AS/RS APPLICATION, BENEFITS AND JUSTIFICATION IN COMPARISON TO OTHER STORAGE METHODS:
A WHITE PAPER

REPLENISHMENT SYSTEM for DISTRIBUTION CENTER

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SCOPE

This White Paper has been written to demonstrate the application, benefits and justification of AS/RS crane-in-aisle based technology. It uses a comparison of an AS/RS solution to a VNA (Very Narrow Aisle) man aboard industrial truck solution for a given application. This comparison considers the application criteria, the layout of the two solutions, the strengths and weaknesses of each, the capital costs, the operational costs and the economic justification. It is a follow-up to a similar White Paper completed in 1999. See http://www.mhia.org/psc/PSC_Products_StorageRetrieval_Whitepaper.cfm

OBJECTIVE

The objective of this White Paper is to present conceptual ideas, useful information, operational conditions, application considerations and appropriate methodology for the analysis when comparing AS/RS with other storage and retrieval methods. The purpose is to provide information that serves to improve the industry's knowledge of storage systems. The ultimate goal is to bring about an increase in the number of properly-applied AS/RS Systems that utilize in-aisle S/R machines.

The example used for the comparison is different than the first White Paper published in 1999. Likewise other examples may be used. As other applications are identified, they may be analyzed by using the methodologies and extrapolating the data from this paper.

The example shown is a solution for a high rate picking system on the picking side of the replenishment storage system. Should the reader have need for a system of 25 to 35% of the example rates, there is a solution in Appendix A for that level of automatic replenishment storage compared to a manual VNA storage solution.

EXAMPLE

An important application in distribution is the picking supported by a reserve pallet storage system. The purpose of the storage system is to provide “cartons picked from pallet” locations and a storage and replenishment system for the reserve stock that will eliminate out of stock at the picking operation. The primary example provides “pick tunnels” in the racks for a high-speed pick to belt picking system. As stated in the objective, there is a solution and evaluation in the Appendix for a lower picking rate, pick to pallet system.

This paper is based on an application that provides 1632 pallet picking positions and 11,424 reserve pallet positions. The maximum pallet weight is 2500 pounds, including the 48” x 40” pallet. Load heights are up to 60 inches, including the 6” pallet. The system is required to work on two shifts of 7.5 hours each. The pick to belt picking system requires the replenishment system to have a peak throughput of 120 “dual cycles” per hour for replenishment of the pick positions, 120 stores per hour of new product and retrieval of 16 stacks of empty pallets per hour.

The system uses good GMA pallets with a bar code tag on two opposite sides. The tags permit a simple inventory control system by correlating all the load information to the pallet ID number.

Concepts

There are two finalists from a number of concepts considered. One concept uses manually operated turret trucks in a very narrow aisle configuration and standard industrial, post and beam pallet racks; this is called the VNA Concept. The second concept uses automatic storage and retrieval machines with high-rise racks; it is called the AS/RS Concept.

VNA Concept

Given the right circumstances, the “VNA Concept” is a justifiable solution to many storage applications. The VNA Concept, for the circumstances of this paper, is shown by two sketches: Figures 1 and 2. The plan view (Figure 1) shows three of the eight-aisle storage / replenishment system with 68 pallet positions down the aisle and double deep across the aisles. The post and beam rack construction has two pallets per bay with their 40” dimension into the opening. Also shown are two of the four three-high pick tunnels, each serviced by two Turret Truck aisles.

The layout shows positions 1 & 2 in the first bay and positions 67 & 68 in the 34th bay. The turret truck aisle is 72” wide, which allows for the height of the turret trucks and enables the pallet to be rotated in the aisle. The rack system is 303’–6” feet long, 12 feet for run-out at the end of the aisle, and 23 feet for run-out maneuvering at the front. This represents an area of 67,122 square feet. In addition, there needs to be an area for the battery charger and spare battery. A 10’ x 45’ addition to an existing battery area would require an extra 450 square feet of low bay building.

