UIC BUSINESS

Warehouse Management:

Fast Pick Area

IDS 552

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Fast Pick Area

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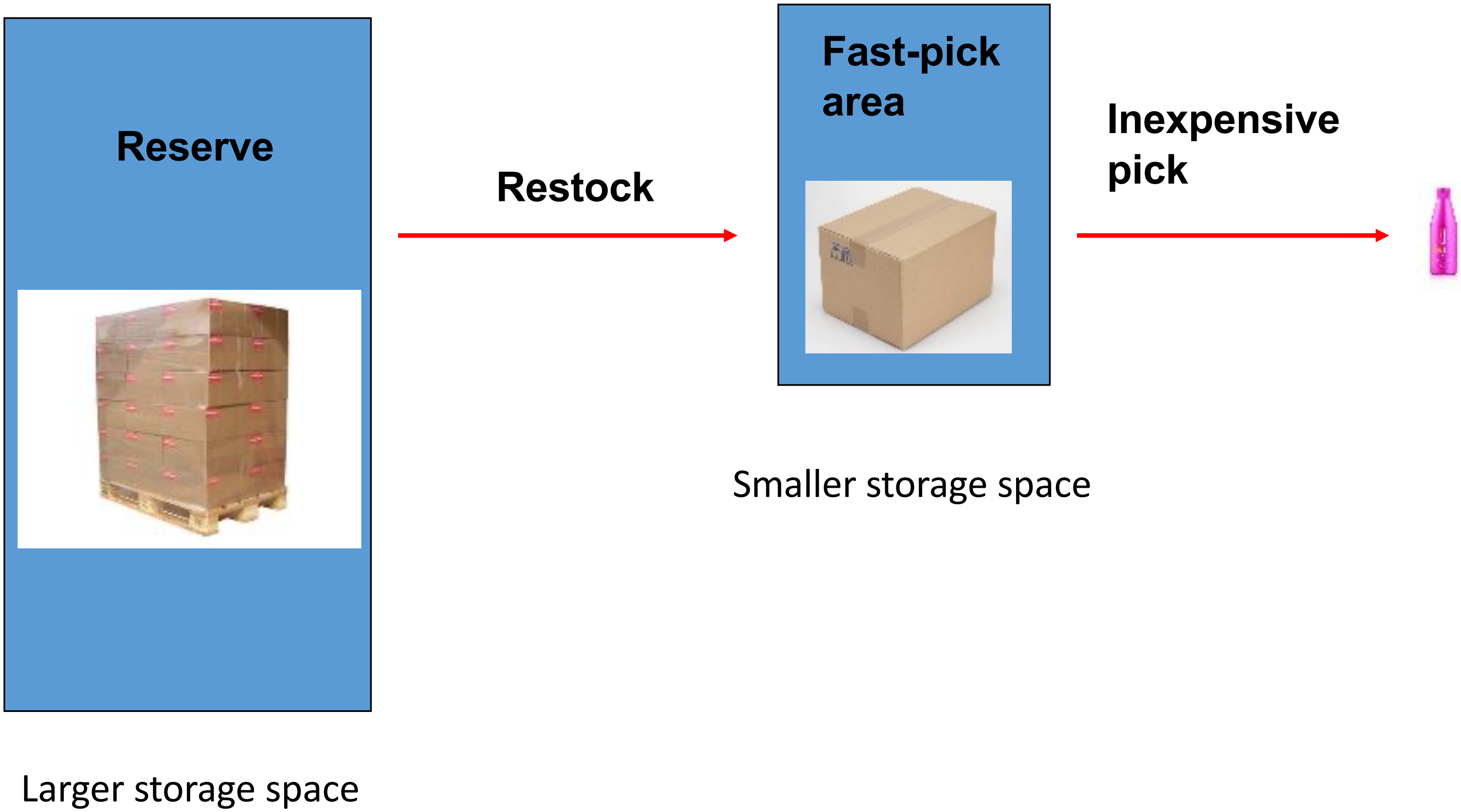
- Also known as
  - Forward-pick area
  - Primary-pick area

- Sub-region in a warehouse for picking

Fast Pick Area



Piece Picking

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Fast Pick Area

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- A "warehouse within the warehouse"
- Store most popular skus there in small amounts, so that most picking can be accomplished in a small area
- Benefit:
  - –Reduces pick "cost"
  - –Increases responsiveness
- Trade-off:
  - –Requires restock

Basic issues

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- Which skus to store in the fast-pick area?

- How much of each sku to store?

