Perspectives on Material Handling Practice

Papers in the Perspectives series have appeared in conference proceedings of the Material Handling Institute between 1992 and the present. As such they provide a point of reference as to how the industry is changing as well as insight into accepted practice during this period. In many cases the authors credited have either changed jobs or are no longer in the industry. Some companies as well have been the subject of mergers or reorganization with a new corporate identity.

HORIZONTAL STORAGE AND RETRIEVAL CAROUSELS CONCEPTS AND APPLICATIONS

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Abstract:

Since their introduction 30 years ago, horizontal carousels have consistently been improved and adapted to a greater variety of roles in material handling systems. Since the beginning, the basic concept of motor-driven mobile shelving has consistently saved warehouse operations the time and labor retrieval searching.

Key benefits in operational efficiency, inventory accuracy, and system throughput have attended each integration of carousels and complementary technology. Carousels are deployed in ergonomic, multi-machine work units that promote a continuous flow of storage media. They are controlled by specialized computer software that coordinates a variety of operator-assisting equipment.

The adaptability of the horizontal carousels to a variety of distribution center roles has brought about sophistication in design and application techniques. System designers must routinely account for the many factors that influence system rate. Most important is weighing the tradeoffs inherent in the choice of overall carousel system layout.

In recent years, carousel applications have moved beyond their traditional role as storage locations for products to staging locations for order accumulation. These "Put" systems let distributors perform rapid mass dispersal of products across the breadth of an organization's outlets. They can

also facilitate precisely-focused point-of-sale replenishment and shipping-schedule-complaint order consolidation.

INTRODUCTION

White first designed horizontal carousels for industrial applications in the early 1960's. These were top-drive machines adapted from the garment conveyor systems White developed in the early 1950's. By the early 1970's bottom-drive machines were developed to handle heavier loads and more demanding duty cycles. During the 1980's the tremendous advances in digital electronics brought about an integration of carousel systems with computer technology—Personal Computers as the heart of the carousel workstation and software that provides complete control of all material handling and inventory.

Today, carousels play a key role in complex warehousing and distribution systems. They are often tightly integrated with conveyer systems. Carousels can be used as primary storage, process buffers, or for sortation. They can be stacked vertically in multiple-tier arrangements and deployed in severe environment. They can work with human operators or fully automatic inserter/extractor machines.

THE MACHINE

The horizontal carousel is a moving assembly of wireform shelves. Electric motors drive stacks of these shelves, called *bins*, around an oval track.

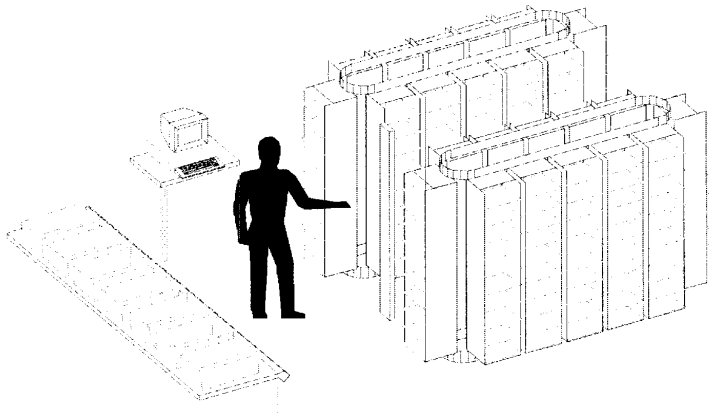
Typically controlled by computer software, the carousel spins to present a requested bin to the operator. When picking from stock, the carousel brings the goods to the operator. When putting new product away, it automatically presents the correct location to stock. The carousel *eliminates the walking and searching* that characterized traditional warehouse operations.

Carousel bins can vary in height and contain a variable number of equal-width shelves. The shelves can be subdivided into smaller cellular compartments. Bins, shelves, and cells are all numbered locations known by the controlling software.

Carousels come in two basic types—*standard* and *Twin-bin*. The standard type spins to present a single requested bin. By contrast, the shelves of the Twin-bin type carousel are arranged in pairs, accessible from their open sides. As a Twin-bin unit spins to a stop, it presents the shelf openings of two-bins, doubling the number of shelf presentations.

