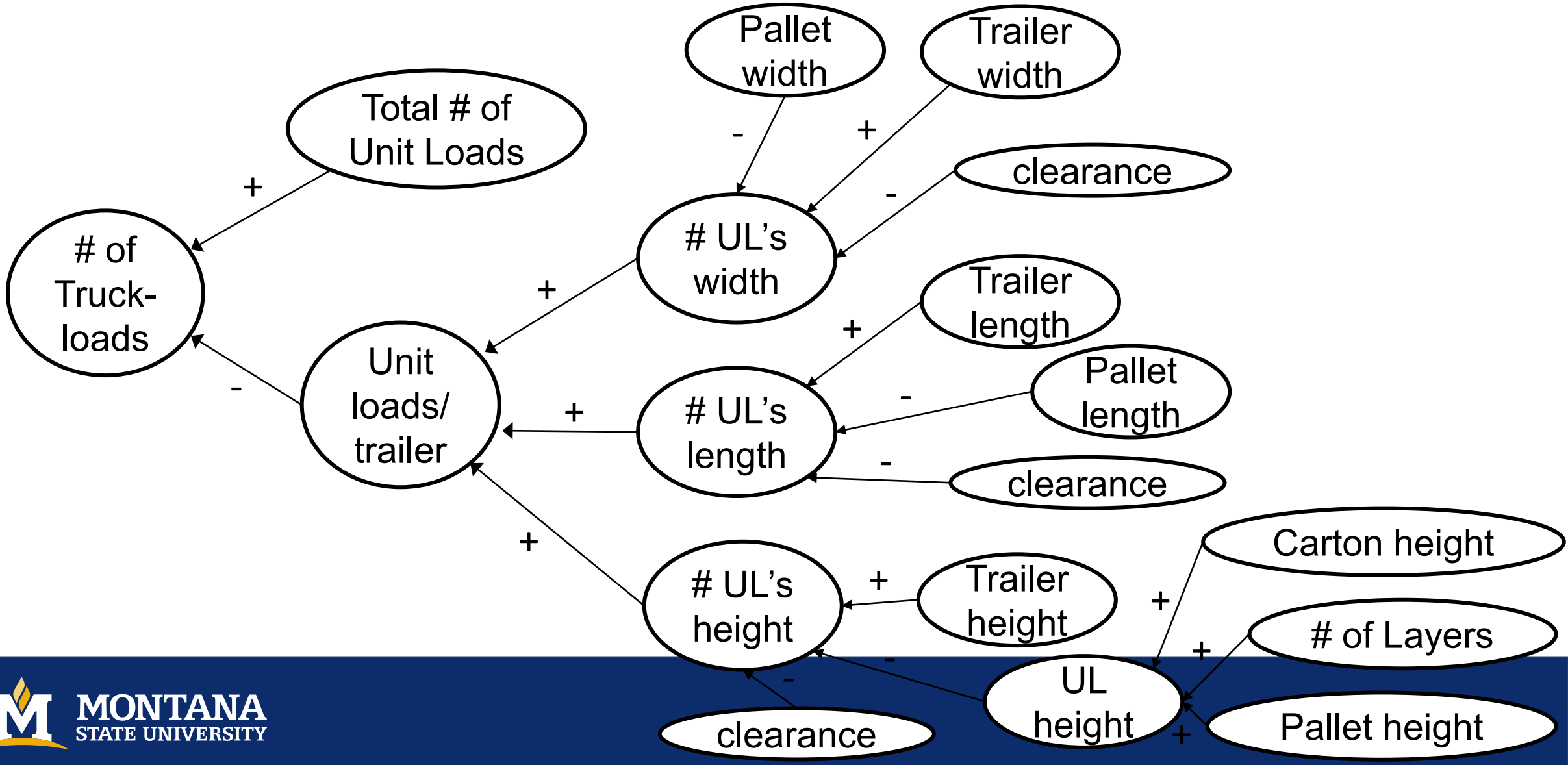
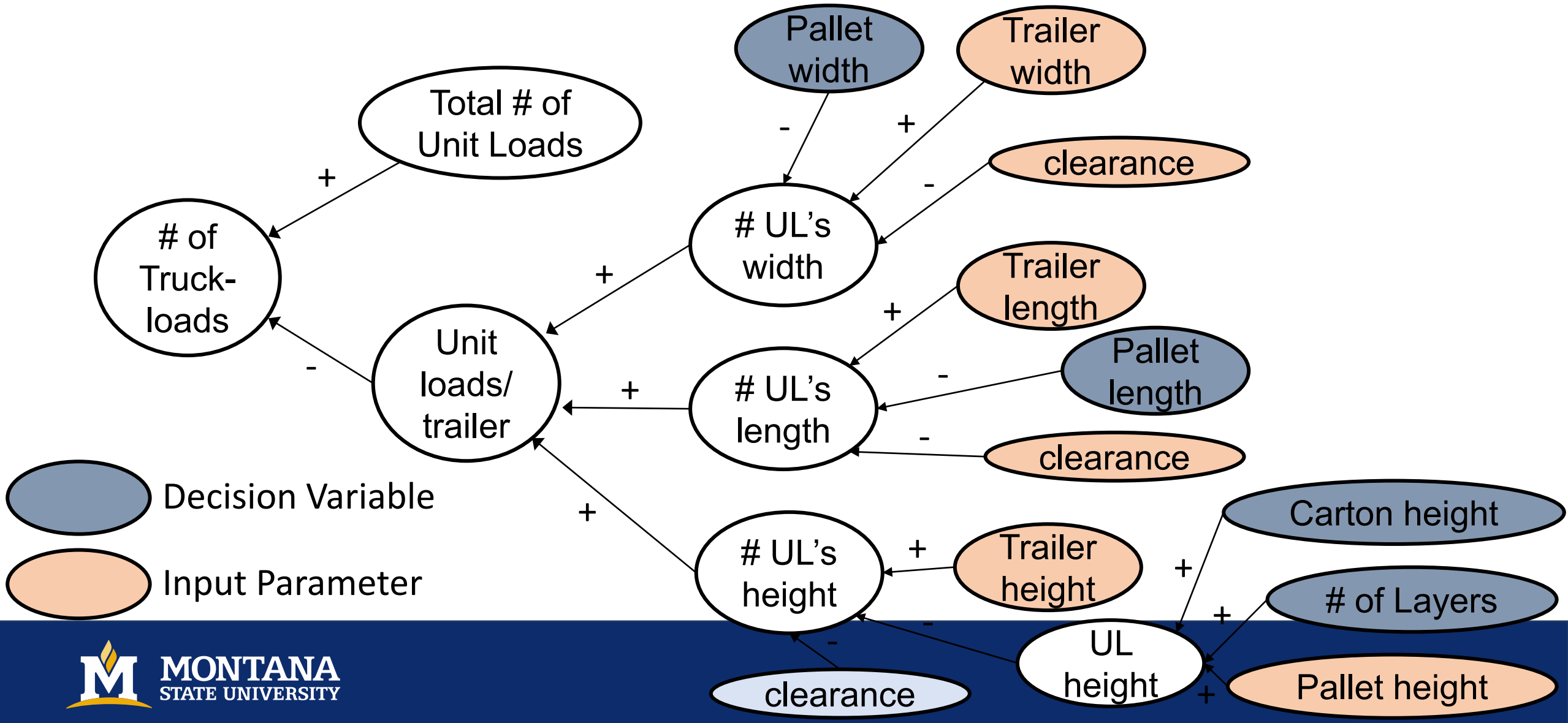


