Perspectives on Material Handling Practice

HIGH DENSITY DYNAMIC STORAGE (HD/DS)

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ABSTRACT

This paper defines High Density Dynamic Storage (HD/DS), highlights the advantages of "Dynamic" storage, presents an overview of the technologies available for HD/DS, and provides guidelines for proper application of these technologies based on the advantages and disadvantages of each. The paper also presents parameters for developing system requirements, as well as, tips to insure successful system implementation.

HIGH DENSITY DYNAMIC STORAGE (HD/DS)

1.0 Introduction

We find the concept of HD/DS intriguing because we are all challenged by the need to get more ***stuff*** in a smaller space, while using less people to fill orders for increasing demanding customers. One might ask, "How did we get in this mess?"

Personally, I blame it all on the introduction of guaranteed overnight delivery, fax machines, cellular phones, and laptop computers, which created an expectation for immediate response and high levels of service. Customers, who don't even have time to shop, expect to find what they need in a mail order catalog, order by phone or fax, and have it delivered to their doorstep the next day. And only God will forgive you if you happen to deliver the wrong item, because the customer never will. You will lose that customer forever!

Further, domestic manufacturers contributed to the demands of higher levels of service making it all possible. They invested in focused factories with flexible automation, allowing them to make products in smaller lot sizes and meet changes in customer demands more easily. They justified their investment on reduced inventories and higher turns. But, more importantly, they created an expectation, that customers could get what they wanted, when they wanted it.

For most, the investments to improve distribution did not keep pace with manufacturing, primarily because material handling was seen as a cost of doing business which did not add value to the product. Furthermore, investments in systems to STORE products, specially AS/RS, were viewed as contrary to the goal of reducing inventory, and thus a WASRE of money that could be better used elsewhere.

In the late 80's and early 90's, many corporations consolidated production into their more automated facilities, causing the distribution channels to become further stressed. Once again, with more products to make, factories had difficulty keeping up with lead times, forcing them to increase inventories. One might think this translates to warehouse expansion and more people to serve distribution. Right? Wrong! Many corporations challenged their Distribution Center Managers to fit the added volume and activity into their existing facilities, using the same manpower, if not less. So, here we are again with ***the need to store more stuff in a smaller space, while using less people to fill the orders of a very demanding customer base***. To maintain our competitive advantage we must constantly strive to improve customer service while reducing the cost of distribution.

One solution is to consider High Density Dynamic Storage, or HD/DS, a method of storage which promises to be one of the fastest advancing technologies of the decade, confirmed in the latest edition of Warehouse Management which reads:

> ***"High density/dynamic storage is the comeback kid of the material handling industry… The chief advantages of HD/DS are the lack of manpower involved in moving the product, the space saved, and the speed with which product moves from receiving the shipping - all money savers."***[1]

If you are facing similar challenges, then I hope this paper will help you determine if HD/DS has the answer to your problem. To help with this decision, this paper defines HD/DS and presents an overview of the available technologies, primarily focusing on handling systems for palletized loads, and more specifically, applications requiring high throughput and FIFO control. The paper also presents guidelines for proper application of each technology along with design parameters to insure successful system implementation. But, if…

2.0 What is HD/DS?

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1 Louding, A., Senior Editor, "A rack Above The Rest," Warehouse Management Jan/Feb 1995, Page 28.

We define HD/DS as a concept where multiple unitloads of the same SKU are sequentially stored in the same location or lane, (one in front of the other), with a minimum distance between loads, thus the item ***high density***. The term ***dynamic storage*** implies moving storage, because a HD/DS system also has the ability to automatically or semi-automatically index or convey the loads from the load point to the unload point of the system. More realistically, it is a flow through rack, where loads pass through the rack toward their next point of use, as preceding loads are used or retrieved.

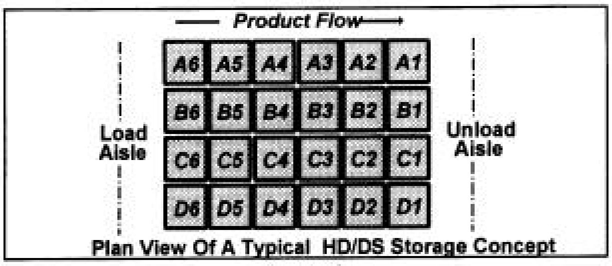


Figure 1

By design, the system uses a minimum number of access aisles to store unitloads in deep lanes to depth of 25 loads or more. Figure 1 shows a plan view, (looking down from above), of a 6-Deep HD/DS configuration.

