DLA-92-P10090

A COMPARATIVE COST ANALYSIS OF MATERIAL HANDLING EQUIPMENT FOR THE CONNECTOR BUILDING COMPLEX

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OPERATIONS RESEARCH AND ECONOMIC ANALYSIS OFFICE

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DLA-LO

FOREWORD

This report identifies the cost of implementing an automated guided vehicle system and compares this to the cost of utilizing conventional equipment for the same functions in the Connector Building Complex at Defense Depot Richmond, Virginia. The report provides the information necessary to decision makers to select an appropriate type of equipment.

The results of this study indicate that several alternatives are feasible and cost effective. The study also describes in detail the resources required to implement each alternative. Finally, the anal sis shows that investment in a full scale automated guided veh e system is not cost effective. Implementation of a more conventional type of equipment would provide Defense Depot Richmond, Virginia, with the ability to meet all processing goals and afford an opportunity for DLA to experience a savings of $6.2 million in discounted dollars.

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Assistant Director
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EXECUTIVE SUMMARY

The construction of the Connector Building Complex (CBC) at Defense Depot Richmond, Virginia (DDRV), is well under way and due to be completed in February 1992. The original concept for the CBC included an automated guided vehicle (AGV) system to be installed throughout. However, based on depot consolidation efforts in progress for all of Defense Logistics Agency (DLA), the mission of DDRV may be changing. For this reason, the Directorate of Supply Operations, Depot Operations Division (DLA-OWM), asked DLA Operations Research and Economic Analysis Management Support Office (DORO) to perform an analysis to determine if an AGV system or an alternative type of equipment would be most cost effective for the CBC.

The results of the study indicate that an AGV system would not be cost effective at any foreseeable workload level. Implementation of a full scale AGV system, which would handle a workload similar to that which DDRV currently handles, would have a 10-year life cycle cost of $8.4 million in discounted dollars. In this study, we propose using forklifts and transporters to handle the same workload, at a cost of $2.2 million in discounted dollars, over the same life cycle. Selection of this alternative would result in a cost savings to DLA of $6.2 million in discounted dollars over the AGV system.

I. INTRODUCTION

A. Background.

The contract for the Connector Building at Defense Depot Richmond Virginia (DDRV) was awarded in December 1989. This contract provided for a building to be built which would connect buildings 11 and 14 in the bulk warehousing area with buildings 60 and 59 in the bin warehousing area. The contract also called for other common connections between existing buildings which when combined with connections already in place resulted in the DDRV Connector Building Complex (CBC) (See Figure 1). The CBC at completion would consist of nine connected warehouse buildings and the Connector Building itself. The original design called for an Automated Guided Vehicle (AGV) system to be used in the CBC to move pallet and module size loads throughout the complex. This AGV system would extend to every building in the complex utilizing 16,850 feet of guidepath. The AGV system as well as other mechanization for the CBC was under a separate contract. Requests for bids were to be released in June of 1991 and could be modified before then to accomodate any changes in requirements. We briefed our results in May of 1991 to provide the necessary information for modifications.

Currently, depot consolidation efforts are underway in the Defense Logistics Agency (DLA). As a result of these efforts, the workload at DDRV is expected to change. This change will probably be manifested in the overall volume of workload, as well as in the ratio of bin to bulk items processed. For this reason, the Directorate of Supply Operations, Depot Operations Division, (DLA-OWM), asked DLA Operations Research and Economic Analysis Management Support Office (DORO) to perform an analysis to determine whether the use of an AGV system or the use of conventional material handling equipment is most cost effective for the CBC.

B. Purpose. Determine the economic impact of implementing a full scale AGV system or utilizing conventional equipment in regard to the changing role of DDRV in the DLA Depot System.