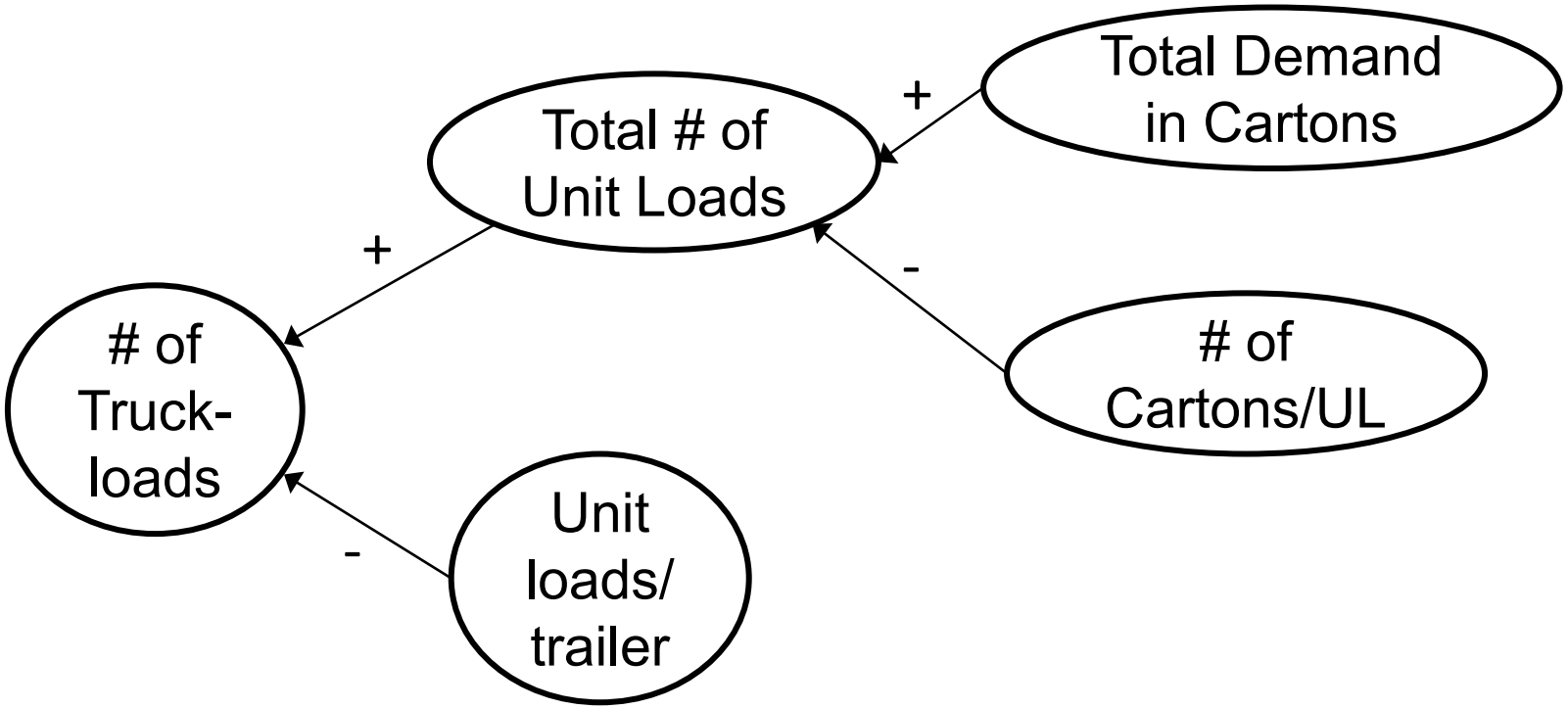
Start of Causal Diagram



Start of Causal Diagram



Causal Diagram, cont.



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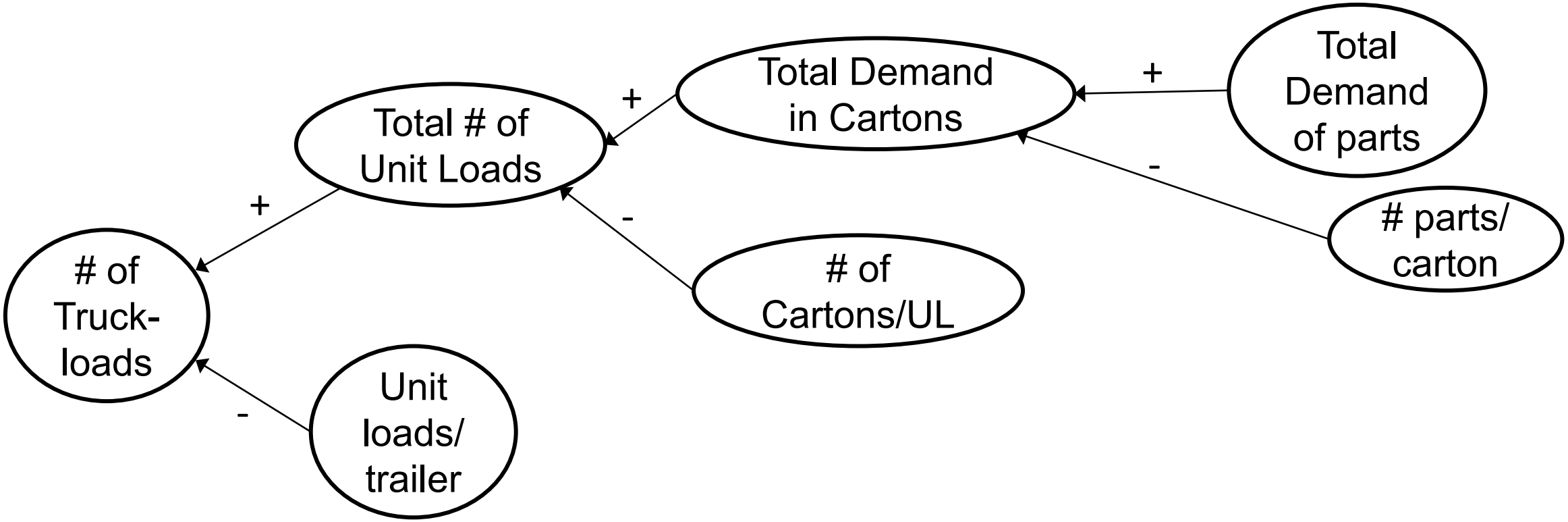
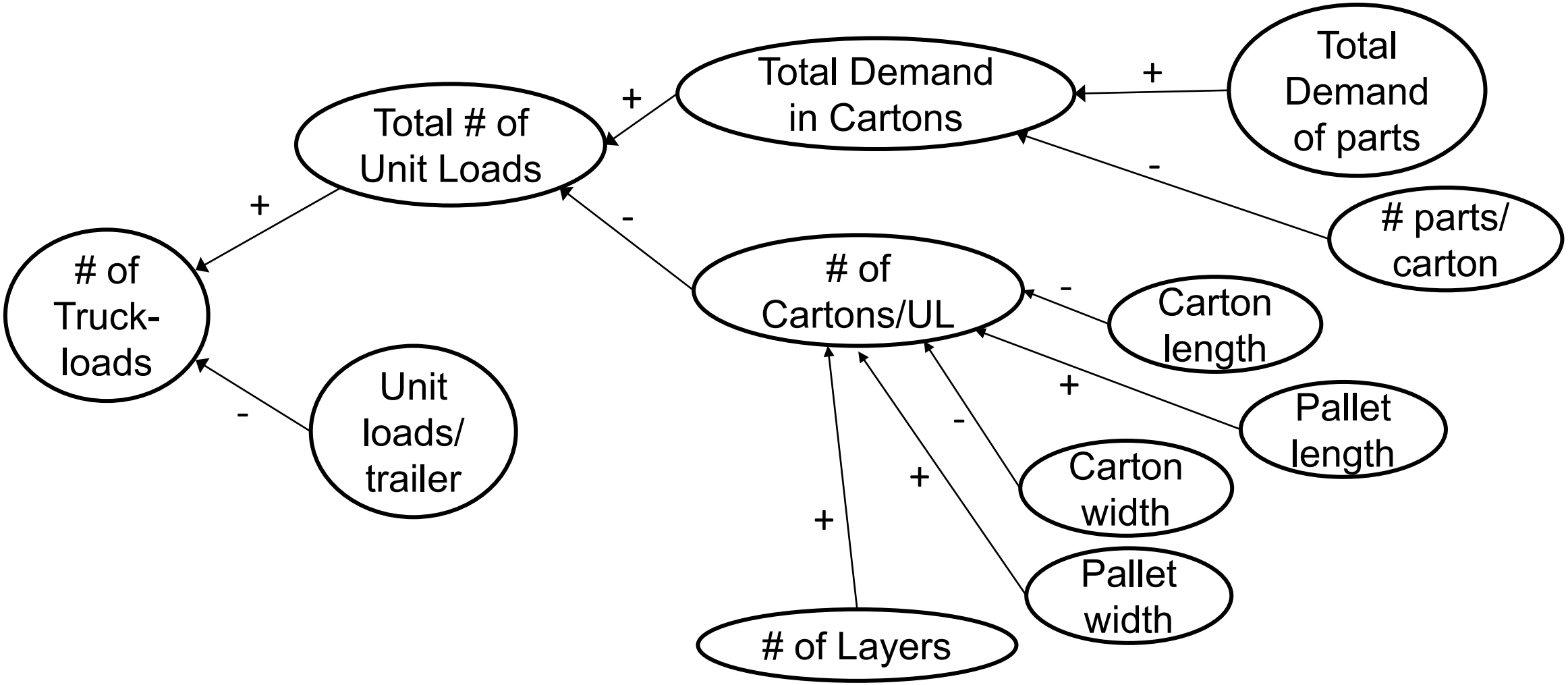
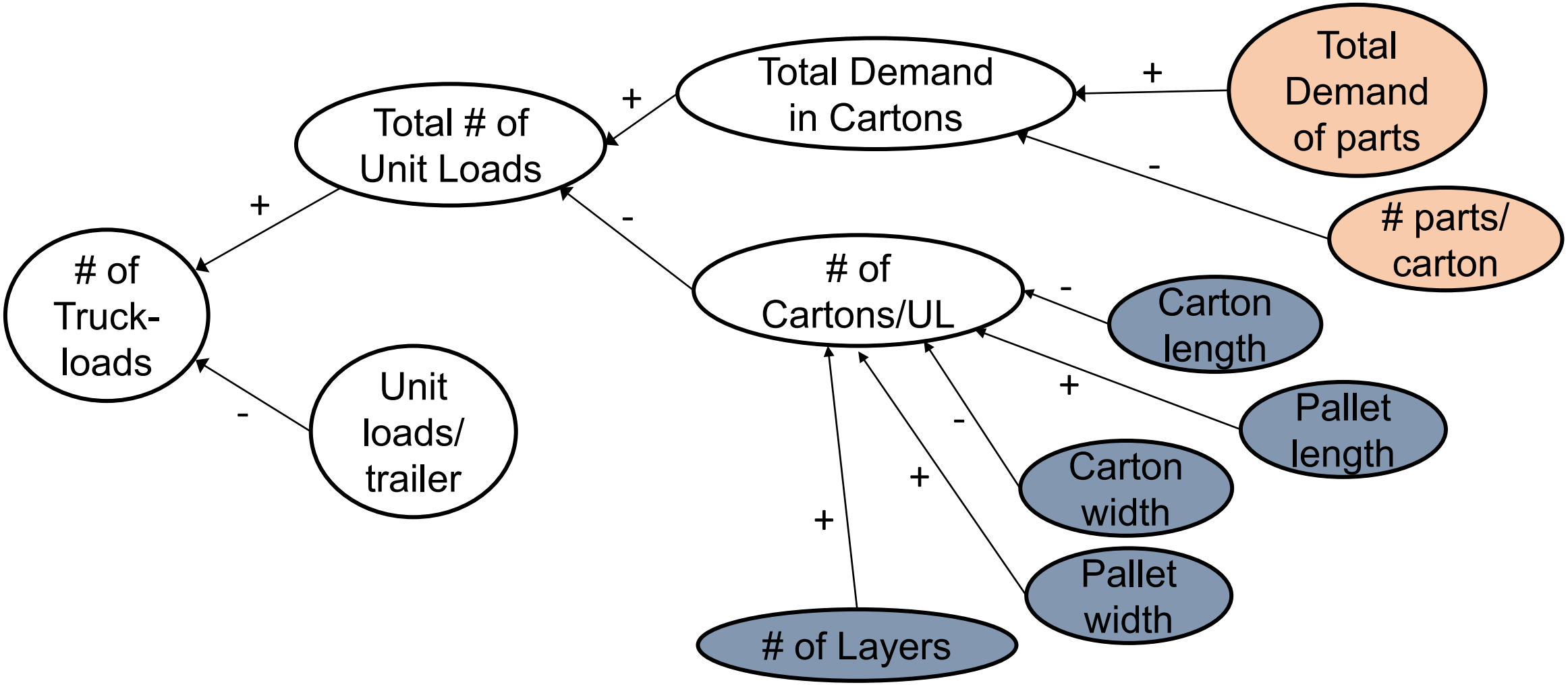