- We will start with the second question assuming we know which SKUs are assigned to the fast-pick area

Fluid Model

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- Treats each sku as a continuously divisible fluid
- We simply measure the cubic feet (or cubic meters) of space to be devoted to each sku
- Advantages:
  - Easy to estimate
  - Results are benchmarks
- Disadvantage:
  - Inaccuracies

Problem Setup

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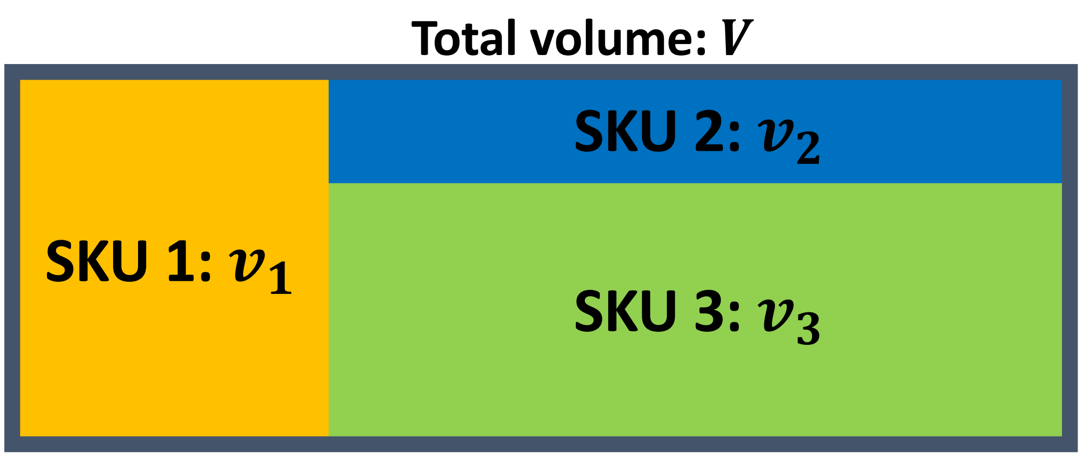
1. We use index i to denote the i-th sku.
2. We use notation (f^3) for cubic feet.
3. We assume V (f^3) is the total volume of the fast-pick area.
4. We assume v_i (f^3) is the volume of fast-pick area that needs to be used for storing sku i.



$$V = \sum_i v_i$$

How frequent should we restock?

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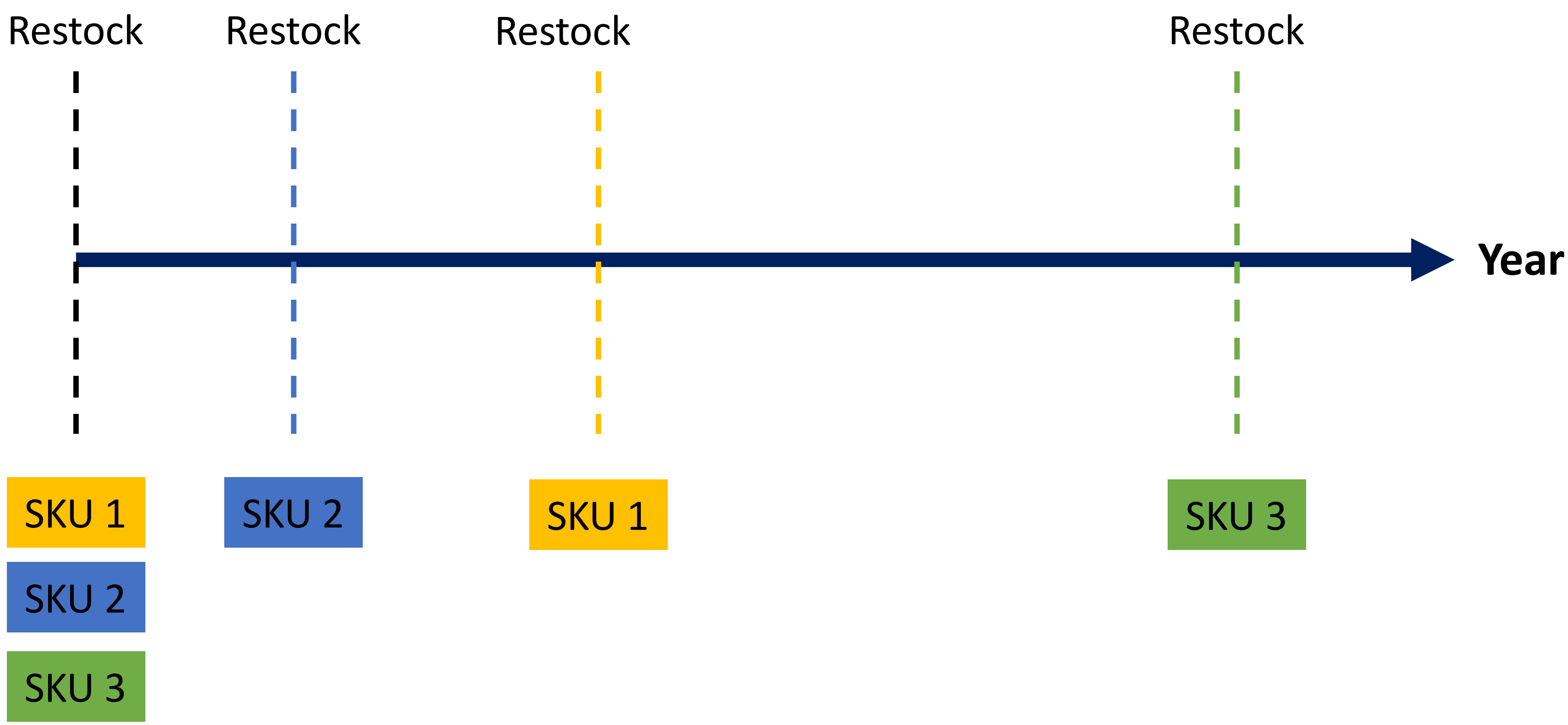

