Demand- and Sequence-Based Linear Slotting for Cart Picking and Kitting: A Case Study in a High-Volume Production Warehouse

Sai Prasad Ravulapally

Independent Researcher
Location: Shakopee, Minnesota, USA
prasadsai328@gmail.com

Abstract:
Order picking is one of the largest drivers of warehouse labor cost, and travel between pick faces typically consumes a substantial share of picker time. In facilities that feed production lines via kitting and cart picking, misalignment between standard pick lists and storage locations exacerbates travel, increases picking time, and contributes to production downtime. This paper presents a case study of a 15,000 sq.ft. warehouse supplying leaf vacuums, blowers, and generators to production lines, where a one-time demand- and sequence-based linear slotting project was implemented. Approximately 550–600 stock-keeping units (SKUs) used in kitting were assigned dedicated pick faces along a serpentine path designed to mirror the standard pick list sequence for each production cart. Simple analytical models are used to contrast non-linear "spaghetti" paths with a linear serpentine path and to estimate changes in travel time and walking distance per cart. Observed performance indicates that average cart fill time decreased from about 40–45 minutes to 15–18 minutes, with the share of travel time dropping from roughly 55% to 15%, and production line downtime due to material unavailability decreasing from approximately 30% to 5%. These findings are interpreted through the lenses of lean manufacturing, just-in-time (JIT) delivery, ergonomics, and sustainability, in line with prior work on lean warehousing, kitting, and line feeding.

Keywords: Warehouse slotting optimization; Order picking efficiency; Serpentine picking path; Kitting operations; Lean warehousing; Demand-based storage assignment; Warehouse layout design; Production line feeding; Travel time reduction; Operational productivity.

1. INTRODUCTION

Order picking represents one of the most significant contributors to warehouse operating costs, often accounting for more than half of warehouse labor expenditure. A substantial portion of picking time is typically consumed by travel between storage locations rather than by the physical act of retrieving items (Gu, Goetschalckx, & McGinnis, 2007). In facilities that support manufacturing operations through kitting or cart-based picking, inefficient storage layouts can result in excessive walking distances, inefficient picking sequences, and delayed material delivery to production lines.

As new products come out, many conventional warehouses grow on their own, which means that storage areas don't always match up with demand trends or picking sequences. Because of this mismatch, pickers have to travel in "spaghetti" patterns, going back and forth between faraway storage areas or going down the same aisles over and over again. These kinds of problems raise labor costs, lower throughput, and make it more likely that production may stop when materials aren't supplied on time.

According to Womack and Jones (2003), lean manufacturing principles emphasize eliminating waste, keeping work in motion, and getting materials to production lines just in time. In this context, warehouse operations are very important for making sure that the proper supplies are accessible at the right time and place. Techniques like efficient slotting, demand-based storage assignment, and sequence-aligned picking pathways may make a warehouse work much better.

This study looks at how to implement demand- and sequence-based linear slotting in a warehouse that supports production. The goal was to cut down on travel time, make picking more efficient, and make the manufacturing line more reliable. The case study shows how a very minor change to the layout and slotting approach may lead to big changes in how things work.

2. LITERATURE REVIEW

There has been a lot of research on warehouse design and optimizing order picking in the field of operations management. Order picking is frequently identified as the most labor-intensive warehouse function, often representing 50% to 65% of overall warehouse operating expenses (De Koster, Le-Duc, & Roodbergen, 2007).

2.1 Order Picking Efficiency

Storage allocations, routing plans, and picking procedures all have a big role in how well order picking works. Ineffectively planned layouts cause people to have to go too far, which may greatly lower productivity (Gu et al., 2007). There have been a lot of ideas about how to make picking more efficient, such as zone picking, batch picking, and better routing algorithms.