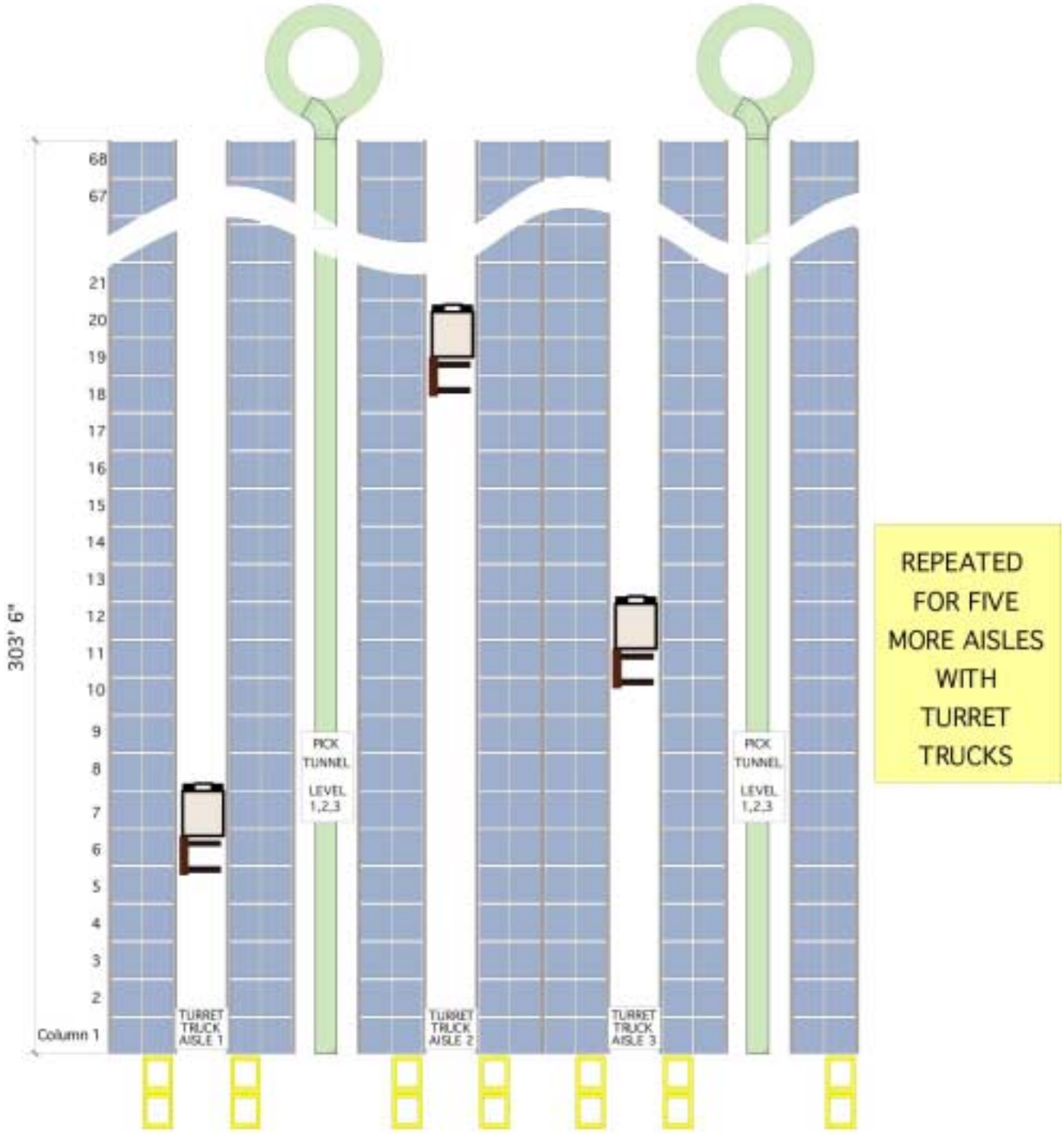

FIGURE 1 - PARTIAL PLAN VIEW: VNA CONCEPT
(THREE OF EIGHT TURRET TRUCK AISLES SHOWN)

The elevation view (Figure 2) shows the six levels. The first level in all the racks is at 22" to accommodate the flow racks and provide the best ergonomic location for picking out of the racks. The storage racks are the same for uniformity. The second, fourth and sixth levels in the picking racks, and all of the storage racks levels, are of a two-deep push back rack construction. A nominal 4" beam has been used to support the two 2500 pound pallets and provide 5" of lift in each opening. The sixth level load beam is at 379" (31'-7"). Adding 10" above the 6th load sets a minimum clear height requirement of the building at 452" (37'-8") say 38'. It is anticipated that there would be two levels of intermediate sprinklers in the racks, and one level in the trusses to provide the required 3' clearance above the top load. Should someone want 6" of lift, the extra inch may be added to each level.

The system uses eight turret trucks, one per aisle, with each truck normally staying in its aisle. Figure 3 provides an illustration of a typical VNA turret truck. The trucks are able to come out of the aisle should one machine fail. The system could then operate at some reduced throughput with two machines each transferring between two aisles, half of the time. Two pick-up and drop-off positions, shown, are provided on the floor at the front of the racks near the aisle for each aisle.

This concept would operate with counter-balanced fork trucks bringing pallets to the system and taking stacks of empties away. A load would be set down in one of the two pick-up locations at one of the Turret truck aisles, using the one nearest the racks if it is open. The turret truck operator would gun-scan the bar code on the load and the barcode on the pallet. The control would make the connection (marriage) of the information about the load and the pallet ID number. This information would be passed on to the Host computer for future use. From then on, the local control would only need to use the pallet ID number for identification and location.

When one of the turret trucks has stored the load, the operator would gun-scan the location to confirm the store operation. The location would be kept in the local control, tied to the pallet ID number.

The replenishment cycle would operate on the basis whereby the Host computer would know when a reserve pallet position is open on a picking lane. The Host computer would give the local control the pallet ID number. The local control would then show the operator the location from which to pull the replenishment. The turret truck operator would drive his/her machine to the rack location and retrieve the load. He/she would then travel to the open pick lane and deposit the load.

Normal operation is for the scheduler to have a queue of empty pick locations to fill, such that after every store operation there would be a retrieve for the truck to get while it is in the aisle. If there aren't any stores to be made, but replenishments are needed, they would be pulled to keep the pick lanes full. Likewise if there aren't any replenishments, but there were stores, they would be put away.