Flow

- Consider time frame of 1 year.
- Assume we stock each sku in cases.
- For sku i, flow is:

Annual demand in terms of items

$$f_i = \boxed{\frac{\boxed{\frac{\#item}{year}}}{\frac{\#item}{case}} \times \frac{volume}{case}}$$

Annual volume needed

Annual demand in terms of cases

$\boldsymbol{f_i}$ = **Volume needed for sku i per year =** $\boldsymbol{\frac{f^3}{year}}$

Number of Restocks Per Year

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- Recall thar we assume v_i (f^3) is the volume of fast-pick area that needs to be used for storing sku i.
- Restock for sku i is:

$$\#\text{Restock} = \frac{f_i}{v_i} = \frac{\frac{Needed\ volume}{year}}{Storage\ volume}$$

- Unit of restock is $\frac{1}{year}$

Example

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Fast pick area space (V) =10 ft^3

SKU	f_i (ft^3/year)
SKU 1	20
SKU 2	1400
SKU 3	400

Needed volume per year

Equal space allocation (EQS)

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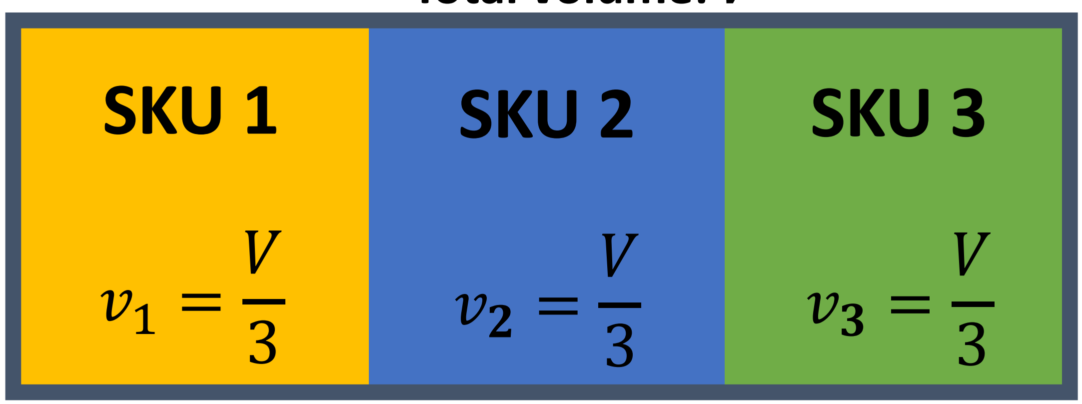
- Allocate the same amount of space to each sku
- Sku i has space $v_i = \frac{V}{n}$,
- Sku i is restocked $\frac{f_i}{v_i} = \frac{nf_i}{V}$ times a year

Total volume: V



Equal time (EQT) allocation:

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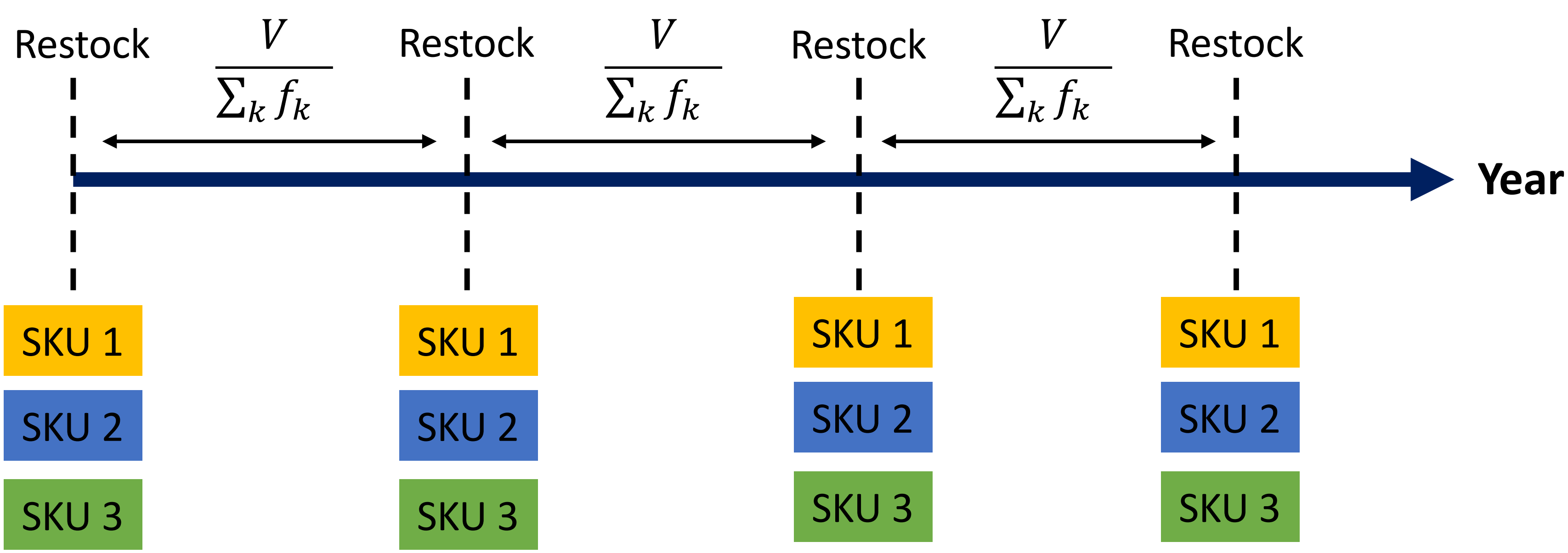
- Store an equal time supply of each sku: $\frac{v_i}{f_i} = \frac{v_k}{f_k}$
- Sku i has space $v_i = \left(\frac{f_i}{\sum_k f_k}\right) V$
- Sku i is restocked $\frac{\sum_k f_k}{V}$ times a year



Equal Space Vs. Equal Time

- Equal Space Allocation
  - Good: simplify space management
  - Bad: difficult to manage restocking process

- Equal Time Allocation
  - Good: simplify restocking process
  - Bad: difficult to maintain the slotting

- Can we do better?
- Try to optimize the allocation under a fluid model

Observation

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Equal Time Allocation

requires the same total #-restocks as

Equal Space Allocation!!!

Equal Space Vs. Equal Time

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	EQS	EQT
Space allocated to sku i (v_i)	$\frac{V}{n}$	$\left(\frac{f_\mathrm{i}}{\sum_k f_k}\right) V$
#Restock per year for sku i ($\frac{f_i}{v_i}$)	$\frac{n f_i}{V}$	$\frac{\sum_k f_k}{V}$
Total #Restock for all sku	$\frac{n \sum_k f_k}{V}$	$\frac{n \sum_k f_k}{V}$

Calculations on Example

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Fast pick area space (V) =10 f^3

SKU	Flow (f^3/yr)	EQS Space (f^3)	EQT Space(f^3)
SKU 1	20	**3 1/3**	0.11
SKU 2	1400	**3 1/3**	7.69
SKU 3	400	**3 1/3**	2.20

SKU	Flow (f^3/yr)	EQS # restocks per year	EQT # restocks per year
SKU 1	20	6	**182**
SKU 2	1400	420	**182**
SKU 3	400	120	**182**

EQS Space = $\frac{V}{n} = \frac{10}{3} = 3\frac{1}{3}$

EQT #Restocks per year =$\frac{\sum_k f_k}{V} = \frac{20+1400+400}{10} = 182$

Cost of Restocks

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- Assumptions:
  - –Restock only after exhausting inventory c_r
  - –Cost of each restock $\mathrm{c_r}$ is independent of the quantity restocked

- Cost of restocking sku i per year

$$= \mathrm{c_r} \times \text{(\#Restocks for sku i per year)}$$

$$= \mathrm{c_r} \times \frac{f_i}{v_i}$$

Allocating Space in the Fast-Pick Area

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- Goal: store the right amount of each sku so that the total restock cost is minimized