THE POD

Horizontal carousels are especially efficient when deployed in ergonomic, multi-machine groups called *pods.*



The pod enhances system throughput by allowing the operator to work with several machines simultaneously. All the equipment in the pd is under the control of software, resident on a computer workstation. Even as the operator is handling product at one carousel, the software is positioning another machine for the next item. Product thus moves in a continuous flow.

Conveyor integration

Conveyors are frequently integrated with carousel systems to move pick boxes for pod to pod or away form a pod to a pack area. Conveyors provide a smooth flow of materials and ensure overall warehouse efficiency.

Using conveyors, product often travels through the system in standard sized plastic containers called *totes.* Totes often have permanently affixes bar code labels, or license plates, that identifies the totes with the system. Laser scanners read a tote's bar code license plate and, recognizing its unique identity code, route the tote through the conveyor system accordingly. The license plates also allow carousel control software to electronically *associate* a tote with a specific work order. Overhead conveyors are often used to bring empty totes to the pod.

The Universal Pod

The universal pod integrates alternative storage devices such as flow racks into the standard carousel work-group. The flow rack is treated just like another carousel machine. While it doesn't spin to make presentations, its stock is still controlled by the carousel software.

Lines picked from the flow rack are part of the same batched work orders that drive the pod's carousels. Light-directing equipment, controlled by the carousels software, guides the operator to the requested flow rack items.

Systems designers routinely analyze the material handled to classify it for the appropriate storage equipment. They examine and classify items by the space they occupy and the speed with which

they move through the system. Accordingly, the fastest movers get placed in flow rack, the slowest movers and bulky items are assigned locations on static shelving, and appropriate stock gets placed in carousels.

The universal pod brings the high-velocity flow rack inventory in to the pod, allowing operator to pick from the flow rack while the carousels are spinning to position. If the number or volume of carousel SKUs is large relative to order size, combining flow rack and carousel media into a universal pod often increases system throughput.

SOFTWARE CONTROL

The advances in computer technology have been the single greatest reason for the accelerated use of horizontal carousels. Computer modeling of the warehouse, warehouse zones, SKU profiles, throughput modeling, and use for data transmission and collection providing a near paperless warehouse are all elements which can provide not only a quality horizontal carousel solution, indeed a complete warehouse plan. Computers are used for local carousel control and information display. Two aspects of software control in particular—batch processing and light-directing equipment—promote high throughput.

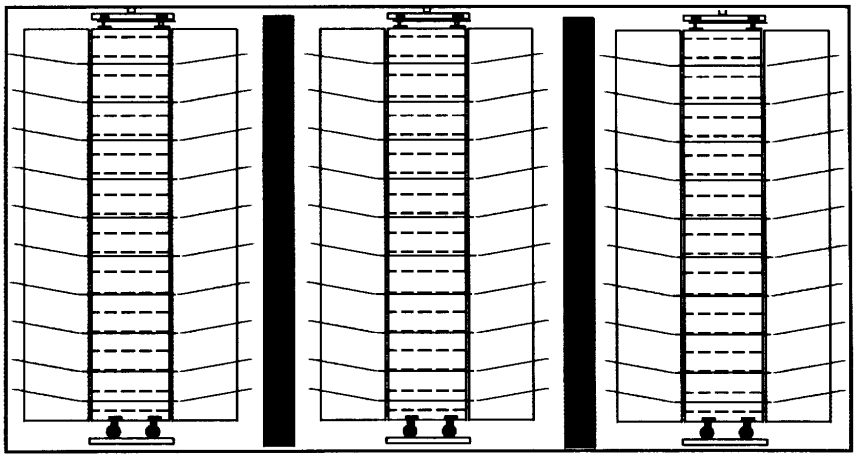
Batch Processing

Control software increases system rate through *batch* processing. Using keyboard entry or bar code scanners, operators associate individual totes with specific work orders. As the associations are made, the software defines the order group as a batch. The software does not direct processing in an order-by-order sequence. Rather, it pools all the lines (picks) from all the orders in the batch and sorts them to devise the most efficient picking sequence. For any given storage location, the pieces for all of the orders in the batch are picked at one stop of the carousel. The machine thus spend the least amount of time moving and present the entire batch in a single rotation.

Light-directing devices

Lightree

Carousel software controls two different *light-directing* devices that guides the pod operator through each transaction. *Lightree* devices are vertical displays that stand adjacent to carousels. For the line currently in process, Lightrees indicate the carousel shelf location where the operator picks the product. They also indicate the quantity of product requested.