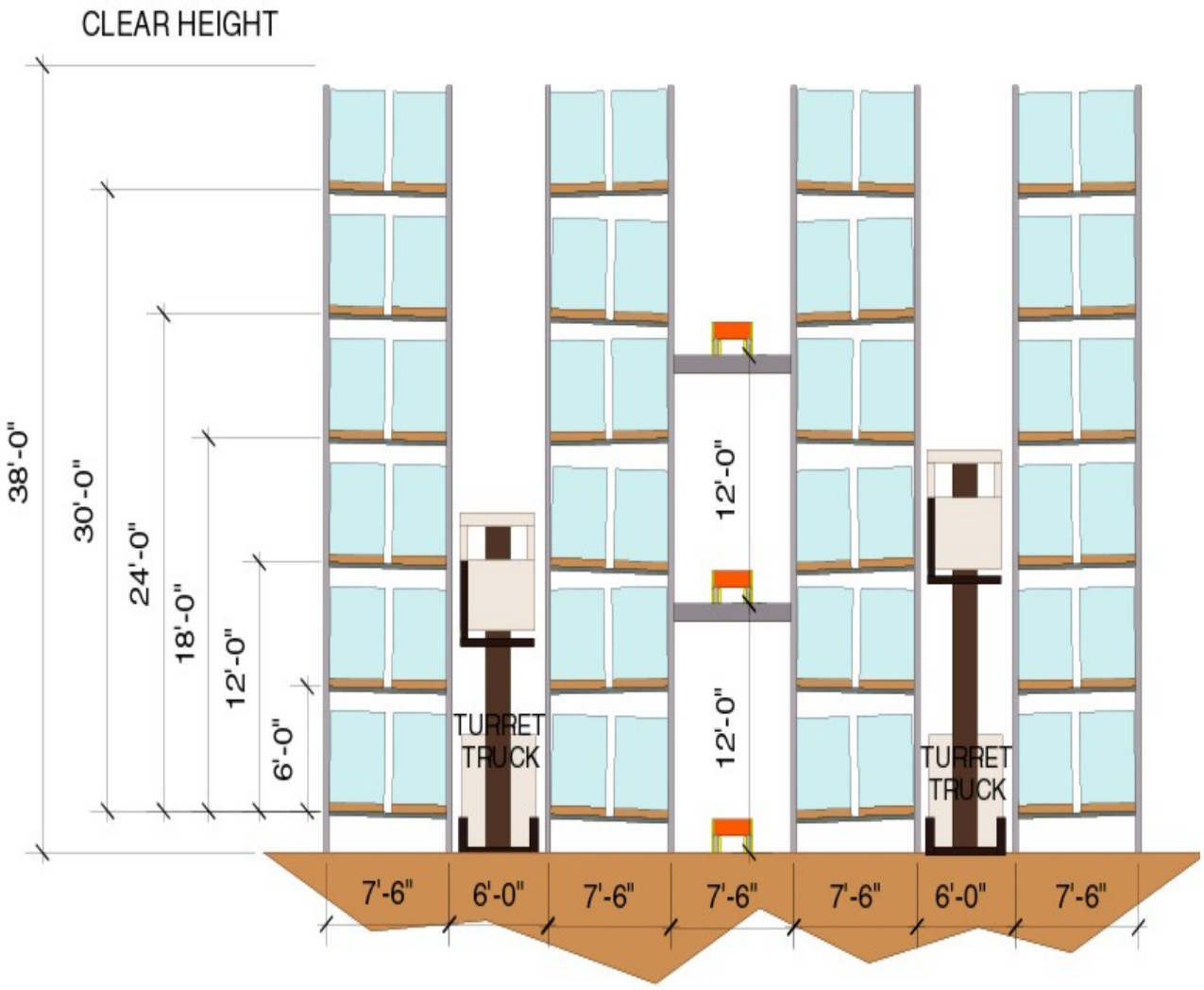

FIGURE 2 - ELEVATION VIEW: VNA CONCEPT

Figure 3 – Photo Showing a Typical Turret Truck in a Storage Aisle

AS/RS Concept

Given the right circumstances, the “AS/RS Concept” is a justifiable solution to many storage applications. The AS/RS Concept, for the circumstances of this paper, is shown by two sketches: Figures 4 and 5. The plan view (Figure 4) shows two of the four-aisle storage / replenishment system with 68 pallet positions down the aisle and double deep across the aisles. The high-rise rack construction has one pallet per column of storage, with the two pallets deep, arranged with their 40” dimension into the opening. Also shown is one of the two, six-high pick tunnels, each serviced by two S/R machine aisles.

The layout shows positions 1 & 2 at the front and positions 67 & 68 at the rear. The storage retrieval machine aisles are 50” wide, which allows a nominal 4” clearance on each side of the traveling load as it, passes the stored loads. The rack system is 312 feet long; 12 feet run-out is planned at the end of the aisle and 23 feet for run-out and delivery or takeaway of the loads at the front. This represents an area of 31,029 square feet.

The elevation view (Figure 5) shows twelve levels. The first level is at 26” to accommodate the flow rack pitch, to accommodate the SR machine’s lowest obtainable shuttle fork level, and to provide the best ergonomic location for picking out of the racks. The storage only racks are the same height for uniformity. The second, fourth, sixth, eighth, tenth, and twelfth levels in the picking racks, and all of the storage racks levels, are two deep, shelf angle construction. Shelf angles are attached to the columns to support the 2500-pound pallets. Space is provided for a 2” lift-off in each opening, and 7” clearance below the pallet for shuttle entry. The twelfth-level shelf angles are at 821” (68’-5”). Adding 16” above the 12th load sets a minimum clear height requirement of the building at 897” (74’-9”) say 75’. It is anticipated that there would be four levels of intermediate sprinklers in the racks plus one level up in the roof trusses to get the required 3’ clearance above the top load.

The system uses four S/R machines, one per aisle, with each machine staying in its aisle. Figure 6 provides an illustration of a typical S/R machine within a double deep, single width aisle construction. Input and output at the front end of the system is by two-position pick-up and drop-off conveyors. The output conveyors are principally for stacks of empty pallets, but may be used if there was ever product in the system that needed to be recalled. These are shown in the plan view (Figure 4) and are provided at 26” above the floor, matching the first rack level.

This concept would operate with fork trucks bringing pallets to the system and taking stacks of empty pallets away. A load brought to the system would be set down on the pick-up conveyor. The information would be passed on to the Host computer for future use. From then on the local control would only need to use the pallet ID number for identification. The local PC control would remember the location for automatic retrieval when required.

