Lecture 08
Order Picking & Bucket Brigades

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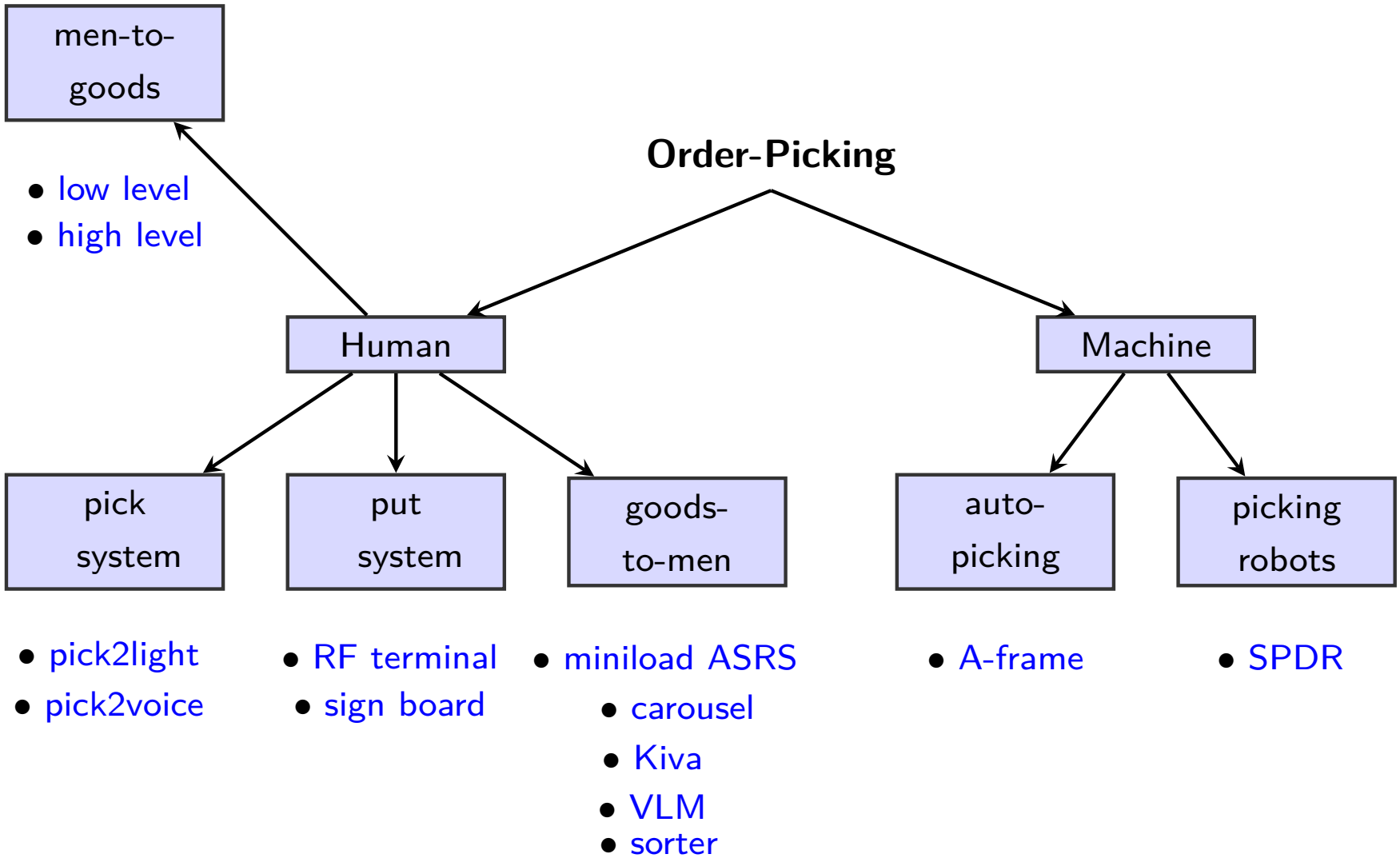
Outline

source: General references [BH09, Mul94, Fra02, **?**]