Product is loaded into the rack on one side, flows through the lane in the same sequence - FIFO, and is unloaded from the opposite end. The HD/DS configuration uses only 2 aisles to access loads, where conventional single deep storage would require a 3rd aisle, as seen in Figure 2.

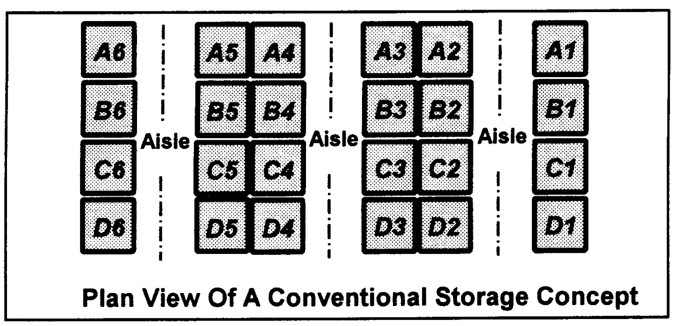


Figure 2

HD/DS Technologies

There are several technologies which are used to provide high density dynamic storage. Their effectiveness depends on the specific application requirements and the limitations of their respective designs. The following paragraphs highlight the function of each technology, and the comparison chart, shown in Figure 3, provides information on the features and benefits of each.

☛ ***Pushback Rack -***

Metal carts sized to fit the footprint of a unitload, are linked together on a common track which mounts to modular rack. The track slightly pitched to allow gravity flow toward the aisle, (home position). Typically 3-4 carts are provided on each track in each opening. Lift trucks are used to load and unload product from the same aisle. During the loading operation, the lift operator uses the load onboard the lift truck to push the load in the first storage position back one cart length. The carts index away from the aisle as the lift truck moves toward the rack. When a full space, (1 load length), is exposed, the lift operator lowers the new load onto the next cart or load position. This procedure continues until all carts and load positions have been filled. To remove loads, the operator uses the lift truck again. This time, the lift truck is used to control the speed of the carts as they return toward the aisle. The lift operator picks the load from the first position, and backs the lift truck from the rack. The remaining loads in the location move forward, (toward home), as the lift truck backs away.

☛ ***Mechanical Brake -***
These systems use gravity wheel tracks, pitched approximately ½" per foot, to transport loads from the load end to the unload end of the storage lane. Mechanical brakes, sometimes referred to as "brake-rolls", are mounted to the rack at each load position. For example, a lane that holds 10 loads would include a minimum of 10 mechanical brakes. The mechanical brakes are self powered, using centrifugal force to apply resistance to the outer wall of the roll as speed is increased. This resistance acts like a disc brake on the roller surface and causes the load in contact with the roller to slow down. The sequence of operation is as follows: Lift trucks enter loads from the charge end of the lane. The load flows forward until it comes in contact with another load, or the permanent stop, at the end of the lane. (Travel speed is controlled by the pitch of the lane and the frequency of mechanical brakes). Heavier loads tend to flow faster, and may require additional brakes. To unload, lift truck operators simply remove the first load from the discharge end of the lane, creating an empty space. Back pressure and lane pitch causes the remaining loads in the lane to begin flowing forward. Once again, the mechanical brakes, in contact with the conveying surface of the loads, create resistance and cause a slow down effect. The "load train" comes to a complete stop again when the first load in the train contacts the permanent stop.

☛ ***Rubber Wheel Principle -***
This method uses soft rubber, or urethane coated conveyor wheels set in tracks, similar to the mechanical brake concept, pitched at approximately ½" per foot. The soft material changes to a oblong shape as loads are introduced to the wheel causing the load to slow down. As loads continue to flow forward, off the wheels, the rubber coating returns to the original round shape. Proper application depends on environmental temperature fluctuations, lane pitch, and consistent load footprint.

☛ ***AS/RS -***
AS/RS refers to automated storage and retrieval systems, or high rise storage, using the dedicated aisle vehicles to store and retrieve unitloads from storage racks, ranging from 50 feet to 100 feet in height. The aisle vehicle receives "move instructions" from a computer to pickup and deliver loads to end of aisle stations. The storage racks are typically configured for single deep loads, providing random access to all openings in the

system. Double deep configurations require a special shuttle device onboard the aisle vehicle, which can extend to the rear position on the double deep location. AS/RS multiple deep systems provide very high density, but often do not provide FIFO inventory logic. In multiple deep systems, a small cart travels with the AS/RS vehicle to the storage location, then runs off-board the AS/RS vehicle on to a track which runs under the loads in the lane. When the cart is in position to pick the first load in the lane, it raises a platform to lift the load off the track, and returns to the aisle vehicle for transportation to the end of the aisle.