Sortbar

Sortbar devices are horizontal displays used when picking into batches of more than one container/order. Sortbars line up with the order totes or cartons. The cartons occupy defined locations on conveyer accumulation zones or work surfaces. For the line currently in process, Sortbars indicate the order carton into which the operator places product. The also indicate the quantity of product requested for each order requesting that product.

Light bars

Horizontal light-directing displays called *Lightbars* are used when flow rack is integrated into the pick pod. Typically, the Lightbar is attached to the overhead portion of the flow rack and indicates the lave and quantity to pick from.

Task complete buttons

Task complete buttons are mounted on the light directing devices. The buttons allow operators to confirm transactions without having to used the computer keyboard.

FACTORS THAT AFFECT PICK RATES

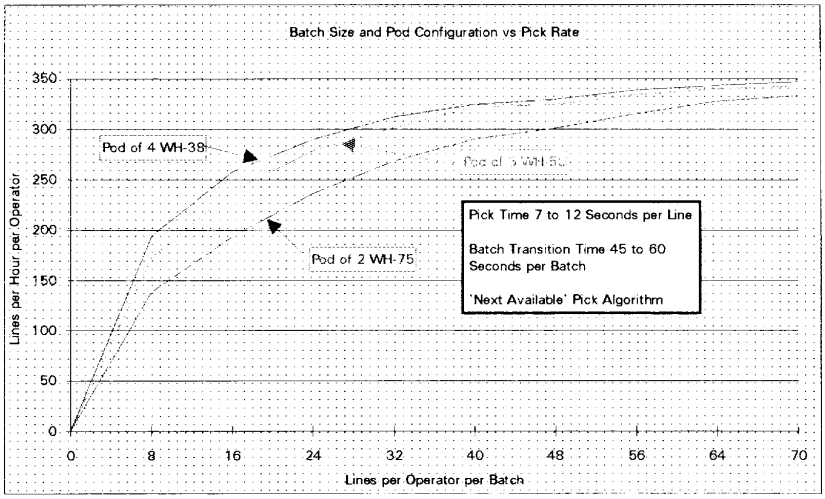
Operator Speed

Order picking can be slowed by:

- Bulky items - especially if there is a large number of single pieces per line
- Small items – particularly if processing includes additional handling such as weighing, counting, bagging, and tagging.
- Many small cells on a shelf making it difficult to find the correct part.

Batch Size

Batch size has profound affect of pick rate. High pick rates (> 300 lines per hour) cannot be achieved with small batches. The chart below relates pick rate to batch size and pod configuration:



Batch Transition Time

The transition time—when batches of order containers travel together from pod to pod—is an often overlooked design factor. To achieve fast transitions:

- Accumulate containers in a staging area.
- Minimize the distance between the staging area and the picking zone.
- Prevent bar code misreads when releasing totes from the staging area.
- In continuous batching scenarios, keep operators picking while containers are reindexing.

Pod Configuration

Pick rate is affected by both the number of carousels in the pod and the length of the machines. For the same storage volume, a pod of four shorter carousels produces a faster rate than two longer ones. This is especially important with low line counts (i.e. small orders). Since long carousels are inherently slower, for fast pick rates, don't slow moving or large items in carousels.

Pick Algorithm

There are three algorithm typically used to control picking:

- *Round Robin*—The simplest pattern but also the slowest.
- *Next Available*—Works similar to Round Robin, but will pick from another carousel if the "next" carousel is not positioned. This algorithm reduces time spent waiting for carousels to positions.
- *Next Available with Pick Down*—Work similar to Next Available, but also gives preference to the carousel with the most picks remaining in the batch. This algorithm prevents all picks at the end of a batch from being from a single carousel.

SKU Selection

Carousels work best with the middle range of SKU velocities. Therefore, the mix of SKUs needs to balance *carousel length* with the *amount of work.*

Too many SKUs stored will require longer carousels and thereby increase carousel travel time. Longer carousels and their increased travel time likewise result from storing too many SKUs will need to be replenished frequently. Replenishment activity must be planned carefully.

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While the ideal carousel SKU is small in size, but a fast mover, if too many SKUs with rapid turnover are stored, the SKUs will need to be replenished frequently. Replenishment activity must be planned carefully.