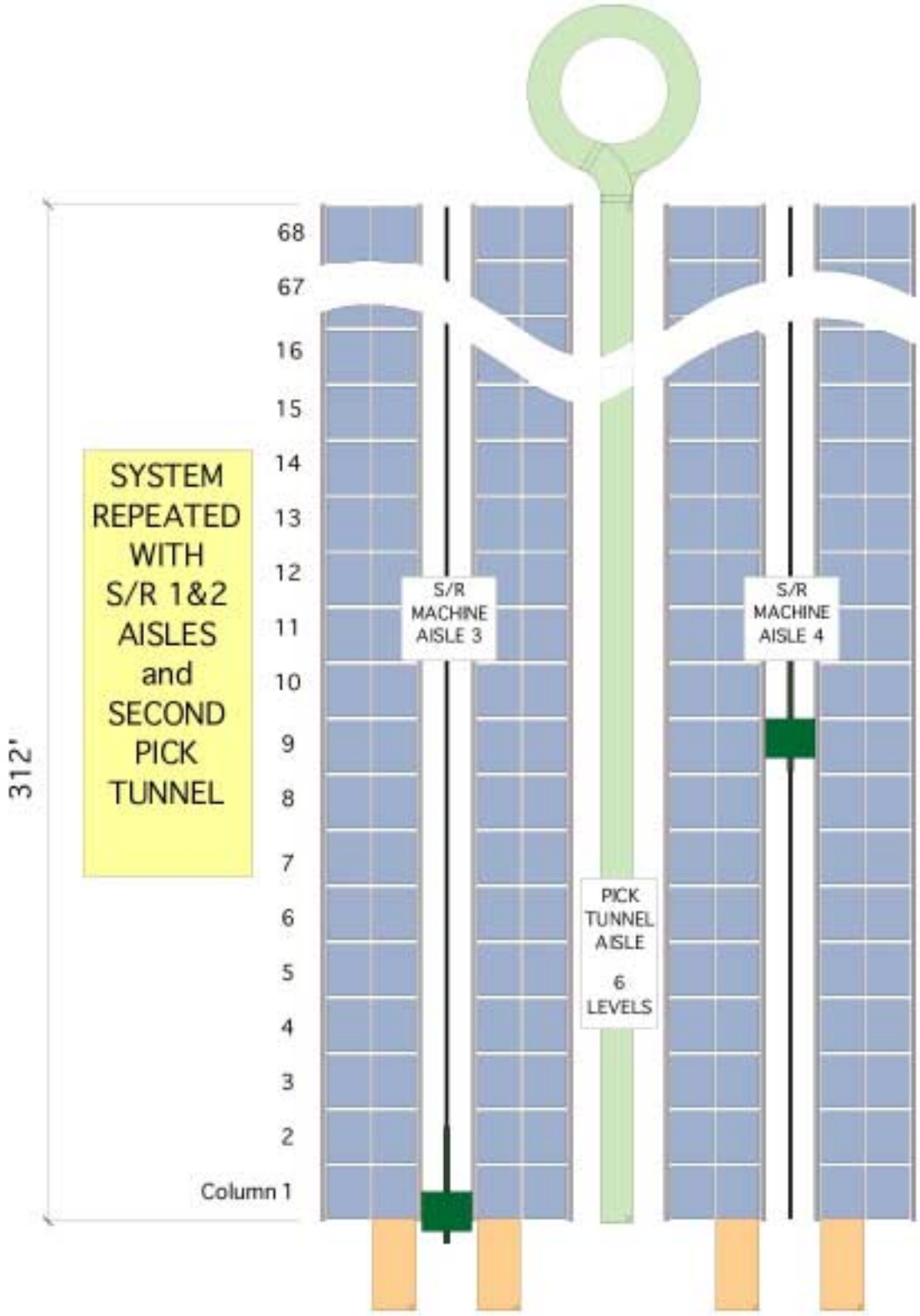

FIGURE 4 - PARTIAL PLAN VIEW: AS/RS CONCEPT

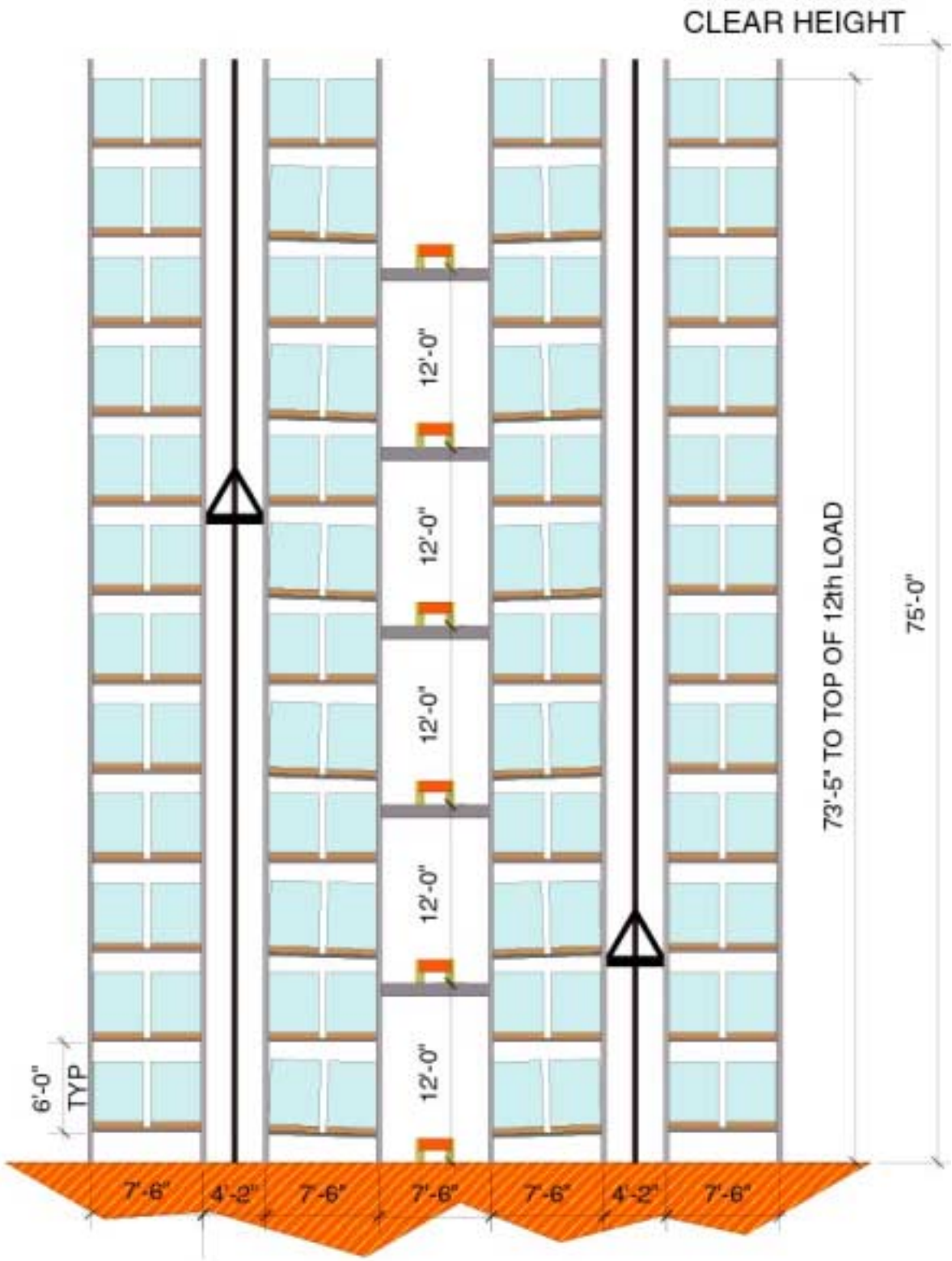

FIGURE 5 - ELEVATION VIEW: AS/RS CONCEPT

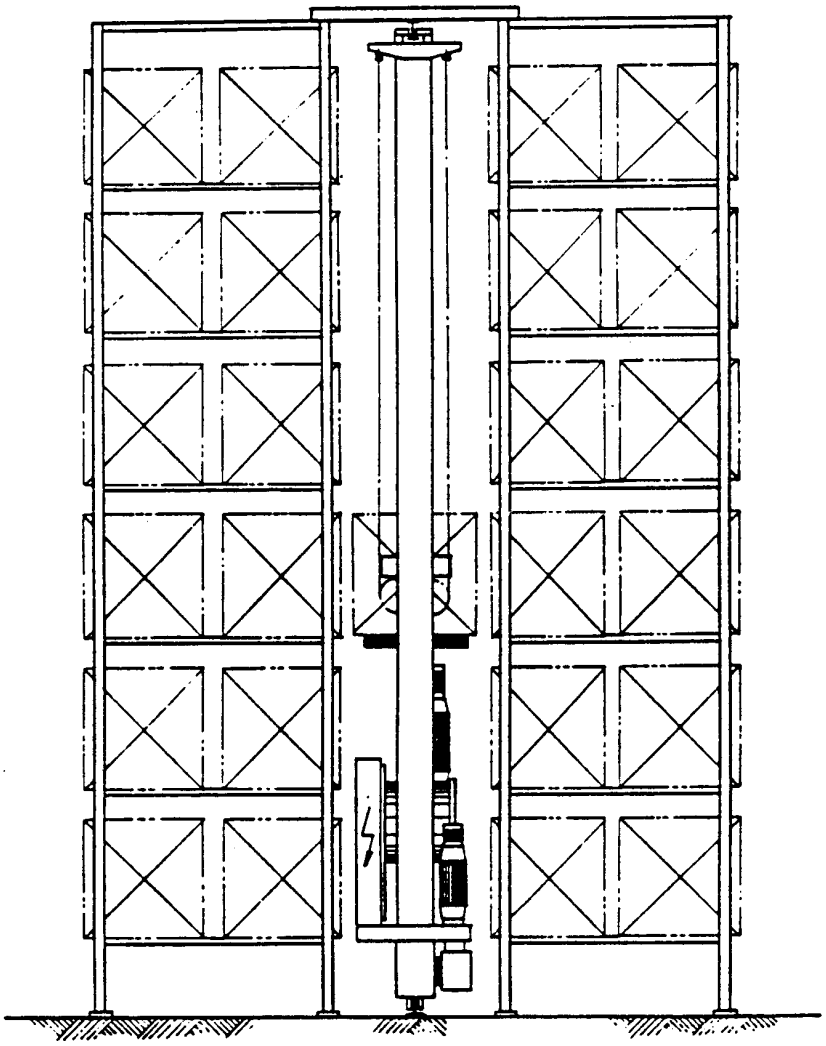

Figure 6a. – End of Aisle Illustration of a Typical Single Aisle / Double Deep / Single Width Aisle Unit Load AS/R

Figure 6b. –View of an Empty Pallet in the Rear Position and a Single Aisle Unit Load AS/RS with its Shuttle Forks Extended to a Double Deep Load

When the storage retrieval machine (S/R machine) stores the load, the location is kept in the PC control, tied to the pallet ID number.

The replenishment cycle would operate on the basis whereby the Host computer or WMS computer would know a reserve pallet position is open on a picking lane. The Host computer would give the local PC control the pallet ID number and the pick lane destination. The control would then start the automatic cycle to pull the pallet from storage. The S/R machine would move to the proper rack location and retrieve the load. Next, the S/R machine would move to the pick lane and deposit the load.

If a stack of empty pallets is ready to be retrieved, the local PC control would give the S/R machine the destination, and the S/R machine would pick up the stack. Next, the S/R machine would travel to the front of the system and place the stack on the drop-off conveyor. If the second position were open, the load would move away from the racks into the second position on the drop-off conveyor.

Normal operation is for the Host or WMS to know, based on the picking activity, when the loads need to be retrieved to keep the picking lanes with a backup pallet to assure the picker always has product to pick. This transfer operation for the S/R machine is normally done after every store operation and happens while the S/R machine is in the aisle. If there aren't any stores to be made, but replenishments are needed, they would be pulled to keep the flow lanes full. Likewise, if there aren't any transfers, but there are stores, they would be put away.

COMPARISON

Several tables have been prepared in which the VNA concept is compared to the AS/RS concept. Table 1 compares operating conditions based on the system design. Table 2 compares equipment performance characteristics. Table 3 deploys a qualitative comparison of the concepts based on a variety of issues. Tables 4, 5 and 6 examine the comparative economics of the two concepts. The bottom line, leading to the conclusion in the paper, is contained in Table 6 wherein the Net Present Worth And Rate Of Return is shown.