Order Picking, so far

- **Importance:** the most labor intensive activity $\rightarrow$ efficiency
- **Order:** customer orders $\rightarrow$ separate / group / sequence $\rightarrow$ picking order
- **Location:** visit bin locations
- **Classification:** $\exists$ many combination
  - **By size:** pallet VS box carton VS piece/ unit
  - **By stock available:** put-away VS flow-through/ cross-dock
  - **By movement:** goods-to-men VS men-to-goods (low.Lv & hi.Lv) VS automation
  - **By order grouping:** single VS zone VS batch VS wave
  - **By configuration** pick VS put

Order-Picking Methods



source: de Koster, R. 2007 [dLDR07]

Role of human in Order-Picking

- **pick system:** picker as retriever + transporter
- **put system:** picker as deliverer + transporter
- **sortition:** picker as arranger
- **men-to-goods:** picker as retriever + transporter + searcher
- **goods-to-men:** picker as retriever

Issues

- **Zone/Wave Separating:** erect some zone, group stores in wave $\rightarrow$ how to complete or balance workloads
- **Line Sequencing:** how to sequence line and minimizing travel distance
- **Order Combining:** how to group order and minimizing man-hour

Comparison of piece picking system

	Pick System	Put System	Sortation System
			
Scalable by	shifts/pre-pick	add shifts/workers	add shifts
Storage	required	no buffer	may be
Footprint	moderate	small	moderate
Throughput	low-moderate	low-moderate	high
Price	low-mid	low-mid+	high
Optional	cycle tote	using RF	wave
Issues	double handling	workers	label
		equipment	curve & speed

Men-to-Goods: Picking Policy

Single-Order picking: one tour for one order (many item)

Batch picking: one tour for many orders

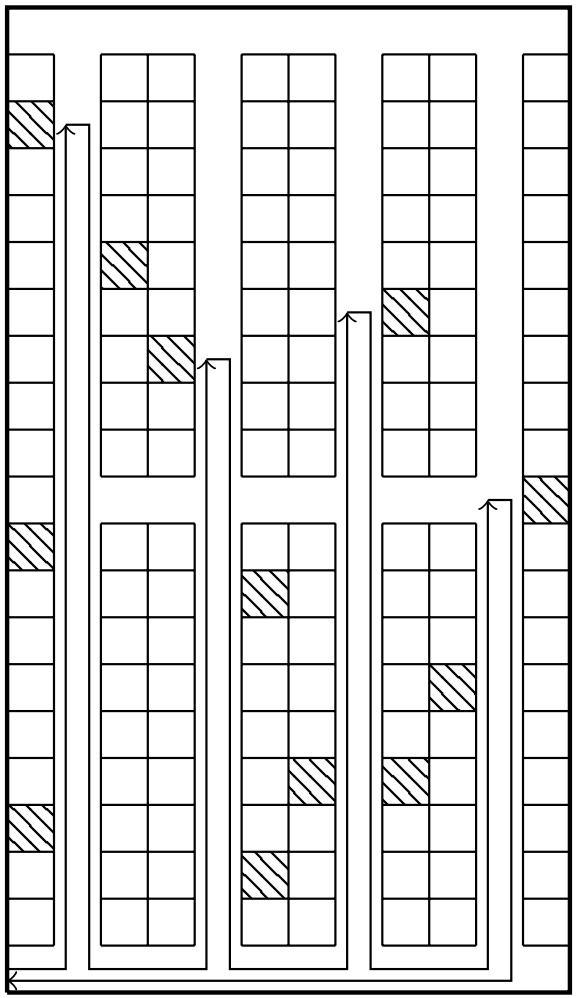
Zone picking: set area for each picker

- **Sequential zone:** order integrity is maintained
- **Batch zone:** orders are batched together within zone
- **Wave picking:** orders is dynamically released to end precisely the same