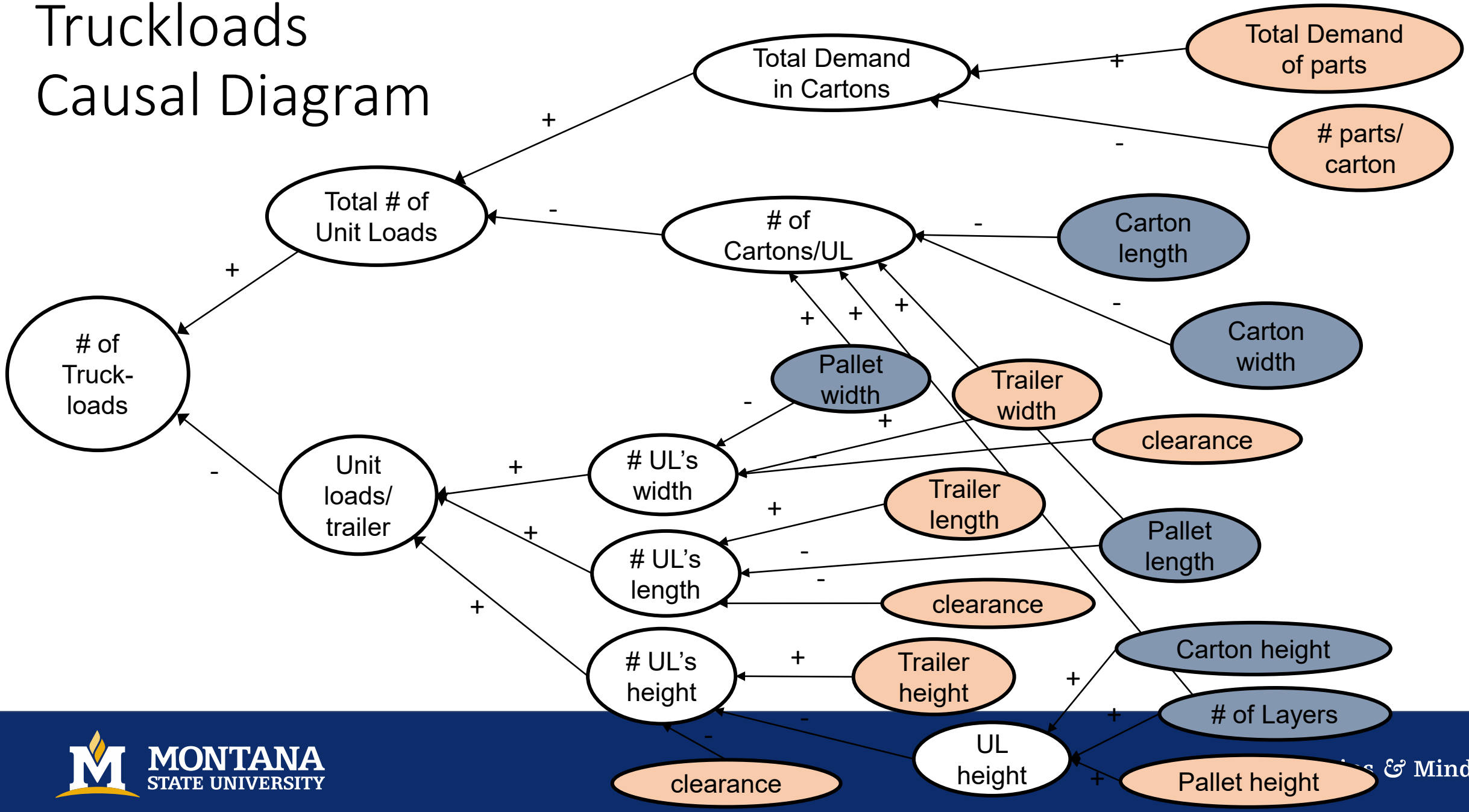
Causal Diagram, cont.



Causal Diagram, cont.