- Let V be the total volume available

- Consider 2 skus: SKU-A and SKU-B with flow f_A and f_B respectively

Space Allocation Problem (2 skus)

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$$\min c_r \frac{f_A}{v_A} + c_r \frac{f_B}{v_B}$$

$$s.t.$$

$$v_A + v_B \leq V$$

At the optimality, equality must hold

$$v_A, v_B > 0$$

Space Allocation Problem (2 skus)

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- The solution is unchanged if we ignore c_r

- To have an optimal solution, it holds that $v_A + v_B = V$

- The problem becomes

$$\min_{v_B > 0} \left\{ \frac{f_A}{V - v_B} + \frac{f_B}{v_B} \right\}$$

Optimization

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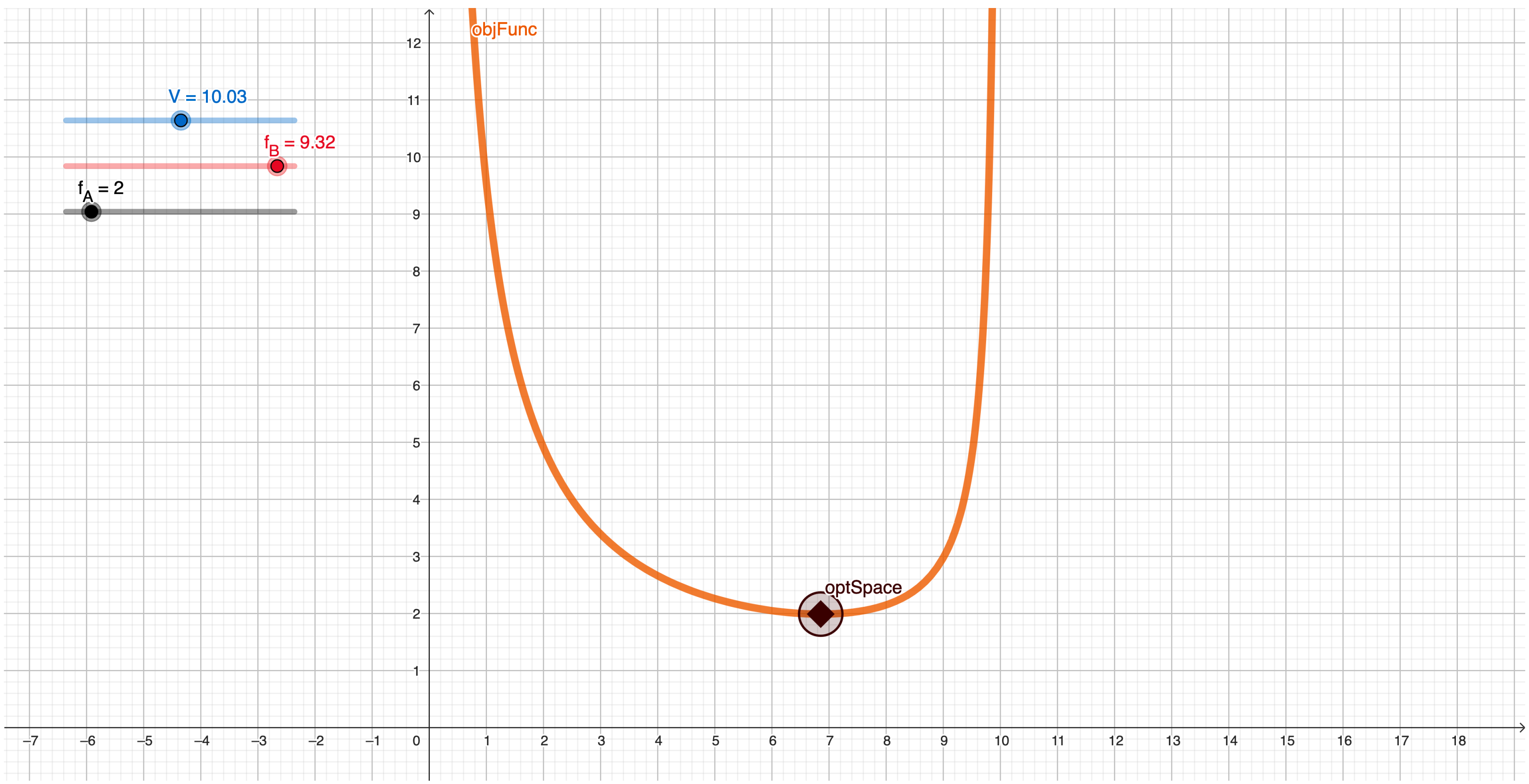

https://www.geogebra.org/m/nkwwsyat

Space Allocation Problem (2 skus)