☛ ***Car in Lane or "Satellite" -***
Similar on the AS/RS multiple deep system, Car-in-lane uses a shuttle device to move unitloads to the end of each storage lane, where they can be picked up by the aisle vehicle and returned to the end of the aisle. However, in this case, the cart or shuttle remains in the storage lane, and there is one cart/shuttle for each lane in the system, thus car-in-lane. The configuration typically has a load and unload end, providing flow through storage (FIFO). The cart's primary function is to keep the loads shuffled toward the discharge end of the system. As the aisle vehicle places a load in a lane, the car-in-lane goes to the input end and picks up the load, moving it as far down the lane as possible. When the aisle vehicle picks up a load at the discharge end, the car-in-lane begins moving each load one position down-stream until all loads in the lane have been moved.

☛ ***Air Logic -***
This method uses the force of gravity for movement and compressed air to control speed or travel distance. It is the most successful system in use for a broad range of applications. Loads rest on metal rail which runs the length of each storage lane. A gravity wheel track fits inside the rail, and underneath the load carrying surface. Air is pulsed into a full length inflatable hose, raising and lowering the conveyor wheels. As the air hose is inflated, the wheels are up and in contact with the load's carrying surface, causing the load to move forward. When the air hose is deflated, the load returns to the lane rails and brakes to a positive stop. The speed is adjusted by controlling the amount of time the air hose remains inflated or deflated, using microprocessor controls.

☛ ***Level Gravity -***
This method combines the Air Logic technology described above with "walking beam" carts that run on pivoting gravity wheel sections. However, in the case the lane rail is level. Only the short (approx. 2' long) gravity wheels sections, which are imbedded in the lane rail, become pitched as air is introduced to the hose. With air in the hose, the gravity wheel section raises above the lane rail, causing the metal cart to contact the bottom surface of the load. The cart, which rests on the gravity wheels flows forward the length of the gravity section, then hits a permanent stop. When the air hose is deflated, the gravity wheel section lowers below the lane rail and the metal cart returns to its position. The load indexes forward the length of the gravity section each time air is introduced to the hose, then comes to rest on the rail when the hose is deflated. This sequence continues until the load has completed travel on the lane, or the pulsing timer expires. This design provides better cube utilization and load stability over HD/DS systems requiring slope. Also, the metal carts allow for positive control of load movement on containers which may not normally be conveyable.

HD/DS Features Benefits Comparison

Feature/ Benefit	Push Back	Break Roll	Rubber Wheel	AS/RS	Car In Lane	Air Logic	Level Gravity
Lane Depth (Loads)	4-5	5-10	4-5	N/A	20-40+	5-40+	20-40+
Weight Range (tons)	1-2	1-2	1-2	1-4+	1-2	1-4+	1-4+
Positive Braking	N/A	No	No	N/A	Yes	Yes	Yes
Inventory control	LIFO	FIFO	FIFO	FIFO	FIFO	FIFO	FIFO
Cube Utilization *	3	7	3	9	10	8	10
Uptime *	10	7	5	9	9	10	10
Maintenance Costs	10	3	3	5	5	7	7
Pallet Alignment	N/A	No	No	N/A	N/A	Yes	Yes
Thruput *	5	10	10	5	10	10	10
Redundancy *	10	10	10	5	8	10	10
Flow Reliability *	N/A	5	3	N/A	NA	10	10
Wgt Variance/Lane	N/A	2:1	1.5:1	N/A	N/A	3:1	3:1
Back Pressure	3-5%	3-5%	3-5%	0	0	0	0
Environmental Constraints *	10	5	1	10	10	7	7
Reconfigurability of the Rack or Lane to Adapt to Changes in the Load Handling Characteristics **	H=10 W=7 D=5 B=10 #=10	H=5 W=5 D=10 B=5 #=7	H=5 W=5 D=10 B=3 #=5	H=1 W=1 D=1 B=10 #=10	H=1 W=1 D=5 B=7 #=5	H=5 H=5 D=10 B=9 #=10	H=5 H=5 D=10 B=7 #=10
OSHA Compliance (Reg. 1910.146) ***	Some Yes	No	No	Yes	Yes	Yes	Yes
System Cost Per Pallet Position *	10	8	9	3	5	7	5

*	Range in values from 1 to 10, with 10 being the best.