When deriving the data contained in the following table, information from two different VNA truck manufacturers was used. The data pertaining to AS/RS also was obtained from two manufacturers.

Table 1. – A Comparison of VNA and AS/RS Operating Conditions

	VNA Concept	AS/RS Concept
System throughput required	Concept Capability	Concept Capability
Peak per hour: 120 pallets stored 120 transferred (replenished) 16 pallet stacks retrieved Total loads moved/system	 15 / truck 15 / truck 2/ truck 256	 31 / SR Machine 31 / SR Machine 4 / SR Machine 260
Sustained per hour: 102 pallets stored 102 transferred (replenished) 14 pallet stacks retrieved Total loads moved/system	 13/truck 13/truck 2/truck 224	 27 / SR Machine 27 / SR Machine 3.5 / SR Machine 230
Common Activity Spread 32% store only 4% retrieved only 32% as dual cycles Total loads moved/system	Common Activity Spread 212	Common Activity Spread 212
Machine operators	16 per day	None
Maintenance personnel	40% of a person	20% of a person
Supervisory personnel	25% of a person	10% of a person
Scheduling personnel	30% of a person	15% of a person

Table 2. – A Comparison of VNA and AS/RS Equipment Characteristics

	VNA Concept	AS/RS Concept
Weight Capacity	2500 pounds	2500 pounds
Speeds		
Travel	6 mph (528 fpm)	525 fpm
Hoist/Lift	50 fpm up/80 fpm down	103 fpm
Store/Retrieve	23 seconds – front 29 seconds - back	7.8 seconds – front 10.5 seconds - back
Rotate in aisle	10 seconds	Inherent
Controls		
Pallet ID number	Bar code tags two sides	Bar code tags two sides
Load information	Randomly tied to pallet ID number at entry	Randomly tied to pallet ID number at entry
Code reading	Operator with gun scanner reds pallet ID number, load contents bar code and storage location bar code	Automatic scanner on input conveyor reads pallet ID number and load contents information provided or bar code read by fixed scanner
Inventory control	Part of bar code scanner equipment and system	Included in PC based AS/RS supervisory control system

Table 3. – A Comparison of VNA and AS/RS Strengths and Weaknesses

	VNA Concept	AS/RS Concept
Strengths		
Operator vs. Automatic	Operator can provide flexibility	Operator-less operation
Training	Higher training	Reduced training
Effective machine usage	Operators require breaks	Automatic machines don't take breaks
Equipment failure	Can run at reduced capacity with one machine not operating – 12.5% loss	Can run at reduced capacity with one machine not operating – 25% loss
Product damage	More due to human error	Less with proper load screening built into system
Floor space		Generally requires less than half a VNA
Expansion	Can add fifth tunnel and ninth & tenth machines	Can lengthen aisles up to the throughput of each of four machines
Security		Secure by safety fence and gates
Inventory Control		Standard PC based supervisory control provides more features than bar code equipment system
Maintenance	With good preventive maintenance has low maintenance	With good preventive maintenance has low maintenance
Reliability	Generally high reliability, but VNA hydraulics and batteries tend to have more failures	Generally high reliability with AS/RS electric drives and PLC having fewer failures
System Cost	Lower initial cost	Lower life cycle cost and higher return on investment
Weaknesses		
Operator vs. Automatic	Requires sixteen operators per day	
Downtime	Only 12.5% loss operation is one machine is down	25% loss operation if one machine is down
Floor space	Generally requires more than two times an AS/RS	
Security	Mysterious item disappearance is common	
Floor cost	The higher the system, the flatter the floor and the higher the cost	

Table 4. – A Comparison of VNA and AS/RS Capital and Operating Costs

	VNA Concept	AS/RS Concept
Capital Costs		
Machines installed	(8) $803,000	(4) $1,742,000
Racks installed	1,288,000	2,373,000
Controls	48,000	225,000
Fire Protection	475,000	350,000
Total Equipment	2,614,000	4,690,000
Building	3,403,000	2,926,377
Land & Site Preparation	808,000	415,464
Total Capital	6,825,000	8,031,841
Operation Costs		
Labor, Direct	560,000	0
Labor, Indirect	28,000	14,000
Supervision	17,500	7,000
Heat, Light, Power	152,615	92,989
Maintenance	24,088	17,422
Total Operation per Year	782,203	131,411

Table 5. – A Presentation of Simple Pay Back Over the Incremental Investment in AS/RS

	VNA Concept	AS/RS Concept	Difference
Capital Costs	6,825,000	8,031,841	1,206,841
Operation Costs/yr.	782,203	131,411	650,792
Pay Back Years without Interest Cost			1,206,841/650,792 = **1.85 years**
Interest Cost at 7%		84,479	
Operation Costs/yr.	782,203	215,890	566,313
Pay Back Years without Interest Cost			1,206,841/566,313 = **2.13 years**

This analysis is without considering soft/ (hard when known) justification criteria such as pilferage costs - security, safety, reliability of production, reliability of retrieval load needs, accuracy of retrieval filling, inventory reduction, etc.

Table 6. – A Tabulation of the Rate of Return Given the Incremental Investment in AS/RS*

Life (yrs)	VNA	AS/RS	AS/RS Vs. VNA	NPW (i=8%)	Rate of Return
0	-$6,825,000	-$8,031,841	-$1,206,841	($1,206,841)	Negative
1	-$782,203	-$131,411	-$650,792	($604,256)	Negative
2	-$782,203	-$131,411	-$650,792	($46,307)	5%
3	-$782,203	-$131,411	-$650,792	$470,313	29%
4	-$782,203	-$131,411	-$650,792	$948,665	40%
5	-$782,203	-$131,411	-$650,792	$1,391,583	46%
6	-$782,203	-$131,411	-$650,792	$1,801,692	49%
7	-$782,203	-$131,411	-$650,792	$2,181,423	51%
8	-$782,203	-$131,411	-$650,792	$2,533,026	52%
9	-$782,203	-$131,411	-$650,792	$2,858,584	53%
10	-$782,203	-$131,411	-$650,792	$3,160,026	53%
11	-$782,203	-$131,411	-$650,792	$3,439,140	53%
12	-$782,203	-$131,411	-$650,792	$3,697,578	54%
13	-$782,203	-$131,411	-$650,792	$3,936,873	54%
14	-$782,203	-$131,411	-$650,792	$4,158,442	54%
15	-$782,203	-$131,411	-$650,792	$4,363,599	54%