SYSTEM LAYOUTS

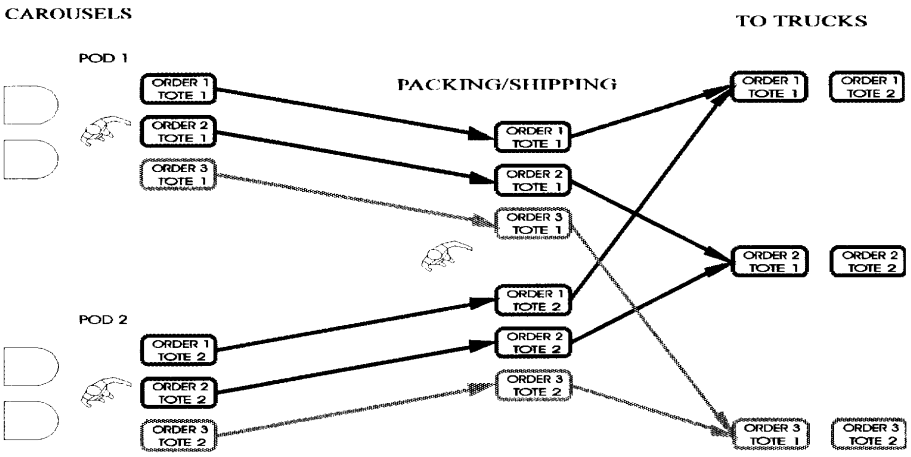
There are four basic types of carousel system layouts:

1. *Parallel picking*
2. *Pure pick and pass*
3. *Dynamic pick and pass*
4. *Dynamic pick and pass with continuous batching*

Each scheme has its own distinct advantages and typical application.

Parallel picking

Parallel picking allows all of the operators to work *in parallel*—on the same order at the same time—picking into different containers.



PARALLEL PICKING

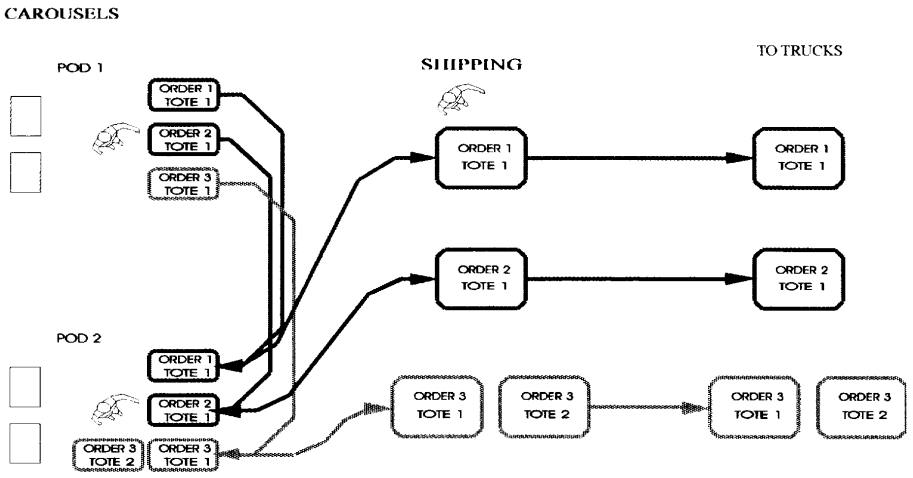
Advantage—Simplicity. For conveyor routing, only a simple takeaway to the sorter or shipping dock is required.

Disadvantage—May require consolidating the components of smaller orders elsewhere in the facility.

Typical application—Used when another sorting system is available to consolidate the contributions from various carousel pods. Also used where large orders are common or where each pod's contribution is shipped separately, such a large retailers.

Pure pick and pass

When the first operator completes all of his picks for a batch, all of the totes or cartons in that batch are passed on to be processed by the next operator. Sometimes carts transfer totes between operators, but more typically conveyors are used.