**	H=Height, W=Width, D=Depth, B=Bottom Boards, #=Weight

***	Permit Required Confined Spaces Regulation 1910.146, dated 7/1/93

3. 0 Benefits Of HD/DS

Regardless of the type of technology used, in comparison to conventional storage concepts, HD/DS is a sense buffer storage system using the fewest number of aisles possible. It controls inventory by keeping product in queue, FIFO, providing added security and requiring less management. HD/DS operates more like a conveyance system, constantly moving the product closer to its next point of use, requiring fewer resources to locate and transport materials. Most importantly, HD/DS combines these features to provide fast throughput using a minimal amount of space and people. The following paragraphs describe these key advantages further.

☛ ***Improved Storage Density***

Most HD/DS systems store product in less than half the space required for conventional storage. The example described in Figures 1 & 2 above showed how HD/DS saves one access aisle on a 6 deep configuration. The concept "Deeper is cheaper" is proven in Figure 3. This graph shows how the savings grow as you apply deeper lane solutions, (1 aisle saved for every 2 loads added to the lane depth). For example, a 14 deep configuration requires 5 fewer aisles and stores the same product in 50% of the space, while the 30 deep solution saves 13 aisles and stores the same product in 40% of the space.

Space Savings Using
HD/DS Vs Conventional Storage

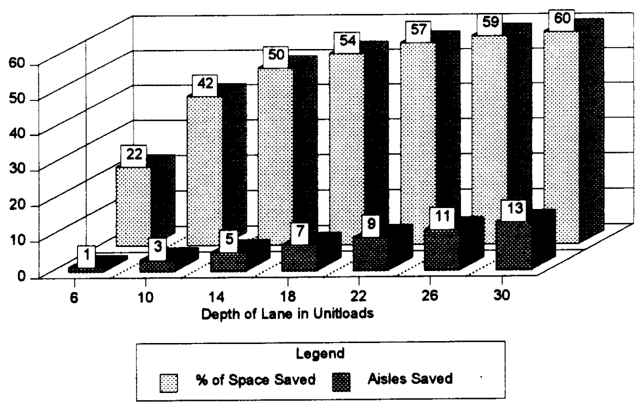


Figure 3

☛ ***FIFO Control***

Most HD/DS solutions provide strict FIFO control, (first in first out). This is true for flow through designs where the products must come out of their respective storage lanes in the same sequence as loaded. The physical system insures consistent inventory rotation without the need for sophisticated controls or operator intervention. This feature is very important for storage of perishable products with limited shelf life.

Pushback systems and some AS/RS deep lane solutions store product first in last out, or FILO. These systems are only effective when strict FIFO by unitload is not required, or

FIFO by production lot is acceptable, and production lots are never mixed in the same storage lane.

☛ ***Lower Operational Cost***

A property applied HD/DS solution lowers the direct and indirect costs of managing your warehouse. The reduced footprint and improved material flow directly affects the number of people required to service customer orders. HD/DS uses manpower more effectively by reducing fork truck travel distance and improving search times for empty spaces or retrieval loads. Figure 4 graphically presents the expected travel time savings for lift truck operators of HD/DS over conventional storage systems.

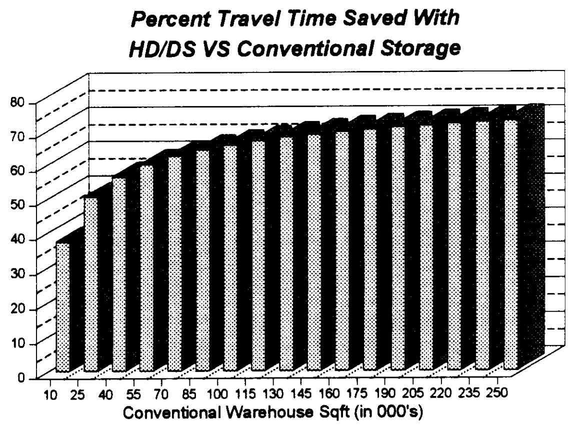


Figure 4

To better understanding how these savings will affect your operation, consider the following example:

Company ABC uses a conventional warehouse to store their product in a rack which takes up approximately 100,000 sq. ft. They currently use 10 fork lift operators working 3 shifts, 5 days per week, to handle their current activity, (10x3=30 lift operators). Each operator spends approximately 80% of their time on the lift truck storing and retrieving loads. Using an HD/DS solution they could expect a savings of 16 operators, determined as follows:

A. Travel time savings from chart	66.7%
B. Amount of time operator spends on truck	80.0%
C. Actual labor time saved (A x B)	53.4%
D. Manpower reduction (C x 30)	16 operators

This also means 5 less lift trucks to own, operate and maintain, in a storage system that occupies approximately 40% of the original space, (see Figure 3), providing room for growth of production or warehousing. HD/DS also reduces indirect costs through: reduced supervision requirements, simplified inventory audits, reduced product damage, improved inventory turns, reduced insurance and overhead.

☛ ***Fast Throughput***

By far, the most significant benefit of an HD/DS solution is fast throughput. HD/DS systems achieve higher throughput using fewer people than conventional warehouse designs because of improved material flows and reduced travel times. Reducing the leadtime to fill orders translates to improved customer service with the ability to promote faster shipment. To illustrate this benefit, consider again the above example, except ***Company ABC*** chooses to keep their current labor levels and reduce truck loading time by 50%, providing twice the turns at the truck dock.

Production scheduling is greatly simplified by reducing the leadtime to fill orders. HD/DS operations also have added flexibility to accommodate surges in customer order or seasonal demands, ultimately allowing companies to provide higher levels of services at no additional cost.

4.0 Requirements & System Development

Although HD/DS may appear to have all the benefits you hope to achieve with a new system, it may not be the right solution to your problem or application. Certain application characteristics must be met for HD/DS to be fully effective. Before taking the leap, take a few precautionary steps to understand all the requirements of your system. In general, you should have a clear understanding of all the products and materials to be handled in the system, including information relating to:

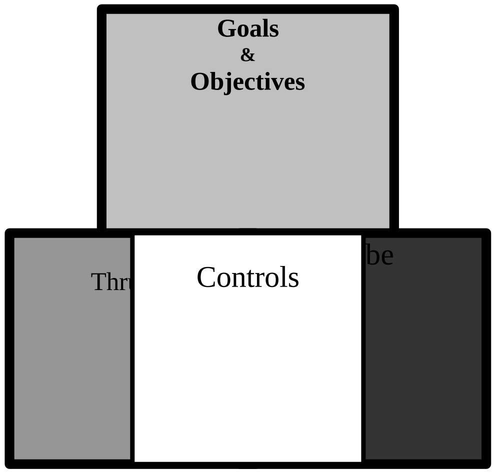
- Load Dimensions, weights, and container specifications, and environment conditions, (specially as it pertains to container conveyability),
- Demand activity, including seasonal and growth adjustments,
- Peak inventory with consideration to sensitivity to functions in manufacturing and supplier deliveries,
- The process flow, sequence of operation, orientation requirements, and special handling concerns.

Also, if you plan to implement the system in an existing facility, you need to verify measurements, building specs and constraints (floor loading capacity), interfaces with current production equipment, along with consideration to interruptions with ongoing operations.

Collecting this data can be time consuming, and if not collected properly could require several iterations before you have all the necessary information to proceed with concept development. I recommend using the ***system design triad*** which should prevent reworking your data collection and concept development efforts.

System Design Triad

The best solutions in any application are those which successfully balance the Thruput, Control and Cube requirements of your business. These criteria establish the foundation for meeting the Business goals and Objectives of your company. If the system design sacrifices the need of any of these elements to favor another, it creates an unstable solution with degraded performance, productivity and system longevity. Figure 5 illustrates the interrelations of these key design criteria and their influence in supporting the long term goals and objectives of the business.



System Design Triad

Figure 5

The following paragraphs describe the specific roles each elements plays in the design process, highlighting special considerations as they relate to HD/DS system design.

Goals

Goals & Objectives

Starting with a <u>clear</u> understanding of the long term goals and objectives of your company allows you to focus on investments which are consistent with your company's business plan, and prevents wasted efforts reworking concepts and budgets. The importance of general management providing <u>clear</u> objectives is illustrated in the following example, (a true story):

> A company President, touring one of his operations, noticed a significant amount of inventory on the floor. Disturbed by the untidiness of the warehouse, he turned to the Plant Manager and said, "The next time I come here I don't want to see any of this material on your floor." In a hurry to the airport the President reminded the Plant Manager to be prepared to report his solution at the next quarterly meeting. The Plant Manager had recently seen a system of storing pallets and he knew it would work well in his plant. Even though the justification was marginal, he had the support from top management, so it was sure to pass.