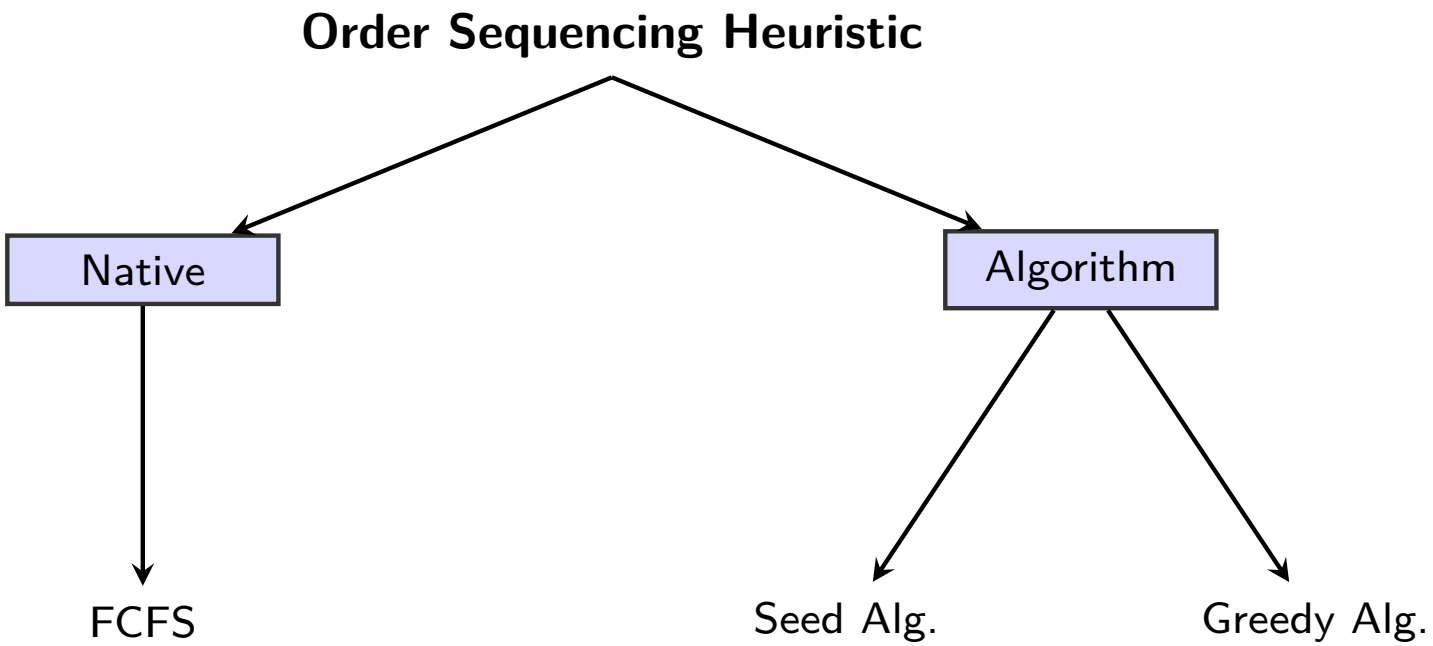
Variations

- **sort-while-pick:** multi-picking followed by immediate sorting on cart
- **pick-and-sort:** sort after all picked completed
- **pick-and-pass:** multiple pickers uses same tote/cart

Default Walking Path



Order-Sequencing Methods



- cluster by appearance
- order by position

- one batch at a time
- choose order

- all batch
- reduce batch

source: de Koster, R. 2007 [dLDR07]

Product Zone Allocation

- **storage assignment:** where to put items (popularity & correlation)
- **walk-pattern:** dynamic & static, routing strategy
- **information:** can be added during picking
- **high level:** beyond reach, need machine
- **put system:** batch of orders (move requested SKU)
- **order consolidate:** how to combine 'similar' order