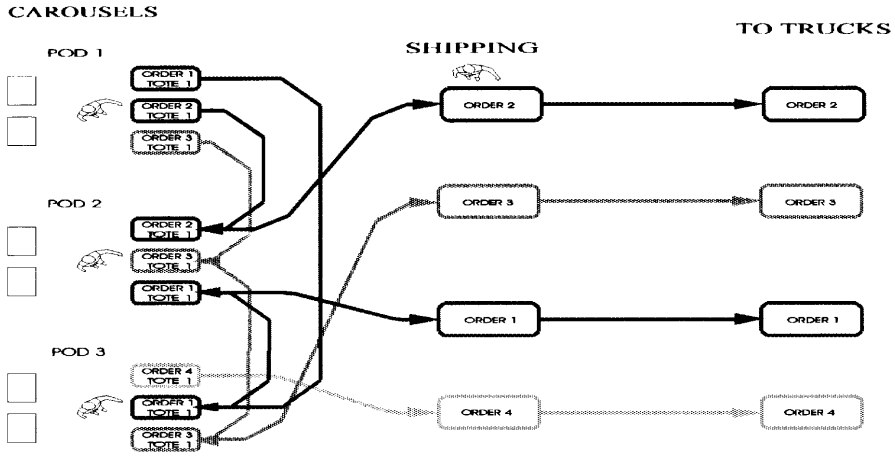


PICK AND PASS

Advantage – each tote or carton is full or contains a full order, minimizing the shipment of "air" and eliminating the need for downstream consolidation.

Disadvantage – Inefficient handling of small orders. Each operator must process a batch with every order, even if his pod makes no contribution to that order. This has the effect of creating batches with fewer lines. When the average number of lines in a batch drops too low, picking efficiency suffers as operators must wait for carousels.

Typical application – Pure pick and pass systems are used with moderate to large orders, relatively small items, and relatively few pods in the system. If a system has a ratio of lines per order greater than about three, it's a good candidate for a pure pick and pass layout.



DYNAMIC PICK AND PASS

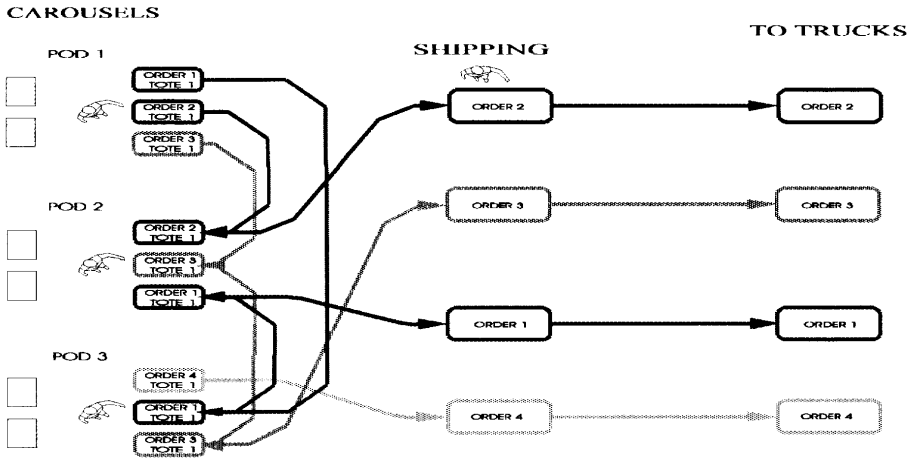
Dynamic Pick and Pass

Cartons pass from operator to operator on a conveyor system. However, the conveyor system allows each carton to visit only those pods which contribute to that order. White developed dynamic pick and pass system while still minimizing consolidation and the shipment of air.

Advantage – Keeps the average batch size higher, allowing the efficient picking.

Disadvantage – Due to the truly dynamic nature of the system, it can be difficult to predict the order completion time, as the carousel processing time can vary widely by order. This can be an important consideration if there are truck schedules or similar or constraints must be met, or if the carousel totes must be consolidated with the bulk and static rack components of the order.

Typical application – Used where the daily activity is high, but the average order size is small. Also used in systems that contain an extraordinarily large number of SKUs.



PICK AND PASS WITH CONTINUOUS BATCHING

Dynamic pick and pass with continuous batching

In systems where the scheduling of outgoing work is important, but the advantages of a dynamic pick and pass system are desired, *continuous batching* can be applied. In this scenario, cartons leave a pod to go to the next pod *as soon as the last line for that carton is picked*, (rather than when the batch is completed). As a carton leaves a pod, the other carton index down to fill the location and another carton is added to the batch. Since cartons are added to the batch one at a time, the pre-patch queue is smaller (typically 2 cartons).