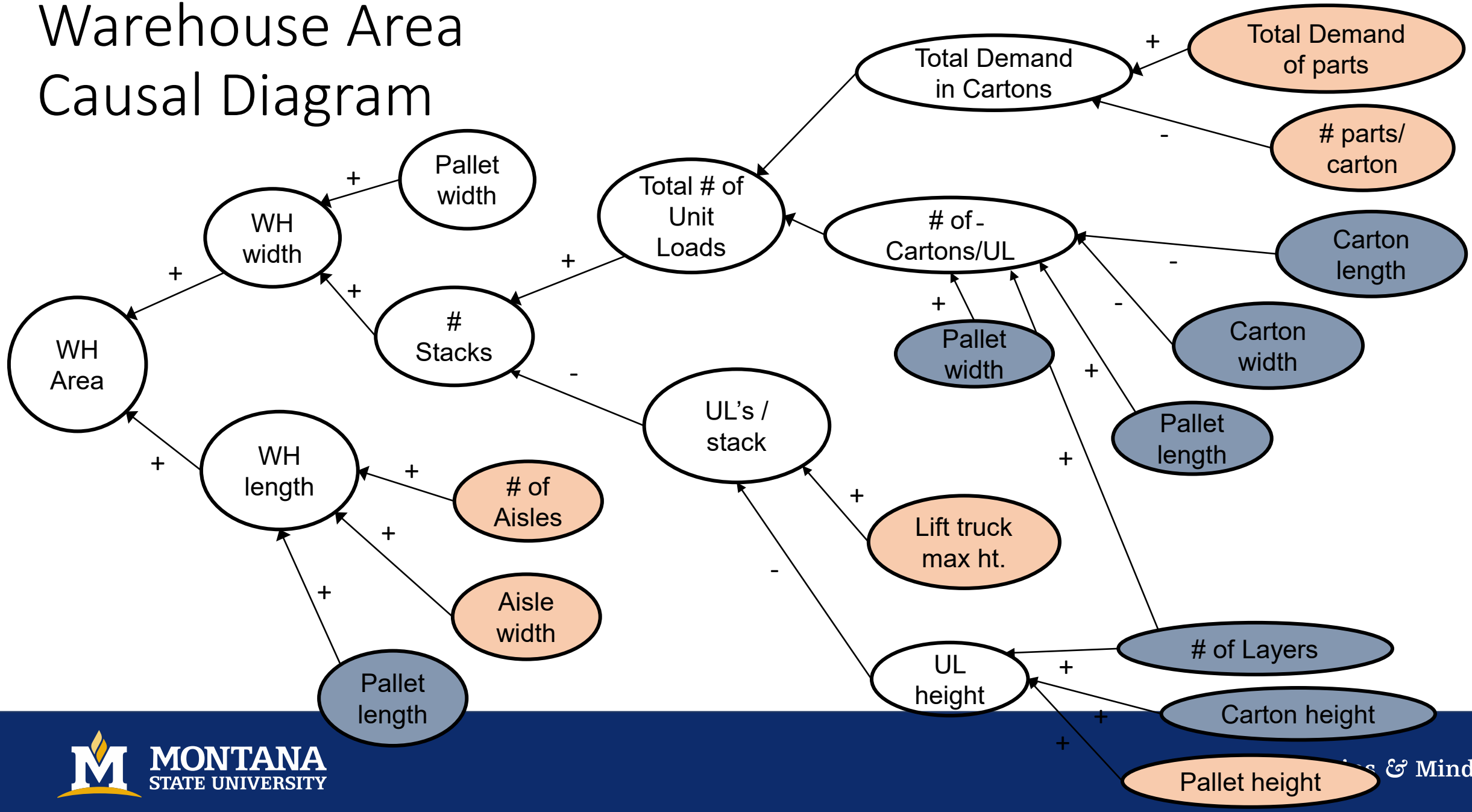


Truckloads Causal Diagram



Do similarly for Warehouse Area

Warehouse Area Causal Diagram

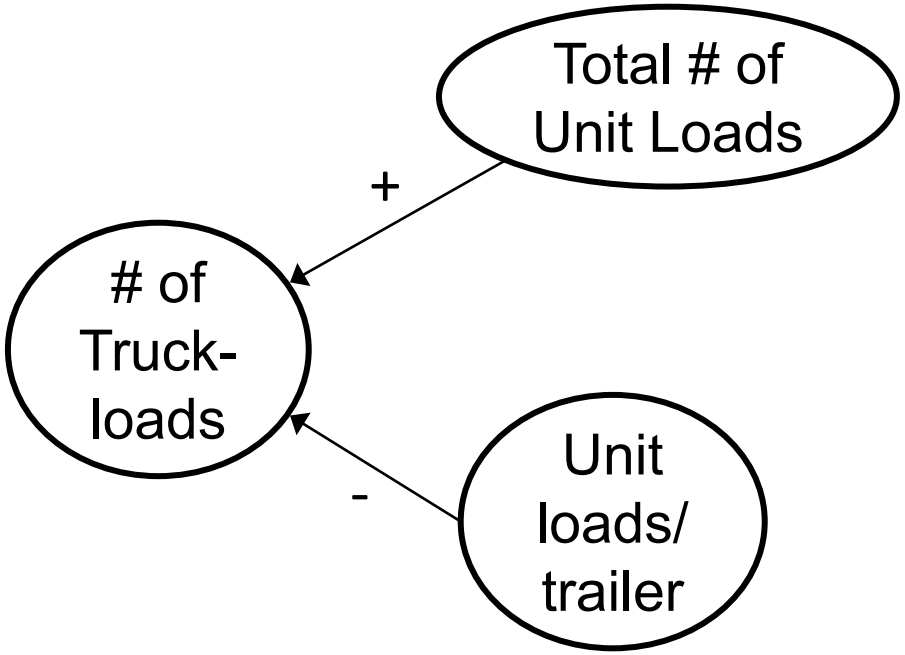


4. Find data and create curves.

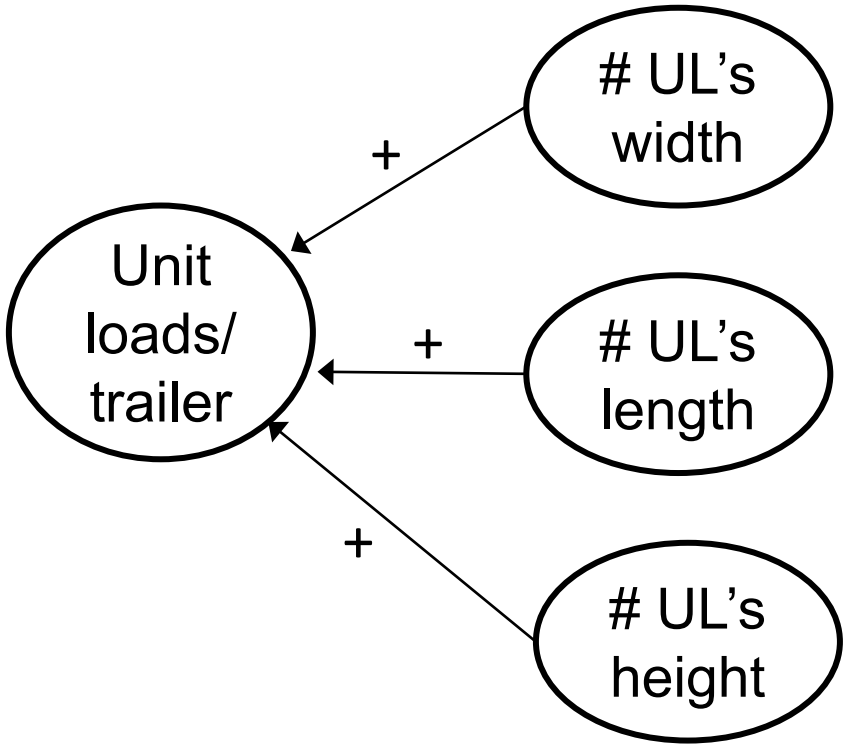
A. Identify clusters of variables that we can handle analytically.
B. Hypothesize relationships among the variables graphically.
C. Find or derive equations relating the variables.
D. Combine equations into compact, generalized parameters.
E. Input parameter values over appropriate ranges and plot curves.

In place of C, D and E you may be able to use historical data or conduct a designed experiment (virtual or physical).

How are these related?