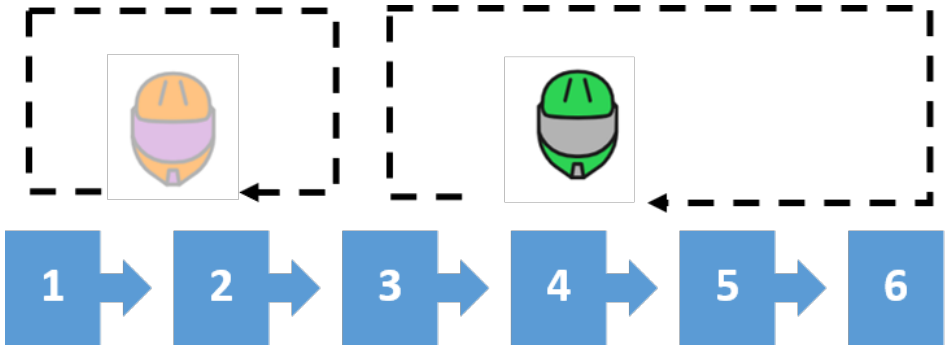
Order Picking Comparison

Picking Method	Benefits	Disadvantage	Simulation
Single-order	• simple/independent	• high travel • passing	
Batch	• less dead head	• optimal batch size • passing	
Zone	• less movement	• 'perfect' zone • WIP	
Bucket Brigades	• no bottleneck • no equipment	• ranking speed	

What is bucket brigades?

- **What:** dynamic zone picking by simple rules
- **Idea:** passing work to other worker once that worker finishes

How to implementing brigades?



- **Rules:** ▶
  1. continue task until
  2. (a) finish all tasks
  3. (b) meet with the next worker → hand over your task
  4. go back to the previous worker
- **Benefits:** self-balancing
- **Issues:** ranking 'skill' from fastest to slowest
- **More:** http://www.bucketbrigades.com/

Important issues in bucket brigades

Practical Issues

- **Ranking workers:** Who are slow workers?
- **Work, itself:** Are the work one dimension, high variability, & ease to handover?
- **Cooperation/Incentive:** fastest worker = leader

Theoretical Issues → not sequential question

- **Self-Balancing:** Is bucket brigade really 'self-balancing'?
- **Productivity:** How much productivity bucket brigade could improve?
- **Next handover:** Given position of a worker, where is his next handover?

What is self-balancing?

- no matter where task starts, work will eventually balance itself
- no bottleneck & minimal ideal time $\rightarrow$ fully utilize workers

Assumptions

- Each worker can be characterized by a working speed only
- Insignificant handover time & walk-back times
- Work-content is spread continuously & uniformly

Two-Workers Bucket Brigade

Notation

v_A = speed of worker A doing the task

v_B = speed of worker B doing the task ($v_A < v_B$)

$x^{(j)}$ = task ratio completed by worker A at iteration j^{th}

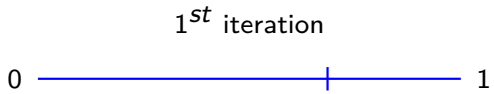
$t^{(j)}$ = time that worker B completed his task at iteration j^{th}

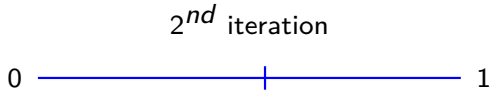
Assumption:

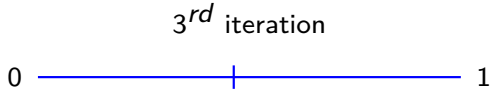
- Task is uniform distributed across normalize line $[0, 1]$
- Worker' picking speed is constant
- Minimal hand over time
- Instant walk back

Where is the next hand-over?