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- The optimal solution:

$$v_A{*} = \left(\frac{\sqrt{f_A}}{\sqrt{f_A} + \sqrt{f_B}} \right) V$$

$$v_B{*} = \left(\frac{\sqrt{f_B}}{\sqrt{f_A} + \sqrt{f_B}} \right) V$$

Space Allocation Problem (n skus)

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$$\min \sum_{i=1}^{n} c_r \frac{f_i}{v_i}$$

$$s.t.$$

$$\sum_{i=1}^{n} v_i \leq V$$

$$v_i > 0$$

$$v_i^* = \left(\frac{\sqrt{f_i}}{\sum_{j=1}^{n} \sqrt{f_j}} \right) V$$

Calculations on Example

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Fast pick area space (V) =10 f^3

SKU	Flow (f^3/yr)	EQS Space (f^3)	EQT Space(f^3)
SKU 1	20	**3 1/3**	0.11
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SKU	Flow (f^3/yr)	EQS # restocks per year	EQT # restocks per year
SKU 1	20	6	**182**
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EQS Space = $\frac{V}{n} = \frac{10}{3} = 3\frac{1}{3}$

EQT #Restocks per year =$\frac{\sum_k f_k}{V} = \frac{20+1400+400}{10} = 182$

Calculations on Example

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Fast pick area space (V) =10 ft^3

Equal space allocation = EQS

Equal time allocation = EQT

SKU	Flow (f^3/yr)	EQS Space (f^3)	EQT Space(f^3)	OPT (f^3)
SKU-1	20	**3 1/3**	0.11	0.72
SKU-2	1400	**3 1/3**	7.69	6.05
SKU-3	400	**3 1/3**	2.20	3.23

	Flow (f^3/yr)	EQS # restocks per year	EQT # restocks per year	OPT # restocks per year
SKU-1	20	6	**182**	28
SKU-2	1400	420	**182**	232
SKU-3	400	120	**182**	124
Total		**546**	**546**	**384**

Example

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Assume V = 1

	Sku A	Sku B	Totals
Flow f_i	16	1	
EQS. Allocations #-Restocks			1 **34**
EQT Allocations #-Restocks			1 **34**
Opt. Allocations #-Restocks			1 **25**

Less Variability with Optimal Allocation

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- Optimal Allocations vary less than those of Equal Time Allocations.

- Under Optimal Allocations the numbers of restocks vary less than those under Equal Space Allocations.

Different restock costs

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- Optimal allocation results hold after substituting f_i with $\widehat{f_i}$ in all related formulas, where