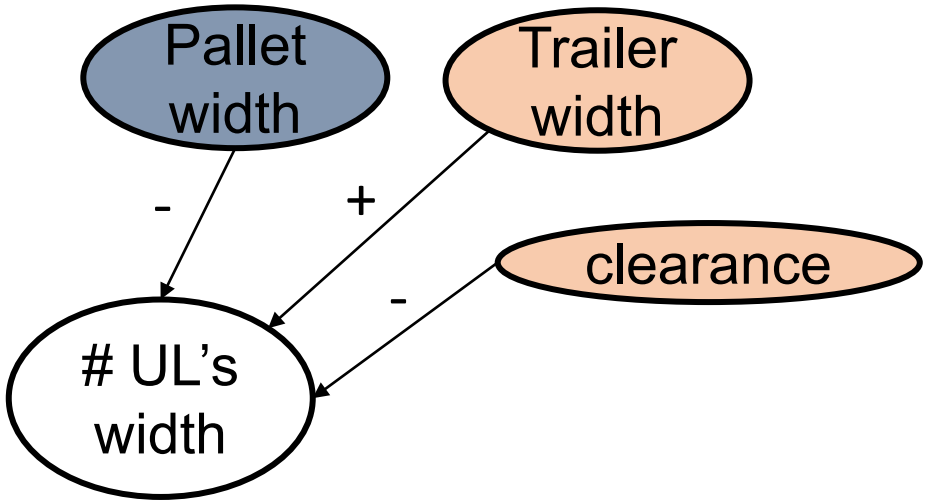


$$\#\ TL's = \frac{\text{Total \# UL's}}{\text{UL's / trailer}}$$

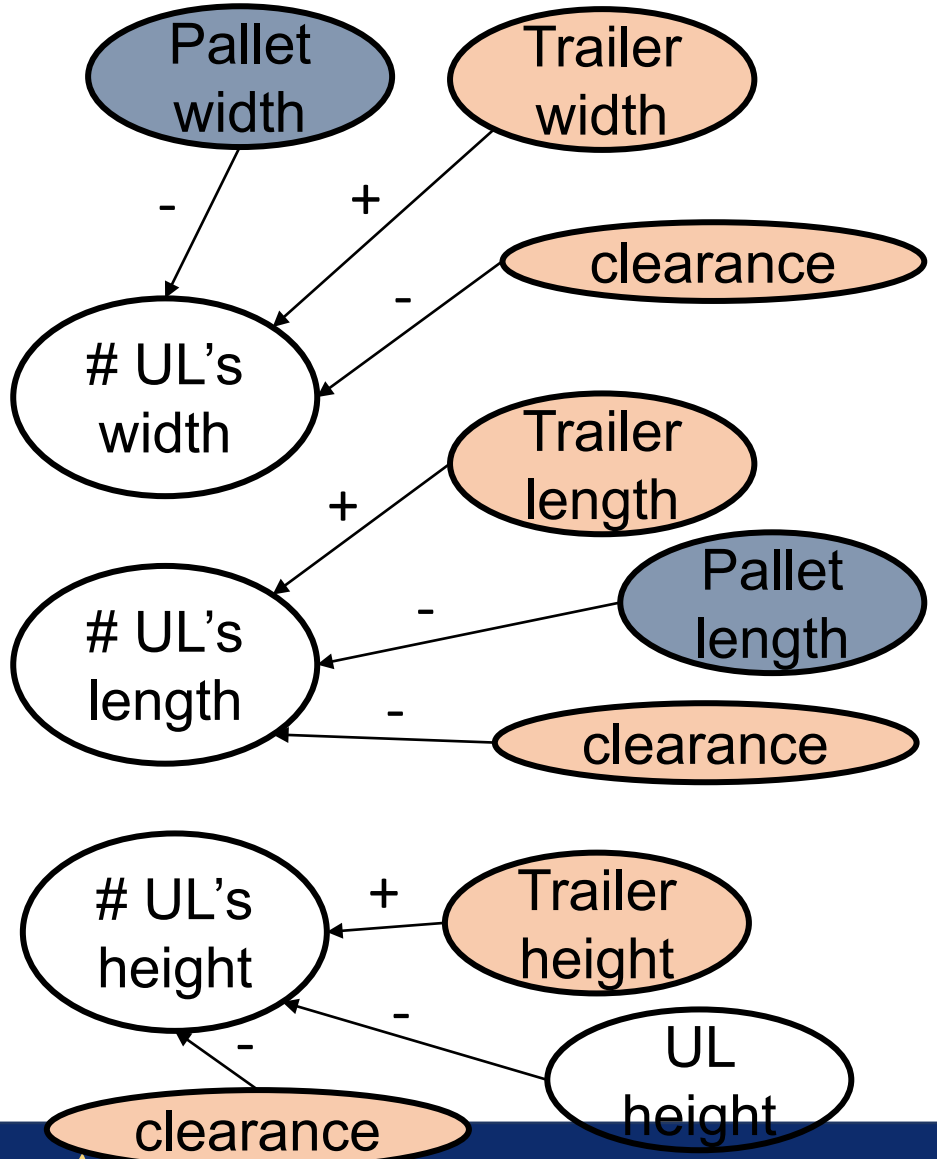


UL's / trailer =

(# UL's width)(# UL's length)(#UL's height)



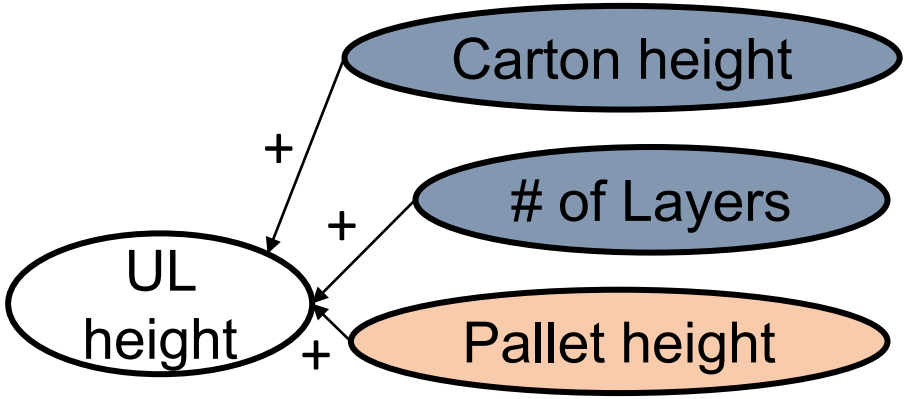
$$\text{\# UL's width} = \frac{\text{Trailer width}}{\text{Pallet width + Clearance}}$$



$$\#\ \text{UL's width} = \frac{\text{Trailer width}}{\text{Pallet width + Clearance}}$$

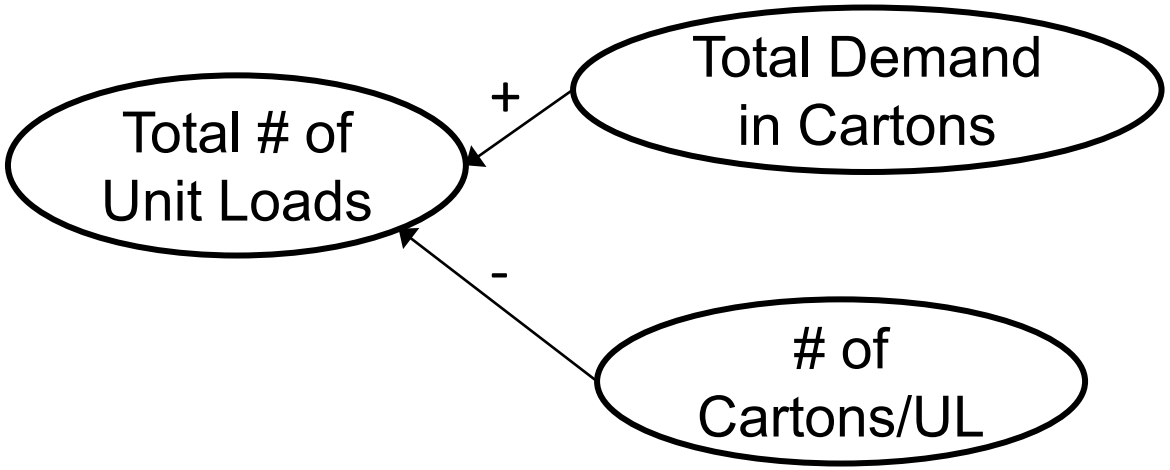
$$\#\ \text{UL's length} = \frac{\text{Trailer length - clearance}}{\text{Pallet length}}$$

$$\#\ \text{UL's height} = \frac{\text{Trailer height - clearance}}{\text{UL height}}$$