- **Initial conditions:** B starts at $x^{(0)}$







Question

- At iteration j^{th}, how much worker B does? & when it is completed?
- Where worker B start his work at iteration $(j+1)^{th}$
- **Next position:** $x^{(j+1)} = \frac{v_A}{v_B}(1 - x^{(j)})$
- **Define:** $r = \left(\frac{v_A}{v_B}\right)$

Solve for $x^{(j+1)}$

$$
\begin{aligned}
& x^{(j+1)} \\
& \quad = r(1-x^{(j)}) \;\; = r - r\left[r(1-x^{(j-1)})\right] \\
& \quad = r - r^2 + r^2 x^{(j-1)} \;\; = r - r^2 + r^2\left[r(1-x^{(j-2)})\right] \\
& \quad = r - r^2 + r^3 - r^4 + \cdots (-1)^{j+1} r^{j+1} x^{(0)} \\
r \times (1); \qquad & \quad = + r^2 - r^3 + r^4 - r^5 + \cdots (-1)^{j+1} r^{j+2} x^{(0)} \\
(1) + r \times (1); \qquad & \quad = r + (-1)^{j+1} r^{j+1} x^{(0)} + (-1)^j r^{j+1} + (-1)^j r^{j+2} x^{(0)} \\
& \quad = r + (-1)^{j+1} r^{j+1} x^{(0)} (1+r) + (-1)^j r^{j+1}
\end{aligned}
$$

$$
x^{(j+1)} \quad = \quad \begin{cases} r - r x^{(0)} & ; \text{if } j = 0, \\ \sum_{i=1}^{j+1} \left[(-1)^{i+1} r^j \right] & ; \text{otherwise.} \end{cases}
$$

Example: Practical Questions

Consider a constant & uniform picking path & two pickers. Pickers A & B can pick individually at speed 50 & 70 units per hour, respectively.

- What is the total productivity of equal-area zone picking if Picker B always the first picker?

  $2 \times \min(50, 70) = 100$ units per hours

- How you apply **bucket brigade** in this picking situation?

  put Picker A first & use bucket brigade rules

- What is total productivity of your **bucket brigade**?