C. Study Objectives.

1. Estimate the cost of moving material throughout the CBC using an AGV system and using conventional equipment.

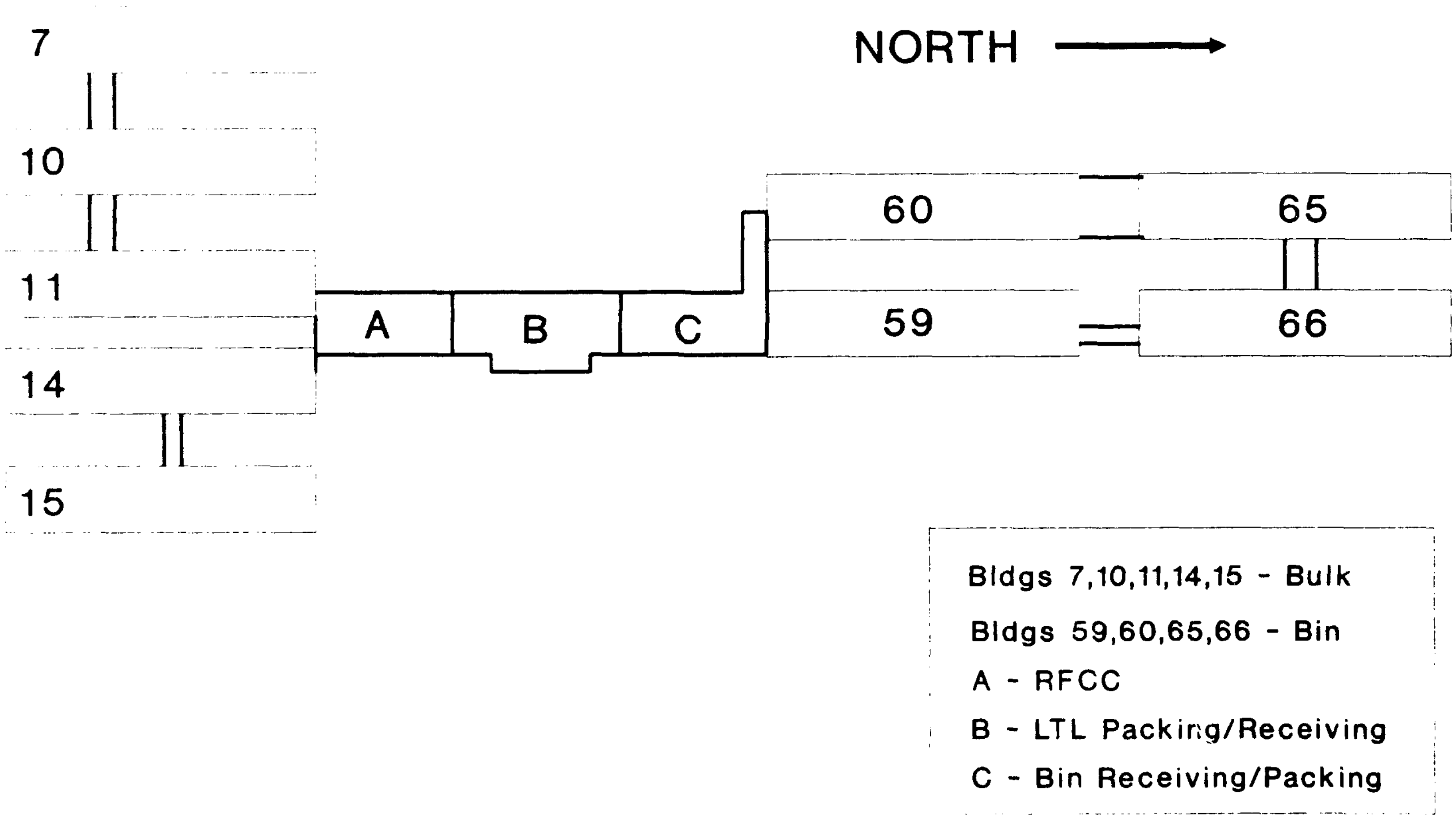
2. Cost each of the systems using several workload scenarios.

3. Cost each of the systems using present value analysis to project and compare costs over a predetermined life cycle.

D. Scope. The study will be limited to material handling equipment for the CBC that is related to the functions that would be performed by an AGV system.

Figure 1

CONNECTOR BUILDING COMPLEX



II. CONCLUSIONS

The analysis yielded the following conclusion:

o An AGV system is not as cost effective as other material handling equipment under any foreseeable workload scenario.

III. RECOMMENDATIONS.

Proceed with the use of conventional material handling equipment, such as transporters, forklifts and mule trains, in the CBC, instead of an AGV system.

IV. SAVINGS AND BENEFITS

A. Savings. The discounted cost for an AGV system which would handle a baseline workload is $8.4 million over a 10-year life cycle. The cost of using the least costly combination of alternative equipment over the same period is $2.2 million. The difference in discounted dollars is then $6.2 million.

B. Benefits. The benefits of using one of the conventional equipment types fall into two categories, flexibility and maintainability. Any alternative which requires installation of a guidepath or in-floor mechanization would configure the CBC to a particular operational plan. Changing this configuration at a later date to adapt to different requirements could be difficult. The use of transporters, mule trains and forklifts does not disturb the useable floor space in the storage areas. Should the missions for these areas change, the areas could be re-configured without regard to problems of moving guidepath or towline.

DDRV already has extensive experience maintaining the equipment in use there. Naturally, this experience has allowed them to become efficient in keeping this equipment up and operating. Furthermore, there is no reason to think that maintaining this equipment in the future will be any different than it has been in the past.

Even under ideal circumstances, the implementation of a new type of equipment is going to cause some maintenance problems. There will be learning curves and training requirements. Additionally, equipment such as AGV systems tends to be maintenance intensive, needing expensive replacement parts and specially trained technicians.