$$\widehat{f_i} = c_i f_i$$

Economics of Order-Picking

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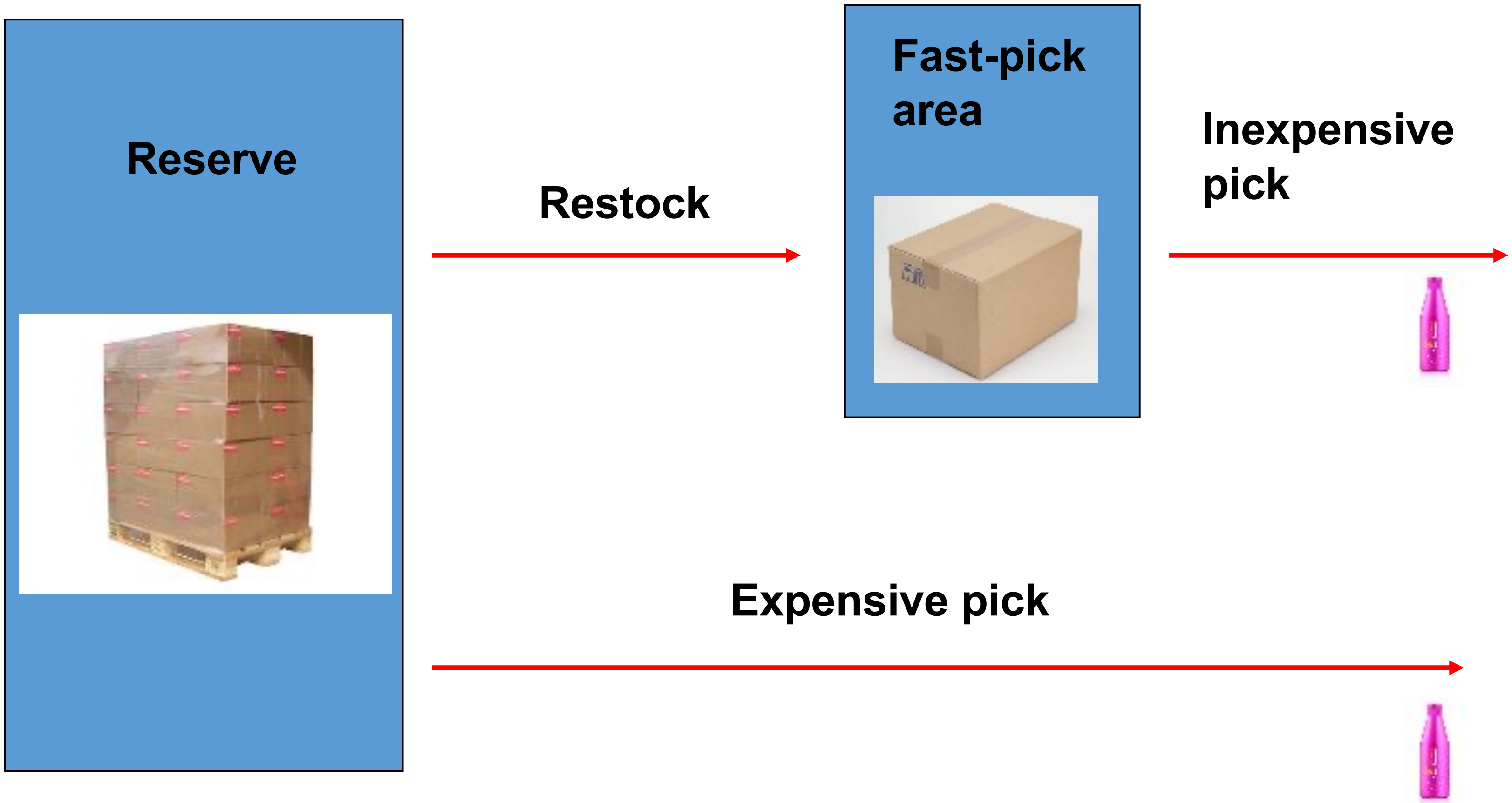

Which SKUs are Assigned for Fast Pick?

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- Do not store slow-moving skus in the fast-pick area.
- Better to store more of a popular sku so that we can defer restocking it.
- This reduces restocks.
- The cost is to occasionally pick the slow-moving skus from the reserve.

Problem Formulation

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- Parameters:
  - c_1: cost per pick from the fast-pick area
  - c_2: cost per pick from the reserve
  - c_r: cost per restock
  - V: total volume of the fast-pick area
  - p_i: #picks per year for sku i
  - f_i: flow (demand) of sku i
- Decision variables for each sku i:
  - $x_i = 1$ if sku i goes into the fast-pick area, $x_i = 0$ otherwise
  - v_i: volume allocated to sku i in the fast-pick area

Problem Formulation

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$$\min_{x_i, v_i} \sum_{i=1}^{n} \left(\left(c_1 p_i + c_r \frac{f_i}{v_i} \right) x_i + c_2 p_i (1 - x_i) \right)$$

$s.t.$

$$\sum_{i=1}^{n} v_i \, x_i \le V$$

$$v_i \ge 0$$

$$x_i \in \{0,1\}$$

Solving Fast-Pick SKU Optimization

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- Challenging nonlinear mixed integer program that simultaneously finds the SKUs for fast picking and then allocates space
- **Observation:** Given an assignment of SKUs to the fast-pick area, we know the optimal allocation in closed form
- Unfortunately, we have too many possible SKU assignments!
- We will resort to a heuristic solution of our formulation based on the above observation

Labor Efficiency

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- Labor efficiency of sku i:

$$p_i / \sqrt{f_i}$$

- The skus offering the greatest labor efficiency have the strongest claim to the fast-pick area.

Heuristic

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(Decides what goes into the fast-pick area and in what amount)

1. Sort all skus from most labor efficient to least.
2. Successively evaluate the total cost of putting no skus, only the first sku, only the first 2 skus, and so on, into the fast-pick area. Choose the strategy that minimizes the total cost.