> Excited about the opportunity to buy the new equipment for his warehouse, he immediately called in several vendors to provide quotes for the storage system expansion. Three months latter, after selecting the preferred vendor, the Plant Manager presented his budget plan to the President, expecting a quick approval. After all, he was directed to "get the material off the floor." Well, the President was confused by the proposal for the new storage system, because he had no intention of adding storage rack to the already excessively large warehouse. His idea for a solution was quite different. The Plant Manager was surprised by the President's response, and reminded him of his statement about inventory on the floor. The President agreed, and then clarified his statement, "What I meant was, I expected you to work with our vendors and have them ship that material directly to our satellite warehouse, bypassing your warehouse altogether."

A simple misunderstanding wasted the efforts of the Plant Manager and several vendors, and… he was no closer to the solution than he was 3 months ago. More importantly, the Plant Manager, excited about the opportunity to introduce new technology in his warehouse, lost focus with the real goals of his company, best said by Dr. John White, a renowned material handling consultant.

> "to frequently, automated warehouse have been installed without regard to the overall objectives of the firm. A fascination with the technology, a desire to create a showcase, or a determination to ***eliminate people*** often takes precedent over providing the best service to customers, enhancing productivity, lowering costs, and providing challenging and rewarding jobs for people."[2]

To prevent yourself from falling into this trap, seek answers to question like: What is the core business and supporting products of our future?, What are the goals for expected service levels to our customers?, What are the expansion and growth expectations of our business?, What are the information needs?, What are acceptable guidelines for ROI measurement and system justification? Beginning the project with a common understanding of the answers to these questions gives you a better chance of designing a system that will serve your customers well and help your company achieve its business goals.

Thruput

Expected Thruput Requirements

Most warehouse designs target the volumetric needs of the system, (number of loads stored). However HD/DS solutions focus first on the thruput requirements and the lead time to fill customer orders, making them ***thruput systems*** rather than ***storage systems***. In a HD/DS system, product is stored in a way to make retrieval faster and easier. Therefore, it becomes very important to understand the total thruput requirements and service expectation. You do this by documenting the material flow from production through order assembly to shipment, for each product class in the system, including project activity growth rates for the foreseeable future. You may also need to include phantom products to simulate activity for planned product introductions.

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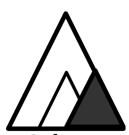
2 White, John A., and E.C. Gwaltney, "Total Quality And The Automated Warehouse," Proceedings from the 44th Annual Material Handling Short Course, March, 1994, page 2.

Define the unit size and package requirements for each step in the process. This important, and often overlooked, design criteria can effect the system's thruput capacity significantly. Be sure to get management consensus on the unitload packing specifications and limits, (weights and sizes). Pay special attention to the conveying surfaces of the unitloads and packages. Most automated solutions require a minimum number of different pallet configurations, with good conveying surfaces. Most important, the pallet configuration and load stability must be consistent within acceptable tolerances. Although many American pallet producers are beginning to realize the importance of automated handling concerns, the responsibility to maintain a consistent load footprint, weight, stability and configuration rests primarily on the User. If you don't already have a standard, or if your container is not consistent or conveyable, you should research container concepts and agree on a minimum number of standard container or pallet configurations. Also, before finalizing the design, you may consult HD/DS suppliers to ensure the chosen configuration is conveyed and to get suggestions on designs that could reduce overall system costs. Once you have a standard, you should establish a preventive maintenance program to insure only quality pallets are used in the system. Because a pallet which does not conform, regardless of the technology being used, will shut it down, and… the cost to remove jams and correct damages easily outpaces a simple preventive maintenance procedure.

System designed to meet only the thruput concerns of the business, may not effectively use the cube. For example, systems designed for high thruput often employ dedicated storage lanes to quicken location access times for fast moving items. However, when those products are not in use, the lanes become idle or poorly utilized. Control systems and information needs for upstream and downstream operations must also be considered even when they adversely affect thruput in the warehouse. The best solution will focus on thruput with appropriate compromise for cube utilization and information needs.


Cube

Cube Utilization

Every system strives for optimum cube utilization, and as shown before, HD/DS solutions are the most effective in saving space. However, in every system design there are many constraints adversely affecting cube utilization, such as facility limitations, seasonal fluctuations, specialized packaging, inventory requirements, and SKU density, (Stock Keeping Unit).