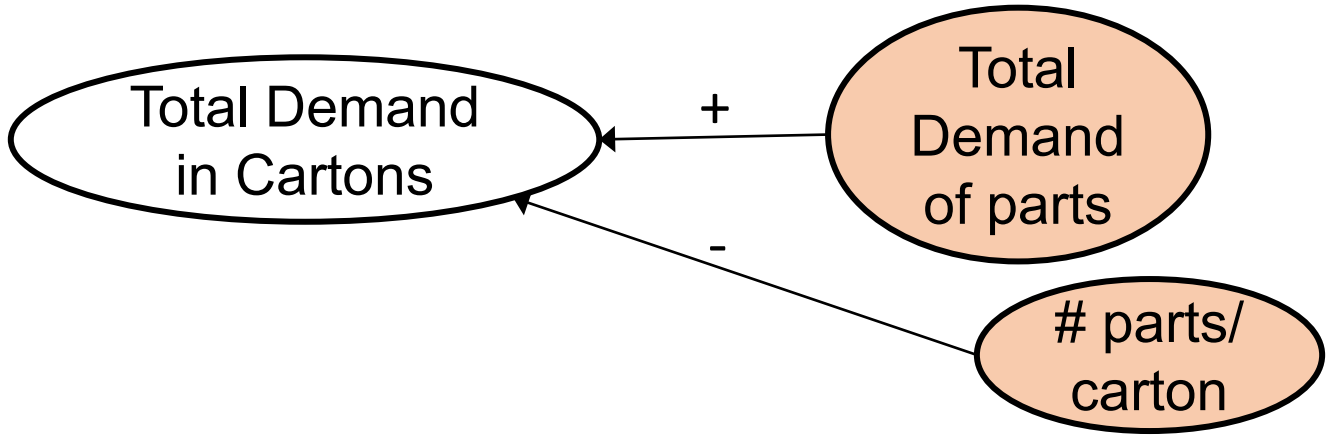


UL height =

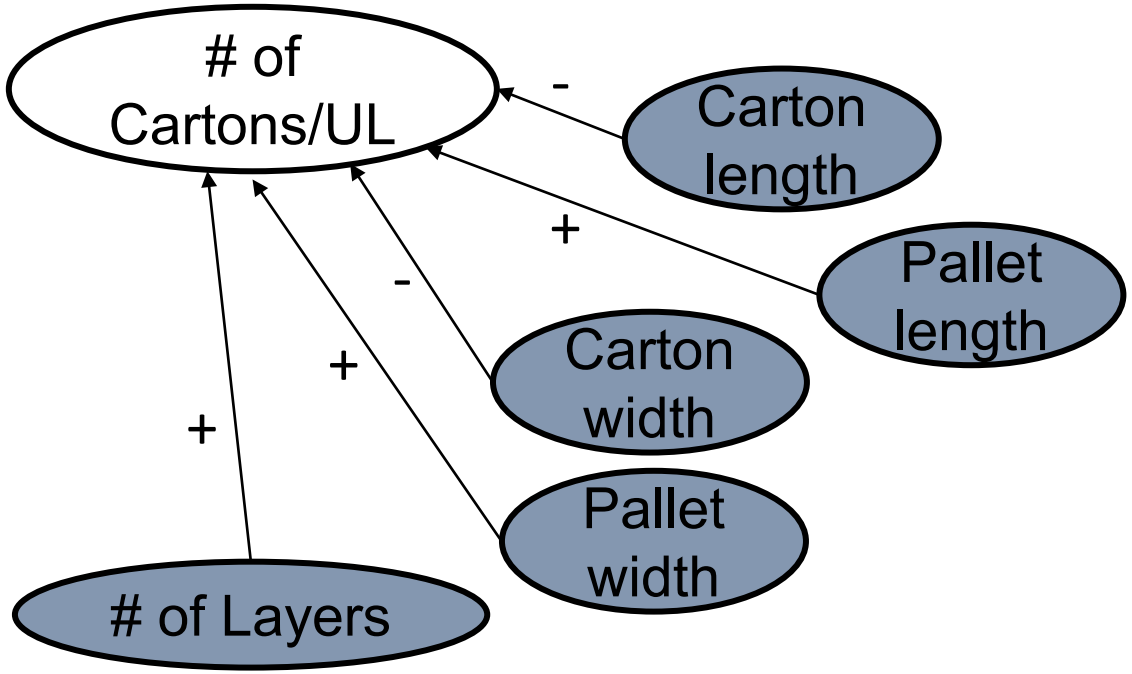
(Carton height)(# of Layers) + Pallet height



$$\text{Total \# UL's} = \frac{\text{Total Demand in Cartons}}{\text{\# Cartons / UL}}$$



$$\text{Total Demand in Cartons} = \frac{\text{Total Demand of Parts}}{\text{\# parts / carton}}$$

