Chapter 21. Order Picking Systems

21.1. Introduction

**Reasons for Order Picking**

Buffer Between Production and Demand  
Consolidation of Products into a Single Shipment  
Exploitation of Transportation Cost Differentials  
Response Time Reduction

**Order Picking Characteristics**

Most Expensive Component of Warehousing  
Increased Throughput, Storage, Response Times, and Accuracy Requirements  
50% of Picking Time is Traveling time
Order Picking Equipment Classes

Automatic
- A Frame

Picker-To-Part
- Bin Shelving, Gravity Flow Rack, Drawers
- Person-Aboard, Order Picking Truck

Part-To-Picker
- Carousel (Horizontal and Vertical)
- Miniload
Figure 21.2. Automatic Order Picking A-Frame  
(Picture courtesy of Electrocom)

Figure 21.3. Manual Order Picking from Bin Shelves (Picker-To-Part)  
(Photo Courtesy of John Bartholdi)
21.2. Order Picking in the Aisle

Introduction to Order Picking in the Aisle

Figure 21.4. Order Picking Carousel (Part-To-Picker)

Figure 21.5. Order Picking in the Aisle Example
Order Picking in the Aisle Characteristics

Person-To-Part
Walking Time Dominant
Determine Picking Sequence
Objective = Maximal Throughput
Within an Aisle and Between Aisles

Figure 21.7. Quantity LED Displays on Shelves (Pick-To-Light)
(Photo Courtesy of AutoPick)
**Picking Density**

The ratio of the number of locations to be visited for this order divided by the total number of locations in the aisle

**Order Picking in Ladder Warehouses**

**Ladder Warehouse Characteristics**

*Figure 21.8. Bin Shelving in a Ladder Arrangement*

*Figure 21.9. Ladder Warehouse Schematic*

- Set of Parallel Aisles
- All Aisles Have Equal Length
- Bottom and Top Cross Aisles
- Multiple Ladder Blocks
Ladder Warehouse Tour Types

Figure 21.10. Tour Types in a Ladder Warehouse

Traversal
Return (Top or Bottom)
Split Traversal
Split Return

Z-Pick Tour Pattern

Figure 21.11. Z-Pick Travel in an Aisle Schematic

Variable
- Shorter Travel Time
- Always Different Paths

Fixed
- Longer Travel Time
- Constant Picking Path
Optimal Z-Pick Pattern

\[ z^* = \frac{w^2 + 1}{2} \]  

(21.1)

**Aisle Order Picking Conclusions**

*In the Aisle Conclusions*

Z-Pick is 12 % Longer  
Best Return is 23 % Longer  
Use Traversal Unless  
• Picking Density > 50 %  
• Turnover Based Storage

*Between the Aisle Conclusions*

Optimal Mix of Traversal and Return  
All Traversal  
• Random Storage  
• Narrow Aisles  
• 2 % Error unless Very Sparse  
All Return  
• Strongly Turnover Based Storage

*Combined In and Between the Aisle Conclusions*

Very Low Order Densities  
• Optimal Between Aisles  
• Mixed Traversal and Return  
Very High Densities of Strong ABC  
• All Return Between Aisles  
• Bottom Return  
Intermediate Order Densities  
• All Traversal Between Aisles  
• In Wide Aisles Use Z-Pick
21.3. Clustering Order Picking Items in the Aisle to a Vehicle

Introduction

Figure 21.12. Clustering to a Vehicle Example Data

Single Stop Schematic
Figure 21.13. Clustering to a Vehicle Single Stop Schematic

**Characteristics**

Items on Both Sides of the Aisle  
Vehicle Drives on Center Line  
Walking Time versus Stopping Time  
Number, Location, and Allocation of Stops

Figure 21.14. Typical Vehicles for Clustering Items in an Aisle

Figure 21.15. Order Picking in the Aisle to a Vehicle Example
Order Picking Patterns

**Fixed versus Variable Patterns**

![Figure 21.17. Clustering to a Vehicle Quad Pattern Stops](image)

- **Fixed Pattern**
  - Pattern = All Locations for One Stop
  - Always Changing

- **Variable Pattern**
  - Shorter Picking Time
  - Always Changing

Figure 21.16. Example of Order Picking in the Aisle to a Vehicle with Double Pallet Trailer
• Constant for All Orders
• Optimal Pattern for a Density

**Comparison of Patterns**

Optimal Fixed Pattern is 13 % Longer
Quad Pattern is 48 % Longer
Clustering Conclusions

Quad Pattern Too Many Stops
Optimal Fixed Pattern Good for Constant Density
Variable Pattern Good For
  • Computer Controlled
  • Variable Density

21.4. Person-Aboard Order Picking

Introduction

Figure 21.20. Person-Aboard Example
Single Aisle

Simultaneous or sequential travel with Chebyshev or rectilinear travel time, respectively.

\[
t^C = \max \left( \frac{\Delta_x}{v_x}, \frac{\Delta_y}{v_y} \right) \tag{21.2}
\]

\[
t^R = \frac{\Delta_x}{v_x} + \frac{\Delta_y}{v_y} \tag{21.3}
\]

\[
S = \max \left( \frac{L}{v_x}, \frac{H}{v_y} \right) \tag{21.4}
\]

\[
\min \left( \frac{L}{v_x}, \frac{H}{v_y} \right) \quad b = \frac{S}{S} \tag{21.5}
\]

"Square-In-Time" are racks with a shape factor \( b \) equal to one.
Figure 21.23. TOURS Person-Aboard Example Problem
Order Picking Tours

Common Tour Types

- Out and Back (2 Strip)
- Nearest Neighbor
- Exchange Improvement
  - 2 Opt
  - 3 Opt
- Convex Hull
- Band

Figure 21.24. TOURS Random Sequence Tour Illustration
Figure 21.25. TOURS 2 Band or Out-and-Back Sequence Tour Illustration

Figure 21.26. TOURS 4 Band Sequence Tour Illustration
Figure 21.27. TOURS Local Improvement 3 Opt Tour Illustration

Figure 21.28. TOURS Lower Bound Tour Illustration
**Tour Type Comparison**

Higher Density = Harder Problem  
Squarer Rack = Harder Problem  
2 Strip has 13% longer travel time.

**Person-Aboard Conclusions**

Improvement Step is Required  
Band Heuristic Preferred (Easy, Fast, Good)

Number of Bands

- 0 < 2 Bands < 25 Items
- 25 < 4 Bands < 75 Items
- 75 < 6 Bands

Item Limits Divided by \( b \) when \( b \neq 1 \)