Advantages – Cartons spend less time in each pod since they leave immediately on completion. Similarly, cartons spend less time in queue since queue are shorter. This allows for a more predictable processing time for an order as it depends less upon the makeup of other orders. A secondary advantage is that that continuous batching minimizes carousel delay time for the operator, since the batch always has multiple picks. (i.e. the batch never "leans out")

Disadvantages – In some cases throughput can be slowed since the time to push away eight totes individually can be longer that the time to push out all eight totes at the end of a batch.

Typical application – Used where daily activity is high, the average order size is *not* small and order scheduling is important (e.g. truck routes, waves, etc.).

PUT SYSTEMS

Until recently, horizontal carousels were only used as a method of storing relatively small items and retrieving them efficiently. In the current business climate, many companies are finding that service and product availability are good ways to differentiate themselves from their competitors. For retail distribution, ways to achieve these goals might include:

1. Custom shipment to retailers:
- Point-of-sale replenishment, to maximize availability of all items
- Stocking orders tailored to demographics

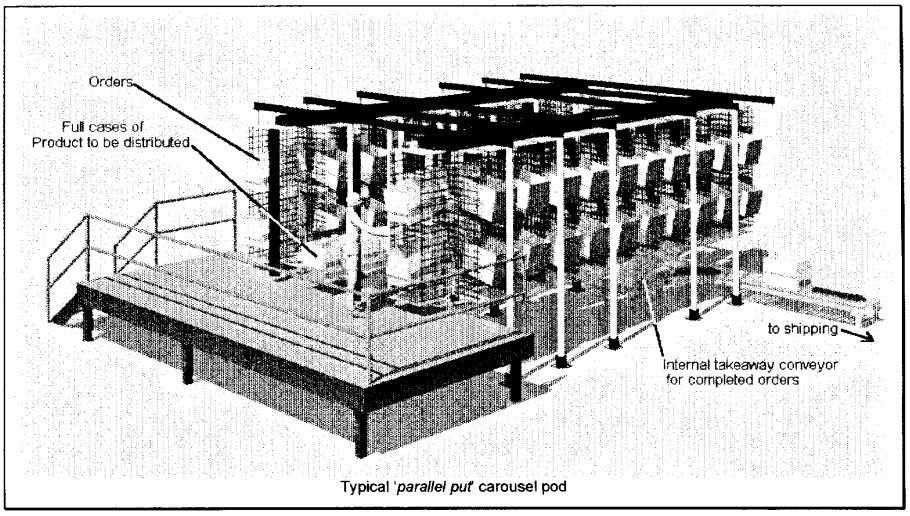
2. Fast order turnaround
3. Low distribution cost

Traditional order picking systems may be able to achieve the custom shipments, and possibly even fast turnaround. However picking systems have high labor requirements, and may need to overship product to ensure full stocking at the retailer. The cost of the necessary storage volume and the carrying cost of the inventory may also contribute to the cost of this type of solution. Thus, they are not typically low cost solutions.

In some industries, the first two goals have been achieved using systems built around a tilt tray sorter. The sorter distributes individual items to lanes which are dedicated to specific orders. Tilt trays, however, tend to be significantly more expensive, require more personnel to operate. They often must operate in smaller waves, resulting in increased residual handling. Because the sorters handle individual items, rather than full cases, double handling of the product is required.

A horizontal carousel put system can often answer all three goals quite well. The product can be picked efficiently in bulk quantities for delivery to the horizontal carousel 'put pod'. At the put pod, the carousel brings orders to the product, rather than the other way around. Many orders can be active simultaneously in the relatively small area occupied by the carousels.

In many applications, the manpower required is cut by over half, while using less expensive equipment. We have also integrated hybrid systems which combine pick and put systems to pick exact quantities efficiently.



Typical '*parallel put*' carousel pod

Push systems

The simplest type of put system is a *'push'* system, also known as a '*store dump'* or '*stocking'* system. In such a system, corporate buyers at a central office decide what product to ship to the stores – the stores do not order the product. Typically the shipments are based on predicted rather than actual demand. This explains the name – the central office pushes product to the stores, whose responsibility is to sell what was sent to them.