Note…
*The AS/RS requires an additional investment of $1,206,841 but saves $650,792 per year in operation costs. Using i=8%, we can find the NPW of this difference and see that it has a positive value as long as the system is used for three or more years. The rate of return is also computed and you can see that it is a very good investment. In fact, the numbers would actually be better if you factored in the effect of inflation. The bottom line is that, given these numbers, the AS/RS is clearly a superior investment over the VNA concept.

SUMMARY

The VNA Concept provides a number of advantages and disadvantages

- Operates at higher throughput with 1 machine down
- But has a machine down more often
- Has lower initial cost
- But lower return on investment

The AS/RS Concept provides a number of advantages and disadvantages

- Eliminates machine operators
- Has less throughput with 1 machine down
- Uses less square footage
- Higher return on investment

The AS/RS Concept has more subtle advantages such as:

- More capability than standard inventory control
- The S/R machine does not take breaks
- Reduced training time
- Higher inventory security
- Less product damage

It is argued that every application should follow the same rigors of analysis used in this example. You might be surprised by the results. At the very least, you can stand by your recommendations with confidence.

CONCLUSION

Crane-in-Aisle, AS/RS, in this case

- Has the advantage
- Economically and
- Most every other way

APPENDIX A

Should the reader have need for a system of 25 to 35% of the example rates, the following is an overview of a solution for that level of automatic replenishment storage compared to a manual VNA storage solution.

The following is an example of a “pick-to-pallet” system with an equal number of SKUs, but with only 25% of the throughput as the first system described in this paper. This means the system provides 1632 pallet picking positions and 11,424 reserve pallet positions. The loads are duplicate of the first system. The picking system uses the pick tunnels, but with pallet jacks for picking-to-pallet, and a vertical lift at the front end of each aisle in the systems for picked pallet to be lowered to the ground floor.

The replenishment system is to have a peak throughput of 30 “dual cycles” per hour for replenishment of the pick positions, 30 stores per hour of new product and the retrieving of 4 stacks of empty pallets per hour.

Concepts

Two finalists emerge from the number of concepts considered. One concept uses manually operated turret trucks in a very narrow aisle configuration and standard industrial, post and beam pallet racks; this is called the VNA Concept. The second concept uses automatic storage and retrieval machines with high-rise racks; it is called the AS/RS Concept.

VNA Concept

Given the right circumstances, the “VNA Concept” is a justifiable solution to many storage applications. The VNA Concept, for the circumstances of these alternate system requirements, is similar to the two sketches: Figures 1 and 2. The plan view (Figure 1) shows the eight-aisle storage / replenishment system with 68 pallet positions down the aisle and double deep across the aisles. The post and beam rack construction has two pallets per bay with their 40” dimension into the opening. Also shown are the four three high pick tunnels, serviced by three Turret Trucks transferring between the eight Turret Truck aisles.

At the head end of each pick tunnel is a vertical lift normally used for lowering picked pallets to the ground floor. These lifts can occasionally be used to raise or lower the pallet jacks that normally stay on each pick tunnel level.

AS/RS Concept

Given the right circumstances, the “AS/RS Concept” is a justifiable solution to many storage applications. The AS/RS Concept, for the circumstances of these alternate system requirements, is shown by two sketches: Figures 4 and 5. The plan view (Figure 4) shows the four-aisle storage / replenishment system with 68 pallet positions down the

aisle and double deep across the aisles. The high-rise rack construction has one pallet per column of storage, with the two pallets deep arranged with their 40" dimension into the opening. Also shown are the two, six-high pick tunnels, serviced by two S/R machines transferring between the four S/R machine aisles. A transfer unit at the back end is automated to provide this transferring function.

At the head end of each pick tunnel is a vertical lift normally used for lowering picked pallets to the ground floor. These lifts can occasionally be used to raise or lower the pallet jacks that normally stay on each pick tunnel level.

Table 1A. – A Comparison of VNA and AS/RS Operating Conditions

	VNA Concept	**AS/RS Concept**
System throughput required	Concept Capability	Concept Capability
Peak per hour: 30 pallets stored 30 transferred (replenished) 4 pallet stacks retrieved Total loads moved/system	 15 / truck 15 / truck 2/ truck 141	 31 / SR Machine 31 / SR Machine 4 / SR Machine 194
Sustained per hour: 25 pallets stored 25 transferred (replenished) 3 pallet stacks retrieved Total loads moved/system	 13/truck 13/truck 2/truck 123	 27 / SR Machine 27 / SR Machine 3.5 / SR Machine 169
Common Activity Spread 32% store only 4% retrieved only 32% as dual cycles Total loads moved/system	Common Activity Spread 123	Common Activity Spread 169
Machine operators	6 per day	None
Maintenance personnel	25% of a person	15% of a person
Supervisory personnel	20% of a person	10% of a person
Scheduling personnel	15% of a person	5% of a person

Table 3A. – A Partial Comparison of VNA and AS/RS Strengths and Weaknesses
(Refer to Table 3, in Main Example, for the Common Strengths and Weaknesses)

	VNA Concept	AS/RS Concept
Strengths		
Equipment failure	Can run at reduced capacity with one machine not operating – 33% loss	Can run at reduced capacity with one machine not operating – 50% loss
Expansion	Can add fifth tunnel and one machine	Can lengthen aisles up to the throughput of each of two machines
Reliability	Generally high reliability, but VNA hydraulics and batteries tend to have more failures	Generally high reliability with AS/RS electric drives and PLC having fewer failures
System Cost	Lower initial cost	Lower life cycle cost and higher return on investment
Weaknesses		
Operator vs. Automatic	Requires six operators per day	
Downtime	Only 33% loss operation is one machine is down	50% loss operation if one machine is down
Floor cost	The higher the system, the flatter the floor and the higher the cost	