  $50 + 70 = 120$ units per hours

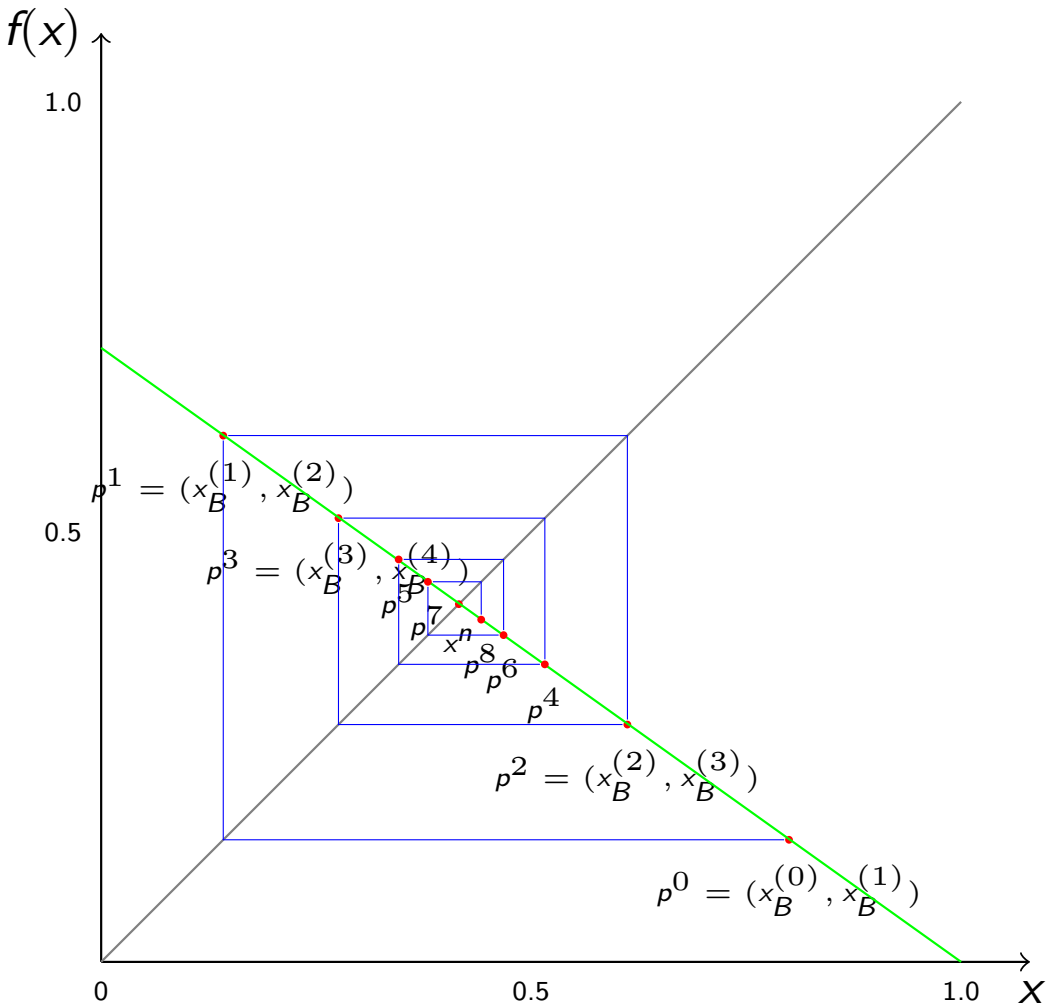
Example: Theoretical Questions

From the previous question, suppose that the task can be normalized from 0.0 to 1.0 & Picker B starts at 0.8 position

- How many iteration **bucket brigade** needed