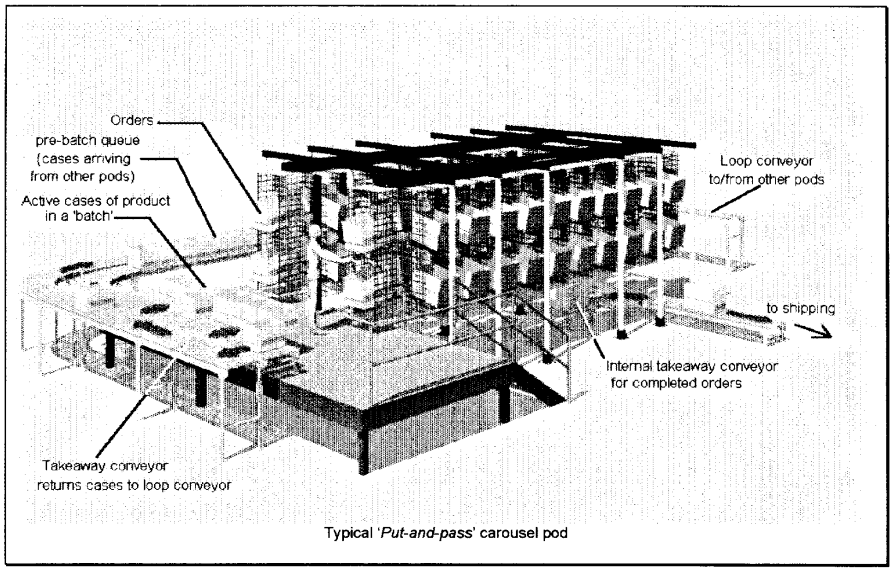
Push systems are most common in apparel and other fashion and seasonal retail industries, particularly specialty retailers. Quite often these are '*cross-dock'* systems where the product is received from the manufacturer and immediately distributed to the stores without being stored at the distribution center. Thus the SKUs processed may change completely from day to day.

Push systems are typically configured in a *' parallel put'* configuration, where each master carton of product is fully consumed at a single carousel pod. This is possible because of their characteristic order profile. Push systems ship large quantities of relatively few SKUs each day. The same SKUs are common to a large number of the orders. This profile often allows push systems to operate efficiently with only a single SKU in front of the operator at a time. Because the SKU is in many of the orders, the carousels do not make long moves between transactions and can be prepositioned when the operator is ready to put into that carousel.

Pull Systems

'*Pull'* systems, also known as *'point-of-sale replenishment'* or '*pick a pair'* systems, are used to replenish product sold by stores. They can help guarantee availability of popular items without overshipping, minimizing the amount of inventory stored locally at the store. In concept, pull systems are very similar to the *'just in time'* theory of manufacturing. Like push systems, pull systems are common in the apparel industry. Rather than specialty retailers, though, pull systems are typically found in large retailers with many stores.

The characteristic order profile for a pull system differs from that for a push system. A pull system ships relatively small quantities of many SKUs each day. Each SKU is typically required in a small fraction of the orders each day, but because of the large number of orders the total aggregate quantity of each SKU shipped each day exceeds a full case.



Typical '*Put-and-pass*' carousel pod

Because each SKU in a push system is in such a small proportion of all orders, each carton of product may have to visit several carousel pods to be depleted. This requires a '*put and pass' layout*, with conveyors connecting the carousel pods. For the same reason, batches of several orders (typically about eight) are worked on by each operator to prevent long carousel moves between transactions. To further increase the likelihood of prepositioned carousels, a '*continuous batching'* scenario is often utilized wherein a carton of product leaves a pod and is replaced immediately after all the transactions for that carton are completed.

Consolidation Systems

Consolidation systems, also known as '*order synchronization buffers'* are often used in warehouses:

- With several different storage/picking media.
- Large numbers of orders (making other consolidation methods difficult).
- Time-critical (wave) systems where pick and pass layouts have too much time variability.

Carousels in these systems synchronize contributions from various areas in the warehouse, consolidating them according to a strict shipment schedule. Such systems help minimize the shipment of partially filled containers ("air"). The entire order can be delivered to the shipping schedule system simultaneously.

SUMMARY

After over 30 years of evolution, the horizontal carousel has grown from a simple storage and retrieval device into a integral part of the overall warehouse/distribution strategy. This development is a direct result of the machine" versatility. Horizontal carousels are typically the most flexible storage device to configure into a warehouse. They are also clearly adaptable to a variety of roles.

However, horizontal carousels need to be viewed as a component part of a total system, not as a stand alone element in a warehouse solution. For system designers and planners, the important understanding lies less in adapting the machine to a specific task than in envisioning its role as part of that larger, complete system.