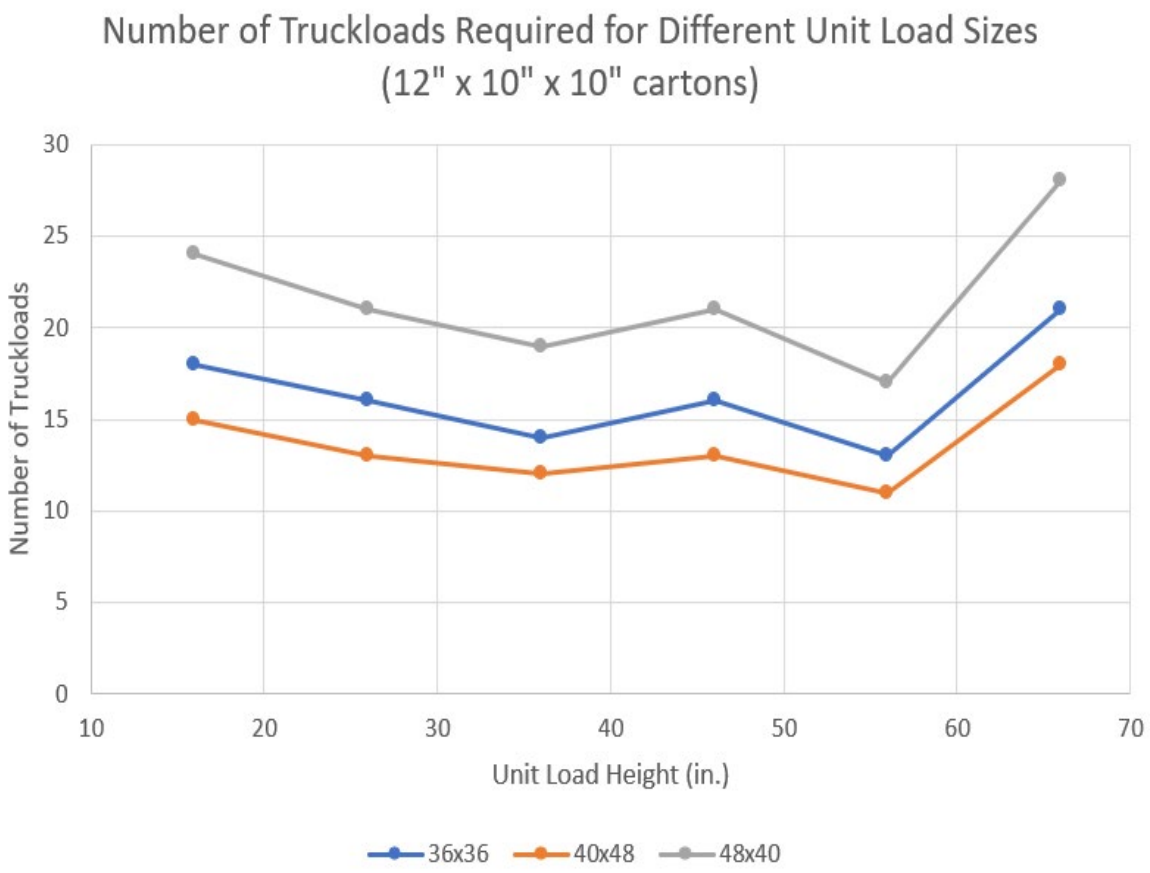


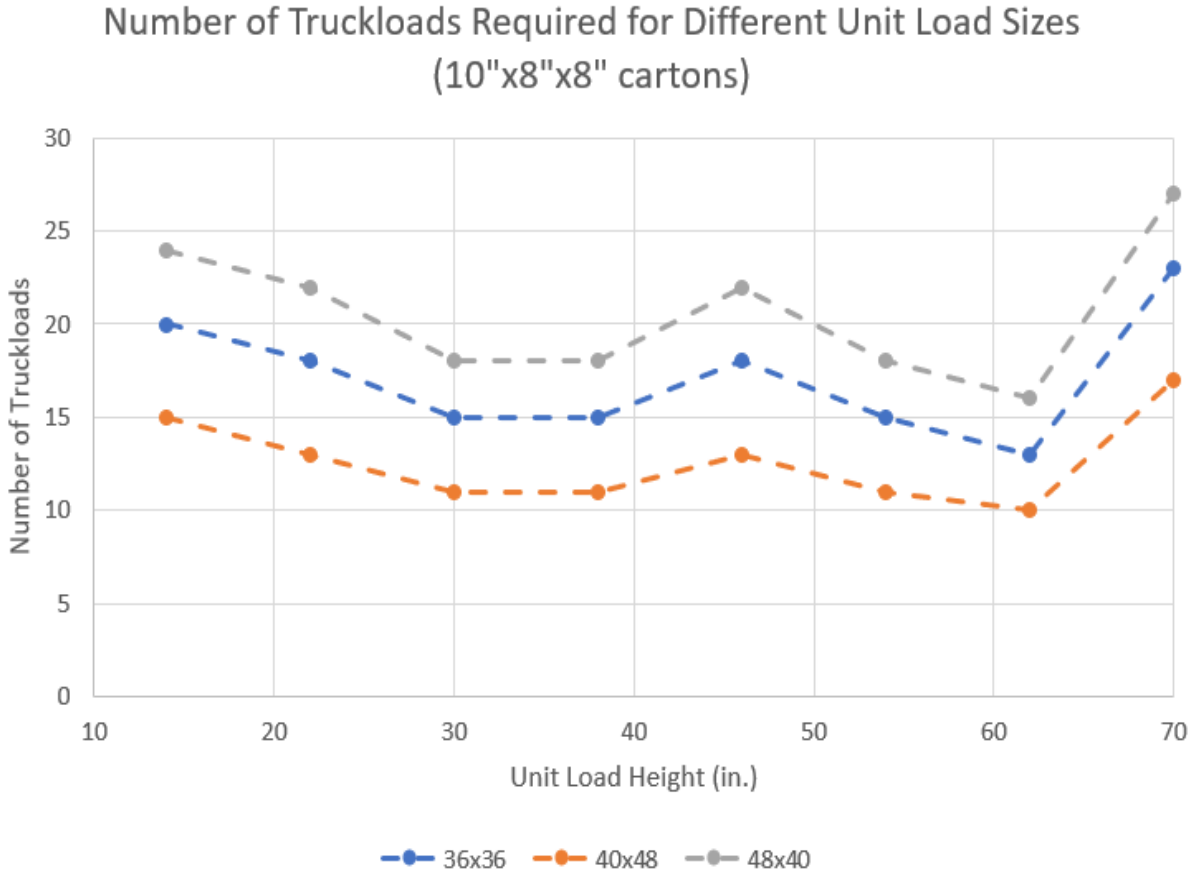
# of Cartons / UL =

(# of Cartons/layer)(# of Layers) =

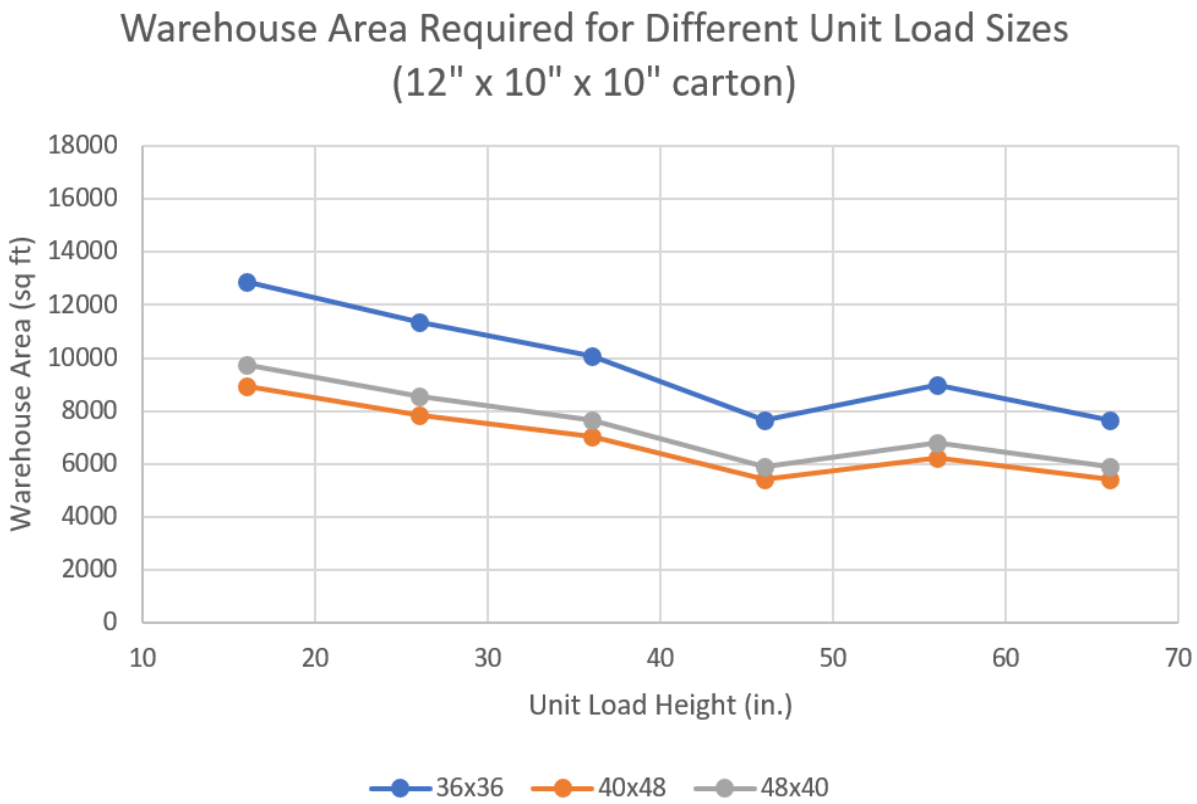
$$\left(\frac{\text{Pallet width}}{\text{Carton width}}\right)\left(\frac{\text{Pallet length}}{\text{Carton length}}\right)(\text{\# of Layers})$$