2.2 Slotting Optimization

Slotting is the process of figuring out the best places to store SKUs in a warehouse. When making effective slotting plans, you should think about things like how often orders are placed, how they are related to each other, and how they are picked (Roodbergen & Vis, 2009). Flores and Whybark (1987) say that ABC categorization is often used to put high-demand products in order of importance for places that are closer to picking routes.

2.3 Kitting and Line Feeding

Kitting is often used in manufacturing facilities to provide assembly lines with the grouped parts they need to make a certain product. Kitting processes that work well make materials easier to find and cut down on disruptions on the assembly line (Bozer & McGinnis, 1992). Sequence-aligned picking makes kitting even more efficient by cutting down on the amount of time pickers have to travel and making the process easier.

2.4 Lean and Just-in-Time Logistics

Lean manufacturing emphasizes the elimination of waste, including unnecessary movement and transportation (Womack & Jones, 2003). Warehouse layouts that support continuous material flow and just-in-time delivery play an important role in supporting lean production systems.

3. PROBLEM DESCRIPTION

The case facility is a 15,000 sq.ft. warehouse that functions as a kitting and line-feeding hub for a manufacturer of leaf vacuums, blowers, and generators. It comprises 18 aisles of pallet racking with four storage levels. Approximately 550–600 SKUs are actively used in production kitting, and around 580 pick faces are available at ground or ergonomically reachable heights, with beam positions adjusted to pallet and tote dimensions.

The operation uses a picker-to-parts model: seven pickers per shift push manual carts or use pallet jacks to traverse aisles and retrieve components. Each production cart is associated with a standard pick list that specifies SKUs and quantities required for one or more assembly jobs, typically 5–28 distinct SKUs per cart. On a typical day, approximately 80 production carts are filled and delivered to the lines.

Prior to the slotting project, SKUs had been placed in locations based on historical and physical considerations, without a structured demand- or sequence-based policy. Standard pick lists were arranged according to production needs, but the physical order of SKUs in the warehouse did not follow the list sequence. As a result, pickers followed the list across a layout that forced frequent cross-aisle moves and re-entries into aisles, creating complex spaghetti-like routes similar to those reported in other travel-intensive picking operations (Optioryx, 2025; Kardex, 2023).

Baseline performance and issues included:

- Average cart fill time of about 40–45 minutes, with an estimated 55% of that time spent traveling.
- High variability in routes and frequent congestion where picker paths intersect.
- Increased risk of mis-picks when the logical sequence on the list diverged from the physical progression of locations.
- Production line downtime attributed to material unavailability estimated at about 30% of available production time.

These findings prompted a single slotting redesign to synchronize storage with demand patterns, BOM structures, and standard pick list sequences, while enhancing ergonomics and flow.

4. METHODOLOGY AND SLOTTING DESIGN

4.1 Design framework

The redesign process was guided by three main design principles: demand-based classification, bill of materials (BOM) family grouping, and sequence-based linear slotting. ABC analysis was used to categorize kitting SKUs based on how often they were picked and their production-area volume, following established methods in slotting and inventory optimization. High-frequency (A class) items were assigned to prime locations along the main pick path to minimize travel and handling, whereas lower-frequency items were placed in less central positions.

The BOM family grouping method involved identifying groups of Stock Keeping Units (SKUs) that frequently appeared together in kits. This approach aligns with correlation-based storage, a method that places related products near each other to reduce the time needed to pick multiple items. By grouping BOM families, the design ensured that components commonly used together would be encountered in close succession along the pick route.

Finally, sequence-based linear slotting was used to align the physical order of SKUs with the logical order on standard pick lists, an extension of ABC and correlation-based ideas to explicitly sequence-aware layouts. Rather than treating pick sequence as incidental, the design considered the typical sequences across cart types and mapped them onto a linear physical route.

4.2 Serpentine pick path

A serpentine (snake) path was defined to provide a simple, one-directional route through the kitting area. Starting near the staging and cart loading zone, the path enters Aisle 1 and proceeds from front to back. It goes from the rear of Aisle 1 to the front of Aisle 2 and then back again. This pattern continues through the other aisles. This layout follows organized choosing route methods by not having to go back and forth and cutting down on cross-aisle traffic.