Probably the most significant design criteria is "SKU Density". This term refers to the number of loads in storage per SKU, calculated simply by dividing the total loads in storage by the number of SKU's. We use the SKU density to determine which storage method provides the best cube utilization, (single deep, double deep, three deep, or deep lane).

Production lot sizes, seasonal fluctuations, and/or surges which may significantly impact short term space requirements of your warehouse should be factored into the SKU density formula. Also, consider viewing high volume/activity products separate from low volume products to determine the variance on the SKU density. By comparing the inventory this way, you may decide to optimize cube utilization by using different storage methods for different classes of product. However, keep in mind, as you combine different storage methods under the same roof, you make the warehouse control system and operational procedures more complex.

For solutions which provide FILO, (first in last out), product rotation, you must factor production lots into your SKU Density calculation. The solutions which operate under FILO logic include: double deep rack, pushback, drive in rack, and some AS/RS deep lane systems. When considering a FILO solution, you need to divide the SKU Density by 2, (at a minimum). This allows you to allocate space for one active picking location and one active storage location of the same product from different lots. Obviously, it the average number of lots in storage at any given time is greater than two, you need to divide the SKU Density by that number. By design, flow though systems provide FIFO product rotation, and lot separation is generally not necessary. The system delivers products in the same sequence as received, keeping production lots in a FIFO queue.

Factoring all these criteria, Figure 6 highlights possible storage solutions based on SKU Densities. The SKU Density helps in selecting the right technology for your application, and approximates the appropriate storage lane depth of system. However, the final design must consider thruput, building constraints, and control requirements before determining the optimum lane depth. For example, you may need to shorten the optimum lane length to fit in the average building footprint, or you may need to double up on the number of rack faces to increase accessibility for higher thruput capacity. Again, the design which balances these constraints will give the best alternative, yielding the highest possible cube utilization and system performance.

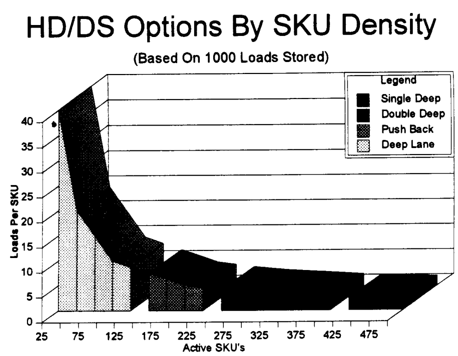
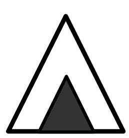


Figure 6



Control

System Control

The most significant technology advancements during the past decade center around controls. Automated information handling gives you the ability to respond quickly to changing customer demands, because quick response, reduction of lead times and quality service all depend on the accuracy and timeliness of information. Hardware solutions help improve material flow, handling methods, and physical control of the product, but without automating the information flows, the system will never reach its full potential.

To achieve this goal, start by documenting the information flows and requirements. Pay special attention to the ***time*** dependencies of information, focusing on what can be done to eliminate bottlenecks or streamline the date collection process. The system should take advantage of the mechanical controls to reduce the complexity of information handling and processing. For example, HD/DS's flow through design ***mechanically*** maintains FIFO inventory rotation and lot control, greatly simplifying the software logic, allowing it to focus on more complicated tasks, such as order processing.

The best solutions integrate the material handling and controls systems so that each time the product is handled, the appropriate changes in information are communicated back to the controls system, ***right now***, keeping the control system in sync with the operation. Simplicity is always the key to successful system design, and this is specially true in the area of control.

Information and material handling flows go hand in hand and their solutions must be designed to fit together. A balanced design providing equal consideration to the Thruput, Cube, and control requirements of the system provides the best foundation for meeting your company's overall business goals and objectives. The next section provides some examples of successful HD/DS solutions, designed using the ***system design triad***.

5.0 HD/DS Solutions

The term SKU, means "stock keeping unit", and is used to provide a unique product identification. For the purpose of designing storage systems, we also use SKU identifiers to classify unitloads with a common application requirement. Some examples of different uses are provided in the following table:

Application	SKU Identifier	Active SKU's # Locations	Lane Length
Receiving Buffer	Vendor PO	Open PO's	Receipt Size
Receiving Warehouse	Product ID Vendor Lot	Max Part no's in Storage	Loads per Part No
Production WIP Buffer	Work Cell/ Prod. Line	Active Work Cells/Lines	Required Queue
Finished Goods Warehouse	Product ID Prod. Lot	Max Part No's in Storage	Loads per Part No.
Order Assembly	Destination	Open Orders	Loads/Order
Shipping Buffer	Shipper ID	Truck Doors	Load/Trailers

As seen in the above chart, HDDS solutions apply to a variety of tasks from receiving through shipping. Examples of some preferred designs using three different technologies are provided below.