Table 4A. – A Comparison of VNA and AS/RS Capital and Operating Costs

	VNA Concept	AS/RS Concept
Capital Costs		
Machines installed	(3) $301100	(2) $871,000
Racks installed	1,288,000	2,373,000
Controls	33,000	175,000
Fire Protection	475,000	350,000
Total Equipment	2,097,100	3,769,000
Building	3,512,681	3,078,178
Land & Site Preparation	807,734	415,464
Total Capital	6,417,515	7,262,642
Operation Costs		
Labor, Direct	210,000	0
Labor, Indirect	6,000	2,000
Supervision	14,000	7,000
Heat, Light, Power	137,015	89,869
Maintenance	19,033	14,710
Total Operation per Year	386,048	113,579

Table 5A. – A Presentation of Simple Pay Back Over the Incremental Investment in AS/RS

	VNA Concept	AS/RS Concept	Difference
Capital Costs	6,417,515	7,262,642	845,127
Operation Costs/yr.	386,048	113,579	272,469
Pay Back Years without Interest Cost			845,127/272,469= **3.10 years**
Interest Cost at 7%		59,159	
Operation Costs/yr.	386,048	172,738	213,310
Pay Back Years without Interest Cost			845,127/213,310= **3.96 years**

This analysis is without considering soft/ (hard when known) justification criteria such as pilferage costs - security, safety, reliability of production, reliability of retrieval load needs, accuracy of retrieval filling, inventory reduction, etc.

Table 6A. – A Tabulation of the Rate of Return Given the Incremental Investment in AS/RS*

Life (yrs)	VNA	AS/RS	AS/RS Vs. VNA	NPW (i=8%)	Rate of Return
0	-$6,417,515	-$7,262,642	-$845,127	($845,127)	Negative
1	-$386,048	-$113,579	-$272,469	($592,841)	Negative
2	-$386,048	-$113,579	-$272,469	($359,243)	Negative
3	-$386,048	-$113,579	-$272,469	($142,948)	Negative
4	-$386,048	-$113,579	-$272,469	$57,325	11%
5	-$386,048	-$113,579	-$272,469	$242,763	18%
6	-$386,048	-$113,579	-$272,469	$414,464	23%
7	-$386,048	-$113,579	-$272,469	$573,447	26%
8	-$386,048	-$113,579	-$272,469	$720,654	28%
9	-$386,048	-$113,579	-$272,469	$856,956	29%
10	-$386,048	-$113,579	-$272,469	$983,162	30%
11	-$386,048	-$113,579	-$272,469	$1,100,019	31%
12	-$386,048	-$113,579	-$272,469	$1,208,221	31%
13	-$386,048	-$113,579	-$272,469	$1,308,407	31%
14	-$386,048	-$113,579	-$272,469	$1,401,172	32%
15	-$386,048	-$113,579	-$272,469	$1,487,066	32%

Note…
*The AS/RS requires an additional investment of $845,127 but saves $272,469 per year in operation costs. Using i=8%, we can find the NPW of this difference and see that it has a positive value as long as the system is used for five or more years. The rate of return is also computed and you can see that it is a good investment. In fact, the numbers would actually be better if you factored in the effect of inflation. The bottom line is that, given these numbers, the AS/RS is a superior investment over the VNA concept, but is not as good as the higher throughput main example.

SUMMARY

The summary is essentially the same as the main example, except the AS/RS concept has 37% more throughput capacity built-in than the VNA concept. In other words, if the throughput went up from 30 to 40 pallets per hour, the VNA concept would have to add one machine and the AS/RS would not.

CONCLUSION

Crane-in-Aisle, AS/RS, in this case

- Has an advantage
- Economically and
- Many other ways

APPENDIX B

There are many successful Unit Load AS/RS applications in North America and throughout the world, especially in Europe and Japan. The situation described in this paper is but one typical application with different throughputs. The following are suggestions where someone might look first for other applications. These ideas are only a few of the characteristics that make good AS/RS applications.

Most Favorable Markets For AS/RS Applications

Manufacturing discrete parts
Machining centers
Manufacturing heavy industry parts
Manufacturing and assembling of electronic family
Warehousing and distribution with high throughput

Most Favorable Operational Conditions For AS/RS Applications

Three shift operation
Two shift operation
Critical Inventory levels
Staging for production flexibility
Joint storage parts and tool
Dual cycle throughput 10 to 35 per hour (20 to 70 loads moved)

Very Favorable Location

High cost of land
Soil - 3000 psi or greater
Where building height restrictions are not limiting
Skilled technicians availability
High value parts or assemblies
Medium number of SKU’s
Existing site space to avoid moving

Very Favorable Environment

Cold storage
Frozen foods
Strict item tracking

Conceptual Ideas for Other AS/RS Applications

Dual load operation
Double deep storage
Machine per aisle
Transfer between aisles

Reduced number of machines saves cost, but will result in lost space in a building for the transfer area; example 2 machines in a 4 aisles system is about 10% loss in a 240-foot system.

Load Sizes And Weights For Pallet/Tub Unit Load Applications

Typical Size: 40” wide x 48” long x 54” high (including 6” pallet)
Typical Weight: 2500 pounds

Size Range Table:

	Width	Length	Height
Minimum	36”	36”	8”
Maximum	120”	120”	96”

Weight Range: 750 # to 6,000 #

Range of Available Machine Speeds Today for Pallet/Tub Unit Load Applications

Motion	Low/Slow	Medium/Nominal	High/Fast
Travel	320 fpm	540 fpm	800 fpm
Hoist	60 fpm	120 fpm	240 fpm
Shuttle	12 seconds	9 seconds	7.5 seconds