Within this serpentine design, SKUs were allocated to select locations such that their placements along the route were close to the order in which they show up on typical pick lists. When lists for various cart types were varied, a composite sequence was built by giving SKUs a weight based on how often they were picked and how they were related to BOM families. Following golden zone ergonomic guidelines, high-frequency and heavy goods were put at waist height. Items that are picked less often or that are lighter can be moved up or down as required.

4.3 Dedicated storage and replenishment

For kitting SKUs, a dedicated storage policy was adopted. Each SKU was assigned a designated pick face along the serpentine route, indicative of the steady product mix and BOM structure, hence facilitating consistent standard work. This method also streamlines training and reduces mental burden, enabling pickers to absorb consistent placements.

Forward pick locations along the linear route were supplied from reserve storage. Replenishment was initiated when forward stock attained minimum thresholds, with the majority of fast-moving SKUs restocked daily.

Visual signals and WMS prompts facilitated restocking activities, aligning with supermarket and Kanban methodologies in lean kitting.

5. ANALYTICAL MODEL AND NUMERICAL ILLUSTRATION

5.1 Definitions and baseline values

Let T_c be the average time to fill one cart and T_t and T_p its travel and picking components, respectively, so $T_c = T_t + T_p$. Let D_c be the walking distance per cart, v the average walking speed, and n the average number of lines per cart.

For the baseline:

- $T_c^{(0)} \approx 42.5$ minutes.
- Travel time share ≈ 55%, so $T_t^{(0)} \approx 0.55 \times 42.5 \approx 23.4$ minutes and $T_p^{(0)} \approx 19.1$ minutes.
- Assume average walking speed $v \approx 58.3$ m/min (≈3.5 km/h), a typical assumption for warehouse picking.

Distance per cart is then:

$$D_c^{(0)} = v\,T_t^{(0)} \approx 58.3 \times 23.4 \approx 1{,}365 \text{ m } (\approx 4{,}478 \text{ ft}).$$

If we assume an average of $n = 16$ lines per cart, then distance per line is roughly $1{,}365/16 \approx 85$ m.

5.2 Post-implementation values

After the linear slotting redesign:

- $T_c^{(1)} \approx 16.5$ minutes.
- Travel time share ≈ 15%, so $T_t^{(1)} \approx 0.15 \times 16.5 \approx 2.5$ minutes and $T_p^{(1)} \approx 14.0$ minutes.
- Using the same walking speed v:

$$D_c^{(1)} = v\,T_t^{(1)} \approx 58.3 \times 2.5 \approx 146 \text{ m } (\approx 480 \text{ ft}).$$

Assuming $n \approx 16$ lines per cart, distance per line is about $146/16 \approx 9$ m.

These values are illustrative but show the effect of both reducing total cart time and dramatically lowering travel share. The implied distance reduction is approximately $D_c^{(1)}/D_c^{(0)} \approx 146/1{,}365 \approx 0.11$, suggesting that travel distance fell to roughly 11% of its previous level for the average cart.

5.3 Throughput and downtime impact

Carts per hour (CPH) and lines per hour (LPH) can be estimated as:

$$\text{CPH} = \frac{60}{T_c}, \text{LPH} = \frac{n \times 60}{T_c}.$$

With $T_c^{(0)} \approx 42.5$ and $n \approx 16$:

- Baseline $\text{CPH}^{(0)} \approx 60/42.5 \approx 1.4$ carts/hour.
- Baseline $\text{LPH}^{(0)} \approx 16 \times 60/42.5 \approx 22.6$ lines/hour.