Receiving Systems (Pushback)

An automotive parts remanufacturer selected a pushback solution to solve its problem in receiving. The company received returned core assemblies from parts dealers on Thursday and Friday of each week. The parts were returned in large boxes on GMA pallets. On an availability basis, inspection operators opened boxes and sorted the parts into the appropriate staging bins. During the inspection process, the dealers received the appropriate credit for the returned part.

Unfortunately, the inspection process took a long time, and the surge of receipts overwhelmed the available space on the receiving dock, while boxes of parts awaited inspection. To make matters worse, the receiving dock was very small and boxed in on 3 sides, not allowing for any aisle space. The pallets were not standard, and they were in poor condition, so drive in rack was not an option. FIFO logic was not required, so they chose a 5 bay pushback design (5 deep by 3 tiers high), to store 75 incoming loads awaiting inspection. This gave them more than enough room to handle surge, and more importantly, they were able to plan their labor staffing in inspection, eliminating weekend and overtime pay required by the earlier system to keep the docks clear.

Work In Process (Level Gravity)

The automotive assembly plant chose ***Arubix,*** a level gravity solution by Loadbank® International, to solve its work in process problem handling car bumpers. The bumpers were delivered to the line staging area from the vendor on containers stacked three high. Load height and the high center of gravity prevented any consideration of sloped solutions. The system had to remain level. To make matters worse, the container bottom surface was not conveyable, so traditional accumulation conveyors could not handle the load. The customer chose Arubix for its gentle handling, flexible design, and ROI value.

Finished Goods (Pushback & Air Logic)

A snack food producer chose Pushback and Air Logic to handle its problems in their finished good distribution center. The warehouse, working at below freezing temperatures, needed to improve the lead time to fill customer orders. They also were acquiring products from other plants after consolidation, and needed to improve the warehouse density, especially true of any warehouse freezer application. The pushback system is used to stock short production runs and special orders. The main warehouse stores product in deep lanes consisting of 70 bays, 2 tiers high, 18 loads deep. The company considered brake roll and air logic for the deep lane storage, and chose air logic because of its high reliability and low maintenance. In an article of Material Handling Engineering, Jack Heim, VP of Engineering for J&J Snack Foods, explained his reasons for selecting Loadbank®, saying "we looked at brake roll technology before we decided on the Loadbank® system. What impressed us was its near fail safe operation. With roller technology, if a brake fails the load is in an active position, not inactive. Plus, working in adverse conditions of minus 10 degrees, we were concerned with having to do maintenance."[3]

Lift Operators load the racks using radio frequency controls to communicate to the Loadbank® and inventory control system. The flow through storage coupled with onboard radio frequency controls simplified order process and improved operator productivity significantly. What used to take 5 hours to load a truck now takes less than 30 minutes. They can process 500 loads in and out each day, with only a fraction of the labor force.

[3] Witt, Clyde E., Sr. Editor, "New Twists in Storage and Handling for Pretzel Manufactures, "Material Handling Engineering, April 1993, page 41.

6.0 Summary

In today's marketplace, quick and accurate response to customer orders is the key to keeping our existing customers as well as gaining advantage over the competition and capturing additional market share. High Density Dynamic Storage, (one of the fastest growing technologies of the decade), streamlines distribution center operations by improving: cube utilization by 60%, worker productivity by 70%, overall operational costs 50%, and thruput capacity by 100%, helping you to provide the best possible service to the customer.

Many technologies offer HD/DS features, but the solution is a function of application, and more specifically the load or product profile. Equipment selection should be requirement's driven and defining an objective set of system requirements starts by using the ***System Design Triad***. Avoid being "fascinated with technology" and focus on system which best meet your overall business goals and objectives. Consider the total costs of the system, (initial cost plus annual operational cost), when calculating the return on investment. Most importantly, select the alternative which provides a safe and productive work environment for your employees.

Good luck in your future system design and implementation efforts, and feel free to contact us if we can be of help in your project. Thank you.