Total cost: $\sum_{i=1}^{n}\left(\left(c_1 p_i + c_r \frac{f_i}{v_i}\right) x_i + c_2 p_i (1 - x_i)\right)$

Multiple Fast-Pick Areas

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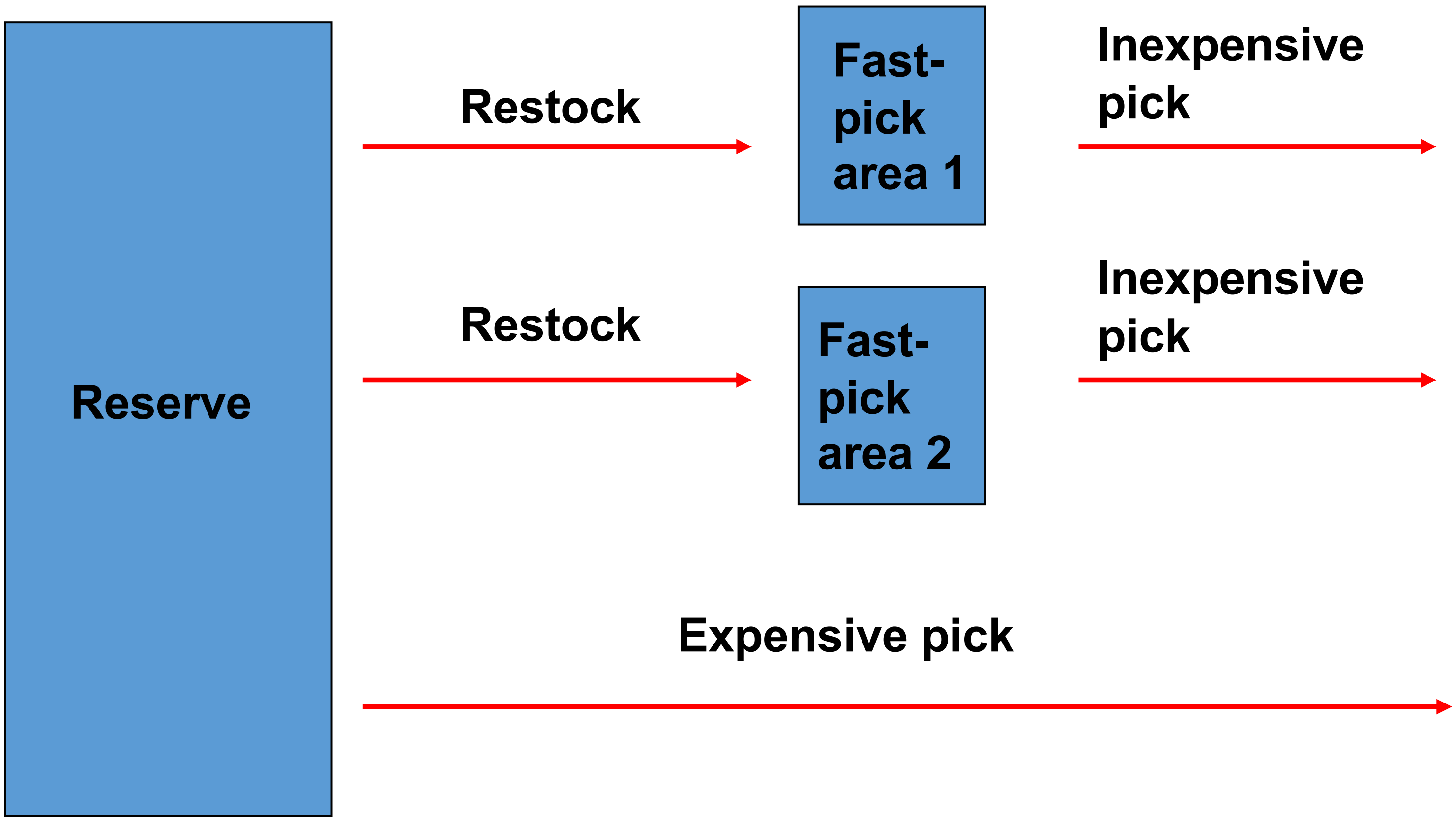

Limitations of Fluid Model

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- Sub-additivity of space
  - E.g. Some products can be stored in nested fashion: 2 pieces occupy only a little more space than a single one.

Limitations of Fluid Model

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- Reasonable for piece picking (our focus)
- Becomes less accurate when the items are large compared to the shelves. E.g. pallets in pallet racks.
- Need a more detailed model: detailed slotting

How Large Should the Fast-Pick Area Be?

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- The larger the fast-pick area
  - The more skus we can store → more pick savings
  - The larger amounts we can store → less restocks
  - But, we get less savings per pick (i.e. *s*)!!!

Summary

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- Concentrating activity in a small area can reduce pick costs and increase responsiveness
- Labor efficiency: $p_i / \sqrt{f_i}$
- Put the most labor efficient skus in the fast-pick area
- Search to determine how many skus to put into the fast-pick area
- For those skus stored in the fast-pick area, the optimal allocation is

$$v_i^* = \left(\frac{\sqrt{f_i}}{\sum_{j=1}^{n} \sqrt{f_j}} \right) V$$