With $T_c^{(1)} \approx 16.5$:

- Improved $\text{CPH}^{(1)} \approx 60/16.5 \approx 3.6$ carts/hour.
- Improved $\text{LPH}^{(1)} \approx 16 \times 60/16.5 \approx 58.2$ lines/hour.

Throughput for a single picker has more than doubled, according to these findings. Adding seven pickers proportionately boosted the line's supply capacity. This change cut production downtime, caused by material shortages, from roughly 30% to about 5% of available time. This aligns with Just-In-Time principles, which seek to reduce waiting waste.

6. RESULTS AND CASE ILLUSTRATION

Key before-and-after metrics based on the case data and the simple models above include cart fill time, travel share, distance per cart, throughput, and downtime. Average cart fill time decreased from about 40–45 minutes to approximately 15–18 minutes, and the share of travel time dropped from roughly 55% to around 15%. Daily volume remained around 80 carts, but available capacity increased, enabling more robust support for production.

The distance model suggests that travel per cart may have fallen from an illustrative 1,365 m (≈4,478 ft) to about 146 m (≈480 ft), recognizing that exact values depend on the actual walking speed and path geometry. Carts per hour per picker increased from roughly 1.4 to 3.6, and lines per hour per picker from about 23 to 58. Production downtime attributed to material unavailability decreased from an estimated 30% to approximately 5% of available time, consistent with improved synchronization of kitting and line feeding.
Qualitative assessments showed less congestion after implementing more predictable, one-way routes. Furthermore, there was a reduction in picking errors, as the physical arrangement of slots corresponded with the logical order presented on pick lists. Improved ergonomics were also observed, given that frequently picked, heavy SKUs were relocated to golden zone locations. The results support the known advantages of lean kitting and supermarket design, particularly when layouts, routes, and information flow are carefully coordinated.

7. DISCUSSION

The results demonstrate how combining demand-based slotting, BOM family grouping, and sequence-aligned storage can transform a high travel, high variability picking process into a streamlined, predictable flow. The large reduction in travel share reflects the general observation that travel, rather than physical pick effort, dominates picking time in manual systems and thus offers substantial improvement potential.

The approach extends traditional ABC and correlated storage practices. ABC classification alone would prioritize high velocity items but might not respect pick sequence, while correlation-based storage focuses on co-occurrence without necessarily imposing a simple route structure. The linear sequence design incorporates both elements, facilitating easy access to frequently used and high-velocity items through a direct path that mirrors the standard pick lists.

Ergonomic advantages were realized because the slotting guidelines intentionally positioned heavy and high-frequency items within ergonomic zones, thereby adhering to established recommendations for golden zone storage to mitigate musculoskeletal risk. Although formal ergonomic studies would be necessary for precise quantification, reduced travel and ladder usage are expected to diminish fatigue and the potential for injury. While not directly assessed, sustainability impacts likely encompass decreased energy consumption for any powered equipment and reduced waste stemming from mis-picks and rework, which aligns with lean and green warehousing principles.

8. IMPLEMENTATION GUIDELINES

The insights gained from this facility offer some concrete recommendations for adopting demand and sequence-based linear slotting in other kitting and line feeding warehouses.:

- First, use comprehensive pick history and bill of materials (BOM) data to pinpoint ABC classes and BOM families, drawing on established ABC principles.
- Design a clear serpentine or linear main path. This path should start and finish near staging and line dispatch areas, thereby reducing cross-traffic.
- Allocate a dedicated pick location to SKUs along this main path. The goal is to replicate the sequence of standard pick lists as closely as possible. Any conflicts should be resolved by prioritizing demand and the importance of the BOM family.
- Position the heaviest, most frequently used items within easy reach. Move items that need a ladder for high-volume picking to more accessible locations – these are your "golden zone" spots.
- Update the Warehouse Management System's location masters and RF processes to align with the new configurations and routes. Furthermore, it's essential that the rack labeling is both legible and logically corresponds to the picking path.