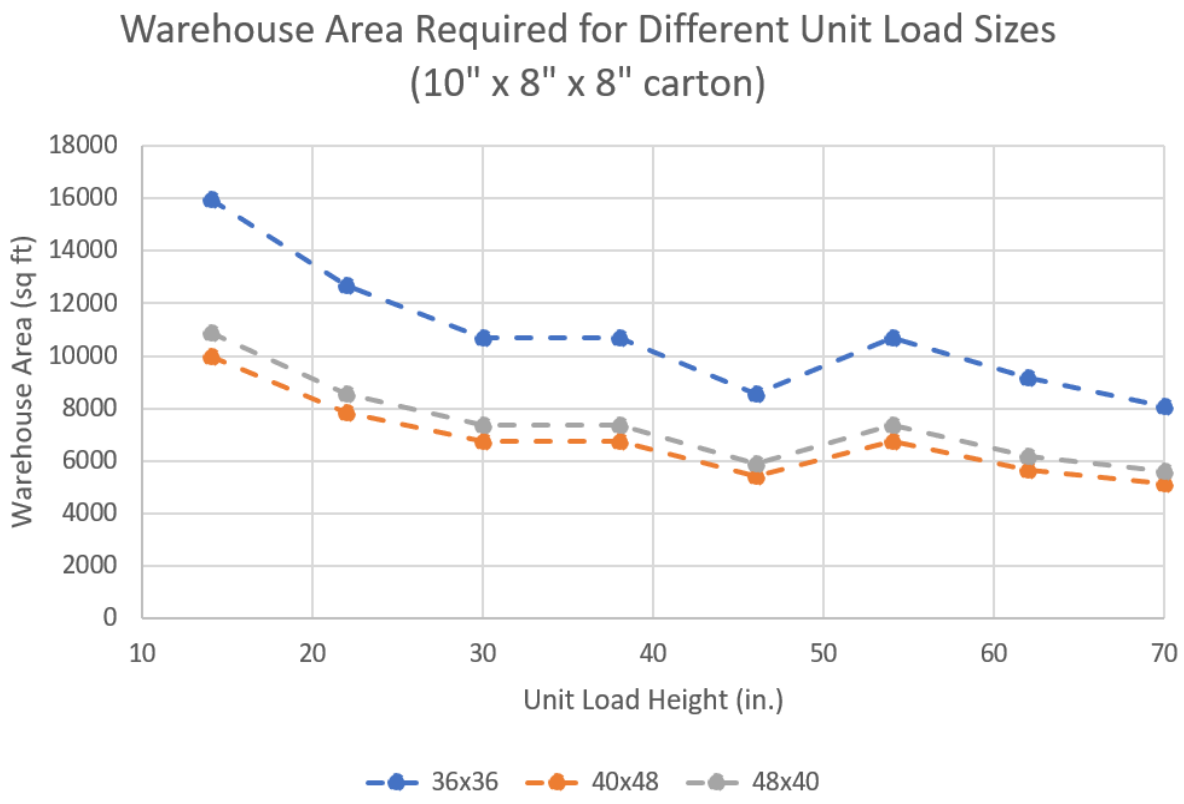
Some interesting trade-off curves



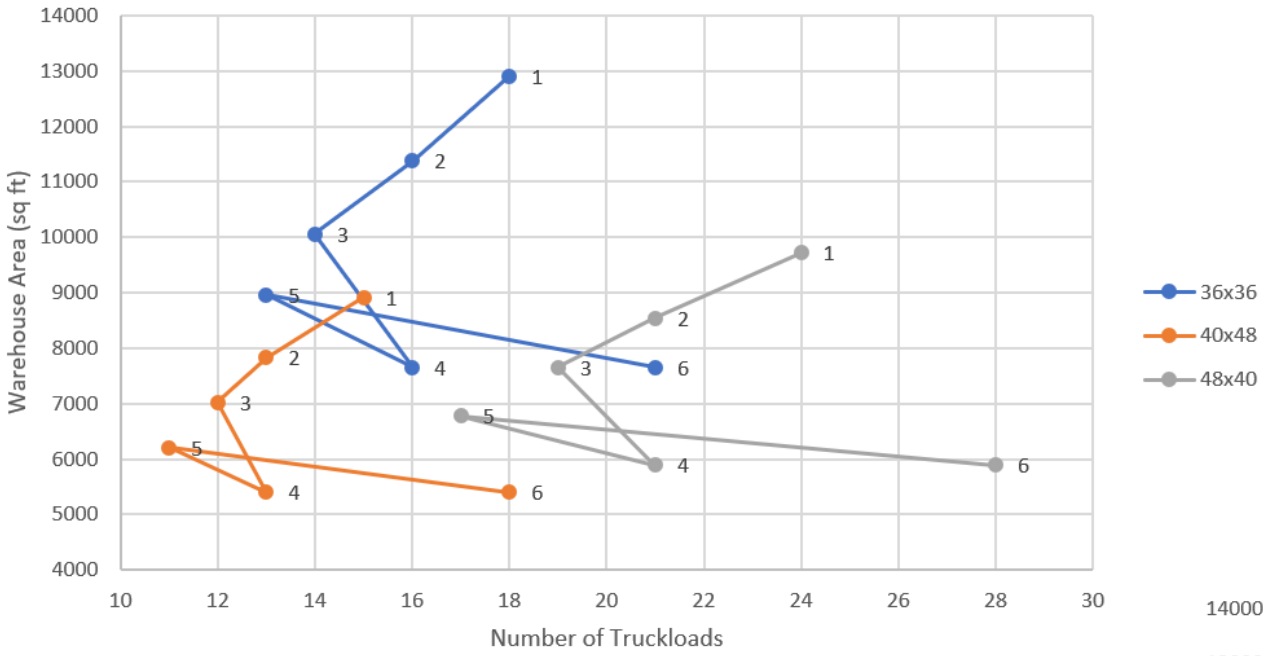


A few more trade-off curves

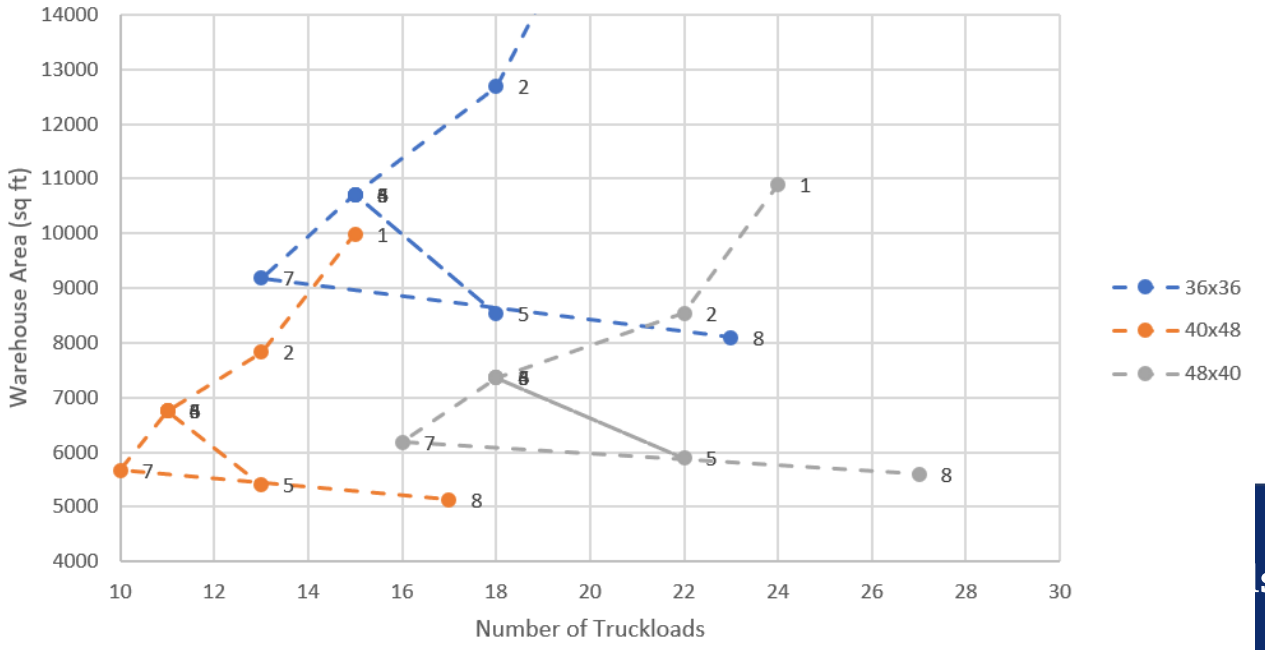




Warehouse Size Versus Truckloads for Different Unit Load Sizes (12" x 10" x 10" cartons)



Warehouse Size Versus Truckloads for Different Unit Load Sizes (10" x 8" x 8" cartons)



Wrap-up

- A visible knowledge approach enables us to:
  - Break down complex problems into manageable chunks.
  - Visualize key relationships and trade-offs.
  - Identify the efficient frontier for a design space.
  - Avoid iterations.
  - Solve problems more generally.
  - Generate knowledge that is reusable.

Key Points

- Knowledge is a central theme within LPPD.
- Conventional “iterative” development is slow with uncertain outcome.
- Building knowledge early, before detailed design, speeds development and increases innovation.
    - Eliminates iteration from guess-and-check.
- Visible knowledge maps out the possibilities, finds the limits, and makes learning reusable.

What are your key learnings?

Questions?

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