before he is within 5% from his 'perfect balancing' position?

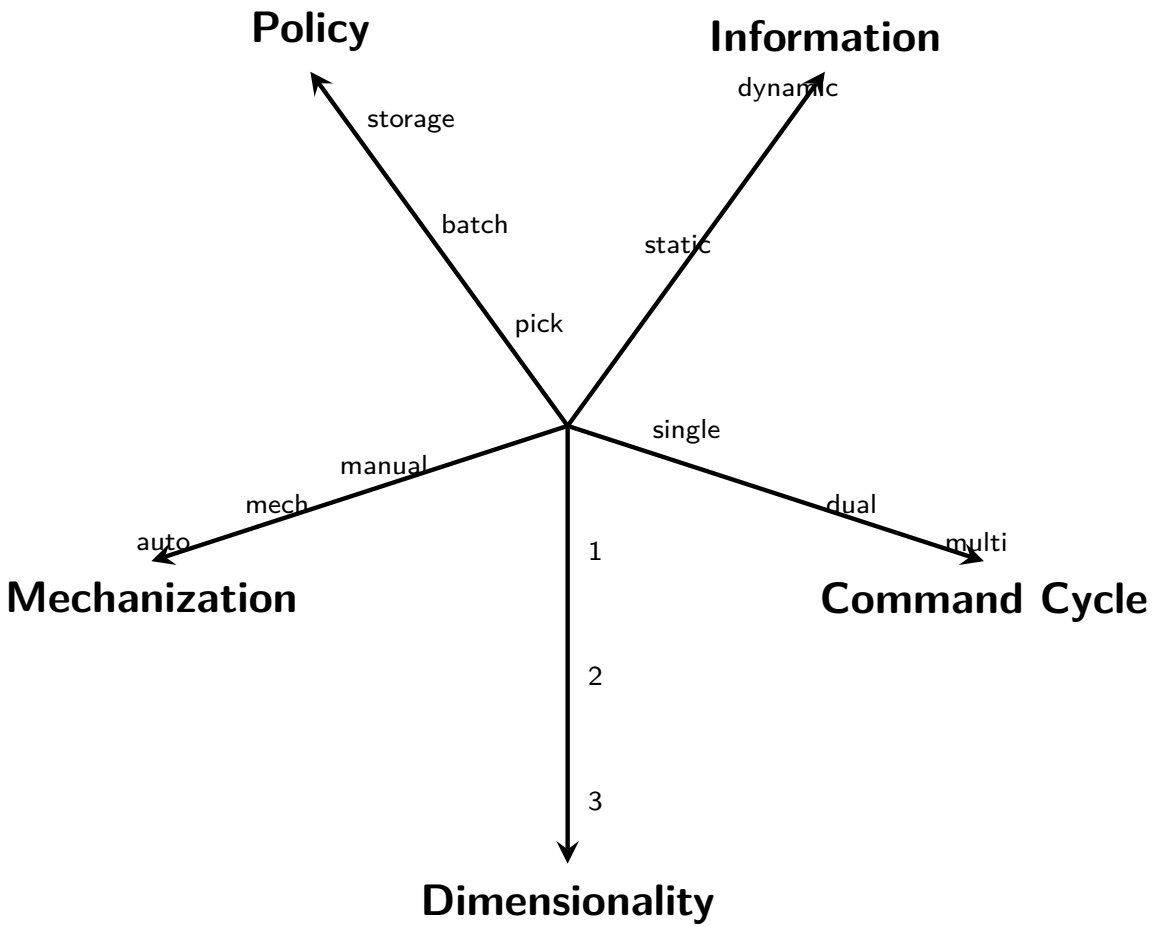
- **Initial position:** $x_B^{(0)} = 0.8$
- **Balancing position:** $x^n = \frac{v_A}{v_A+v_B} \frac{50}{50+70} = 0.4167$
- **5% of $\mathbf{x^n}$:** $[0.396, 0.437]$