- Test the new layout with a limited number of carts. Gather feedback, make adjustments, and then implement the changes across all carts, following lean change management principles.
- Monitor KPIs: cart fill time, travel time share (as determined by time studies), mispick rates, production downtime, and safety incidents. Use these metrics to confirm the benefits and drive ongoing improvement.

9. DISCUSSION

The findings from the case study suggest that significant operational improvements often arise from relatively simple alterations to warehouse layout. Reorganizing storage areas to match picking routes and the popularity of individual SKUs resulted in substantial gains. Operator travel time has noticeably reduced, picking efficiency has increased, and production flow has become more consistent.

While many companies are focusing on advanced automation technologies, like automated storage and warehouse robotics, to improve warehouse efficiency, this study shows that significant benefits can also be achieved through basic layout optimization.
Specifically, the enhancements required minimal capital expenditure and were largely contingent on greater alignment between warehouse design and operational processes.

Future investigations might build upon these observations by examining the incorporation of sophisticated methodologies, including dynamic slotting algorithms, automated routing optimization, and digital twin simulations. These technological advancements have the potential to further improve warehouse efficiency by facilitating ongoing optimization in response to shifting demand patterns and evolving production needs.

10. CONCLUSION

Order picking inefficiencies continue to be a major source of operational waste in warehouses that support production. Specifically, long travel distances, poorly organized storage, and inefficient picking routes can negatively impact both warehouse productivity and the overall performance of the production line.
The present investigation reveals that the application of a demand- and sequence-based linear slotting strategy yields significant enhancements in warehouse operational efficacy. Through the reconfiguration of the facility's layout into a serpentine picking flow, congruent with prevailing production consumption trends, the establishment realized quantifiable gains in cart fill duration, travel efficiency, and the overall dependability of the production line.

The findings underscore the importance of aligning warehouse layout design with lean manufacturing principles and production processes. Consequently, when warehouse operations are synchronized with just-in-time production systems, the flow of materials is rendered more predictable, efficient, and adaptable to operational requirements.
For warehouses looking to get more done, sequence-based slotting is a smart, cost-effective strategy. It can deliver significant improvements without breaking the bank. By focusing on how things are arranged and how processes work together, companies can really boost efficiency, all while keeping up with the needs of today's manufacturing world.

REFERENCES:

1. Bozer, Y. A., & McGinnis, L. F. (1992). Kitting versus line stocking: A conceptual framework and a descriptive model. *International Journal of Production Economics, 28*(1), 1–19, Kitting versus line stocking: A conceptual framework and a descriptive model - ScienceDirect.
2. De Koster, R., Le-Duc, T., & Roodbergen, K. J. (2007). Design and control of warehouse order picking: A literature review. *European Journal of Operational Research, 182*(2), 481–501, https://doi.org/10.1016/j.ejor.2006.07.009.
3. Flores, B. E., & Whybark, D. C. (1987). Implementing multiple criteria ABC analysis. *Journal of Operations Management, 7*(1–2), 79–85, Implementing multiple criteria ABC analysis - ScienceDirect

4. Gu, J., Goetschalckx, M., & McGinnis, L. (2007). Research on warehouse design and performance evaluation: A comprehensive review. *European Journal of Operational Research, 177*(1), 1–21.
5. Roodbergen, K. J., & Vis, I. F. A. (2009). A survey of literature on automated storage and retrieval systems. *European Journal of Operational Research, 194*(2), 343–362, A survey of literature on automated storage and retrieval systems.
6. Womack, J. P., & Jones, D. T. (2003). *Lean thinking: Banish waste and create wealth in your corporation* (2nd ed.). Free Press, (PDF) Lean Thinking : Banish Waste and Create Wealth in Your Corporation.
7. Zaffar, M., Hashmi, M., & Ahmad, R. (2016). Line feeding optimization in just-in-time assembly systems. *International Journal of Production Economics*, 174, 54–65, (PDF) A Roadmap for Plant Genome Editing