How fast the system converge?



i	x_i	$f(x)$
0	0.800	0.143
1	0.143	0.612
2	0.612	0.277
3	0.277	0.516
4	0.516	0.345
5	0.345	0.468
6	0.468	0.380
7	0.380	0.443
8	0.443	0.398

Warehouse Complexity



source: Goetschalckx, M. & Ashayeri, J. 1989. [GA89]

Inputs & Constraints in Design

External

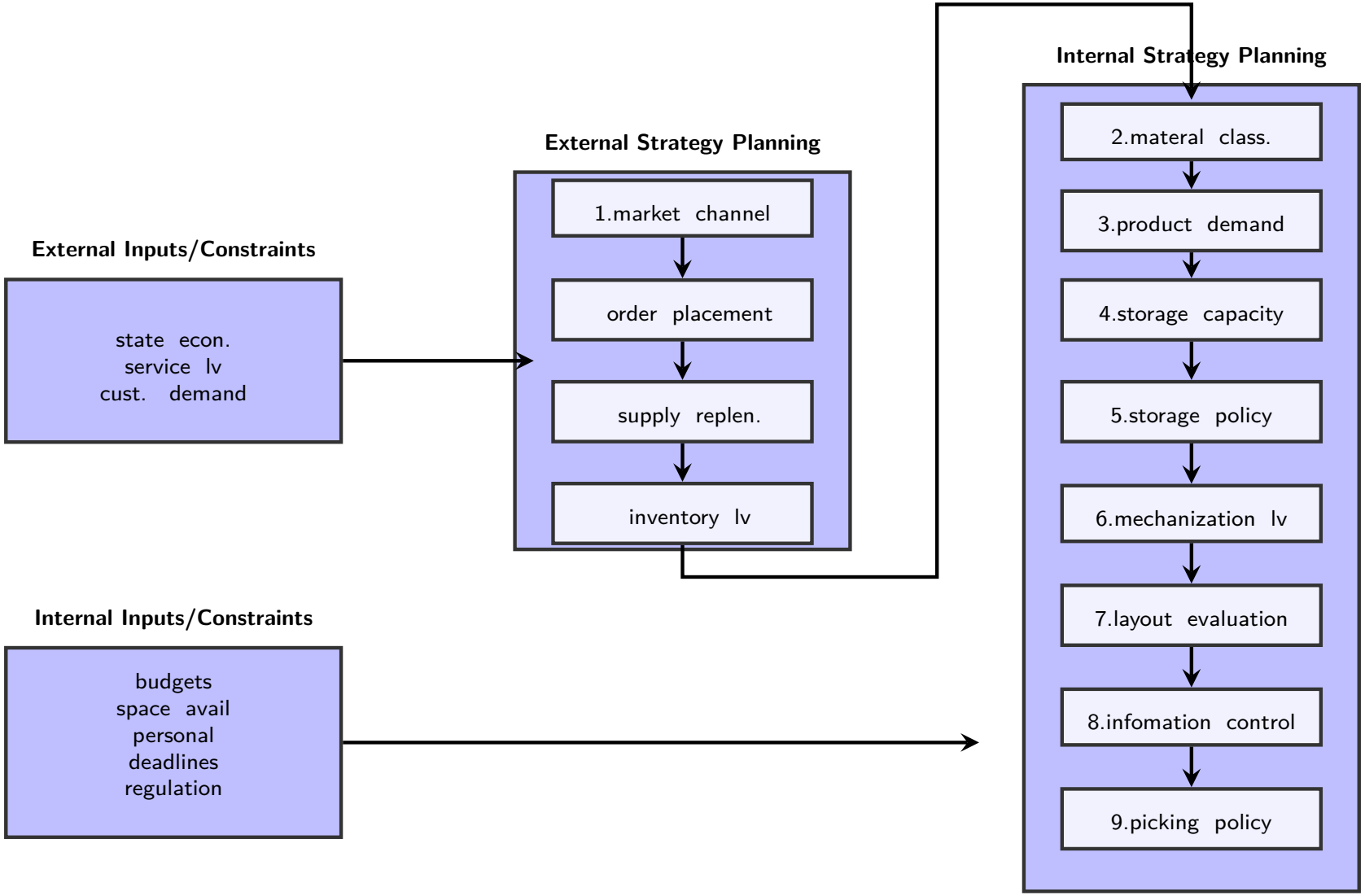
- **State of economy:** product/industry life cycle
- **Required service level:** market channel, lead time, inventory level
- **Customer demands:** pattern, relationship, throughput

Internal

- **Budgets:** loan, equipment
- **Space availability:**
- **Personal:** education, experience, wage
- **Implementation deadline:**
- **Regulation:** labor rule, environmental

source: Goetschalckx, M. & Ashayeri, J. 1989. [GA89]

Systematic Planning & Design



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Common Suggestions to Improve Picking

Reduce Lose in System

- **Avoid non-productive activity:** counting, searching, traveling, double handling
- **Simplify document & information:** minimized paper work/ eliminate conversation

Improve Information

- **Maintain stock location system:** simplify picking task
- **Achieve order accuracy:** pick confirmation (bar code), checker

Process Re-Engineering

- **Understand business:** understanding natures & exploiting patterns
- **Implement system:** execute pre-routed tour, enforce system

Problems

1. Compare similarities & differences between *zone picking* & *wave picking*
2. Explain why do a warehouse manager may interested in **bucket brigade**
3. A simple assembly line (i.e., tandem line) requires 3 workers, namely workers A, B & C. Each worker has different speed to assemble a product. If each worker assembled a product individually, workers A, B, & C would produce 12, 18, 15 units, respectively.
   - If each worker is assigned work equally, what is throughput of this line?
   - How to assigned worker to maximize throughput?
   - Explain implementation of bucket brigade in this assemble line & compute throughput?

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