V. METHODOLOGY

A. General Methodology. The basic approach for this analysis involved costing the AGV system as designed by Depot Operations Support Office (DOSO) and comparing that cost with the cost of available alternatives which would perform the same functions as the AGV system. This was accomplished using the following five step process:

1. Review of the Design and Operation of the CBC. The CBC was originally designed with an AGV system to move pallets and modules throughout

the complex. Any alternative equipment, therefore, would have to satisfy the requirements associated with the AGV system. In order to isolate the tasks performed by the AGV system, DORO reviewed the design specifications with DOSO and DDRV. We then developed flow charts to record pallet and module movements. These flow charts included the number of pallets and modules to be moved from each location as well as distances between locations. Ultimately, the distances from location to location were used to calculate travel times for the various types of equipment.

In reviewing the operation it became evident that the bin and bulk areas were serviced by a contiguous AGV system. For all practical purposes the bin and bulk areas are separate and distinct operations. The areas are located at opposite ends of the complex and have separate packing and receiving operations. It was one of our initial proposals that bin and bulk be examined as distinct areas particularly from the aspect of using different alternatives in each one.

2. Establish Workload Levels. The number of pallet and module movements in the DOSO design of the AGV system are derived from a baseline workload which approximates what DDRV is currently handling. One problem that exists in estimating pallet and module loads is that the density of the load often varies. There is no way to convert a given number of items directly to a module or pallet load. This fact is particularly evident in the bin area. We were aware of the variation in module and pallet loads, and we also knew that the workload at DDRV would change. In order to compensate for these two conditions, we conducted the analysis using several workload levels. The different workload levels used were percentage increases and decreases to the baseline workload for bin and bulk. These percentages and the associated number of modules and pallets are listed in Table 1.

3. Determine equipment alternatives and configurations. DDRV uses a variety of equipment to move material. This equipment includes transporters, mule trains, fork lifts and conveyors (both pallet and package conveyors). Since these types of equipment are already used successfully they were obvious candidates for alternatives to an AGV system. Also considered as an alternative was a towveyor system. Towveyers are not in use at DDRV, but are in use at other DLA depots.

The final list of alternatives we presented to DLA-OWM was as follows:

- AGVs
- Transporters
- Mule Trains
- Towveyors
- Forklifts (Exclusively)
- Conveyors

The conveyor alternative consisted of powered pallet conveyors in the bulk area and package conveyors in the bin area. These conveyors would be installed to basically overlay the AGV guidepath. From the onset it was evident that this alternative would be far too costly. By mutual agreement with DLA-OWM and DOSO the CBC-wide conveyor system was dropped as an

Table 1

DAILY WORKLOAD BIN AND BULK AREAS

DAILY WORKLOAD - BIN AREA

MODULE MOVES	SCENARIO 30%	60%	BASE	120%
RECEIVING TO STORAGE	30	60	100	120
STORAGE TO PACKING	18	36	60	72
PACKING TO LTL	20	41	68	82
TOTAL	68	137	228	274

DAILY WORKLOAD - BULK AREA

PALLET MOVES	SCENARIO 75%	BASE	125%
STORAGE TO PACKING	157	209	261
RECEIVING TO STORAGE	288	384	480
TOTAL	445	593	741

alternative. Some additional explanation is required regarding the forklift alternative. Forklifts are required to some extent with several of the other alternatives. For example, if mule trains are being used as the primary method to move pallets and modules, forklifts are required to unload the mule trains at the packing induction points. When the cost estimates were done for the mule train alternative the total cost included the required forklift and forklift operator. The forklift alternative involves using forklifts exclusive of any other equipment to replace an AGV system.

4. Cost the Equipment and Personnel. The cost of the AGV was developed by DOSO. This cost was based on current industry data for comparable systems, and itemized by all major components. Because the costs were itemized, it was possible to configure and cost an AGV system for each workload scenario considered.

The conventional material handling equipment used in this analysis is already in use at DDRV. The purchase price and maintenance costs for this equipment were readily available.

The personnel costs were computed using the current pay scale for wage grade personnel at DDRV. In addition to the basic hourly wage rate, factors were also added to account for leave and benefits. This will be discussed in further detail in the following sections.

5. Perform a present value analysis over a 10-year life cycle. A 10-year life cycle was chosen as a reasonable analysis period based on the fact that the equipment involved has an approximate life span of 10 years. Present value factors were applied to the costs for all alternatives in the same manner. All of the equipment involved in the analysis was for the most part homogeneous in type. Therefore, it was unlikely that inflation would have a significantly different effect on any one type. The labor costs for the entire analysis involved the wage grade labor force at DDRV.

VI. ANALYSIS

A. Operational Procedures for the AGV System and Alternate Equipment.

1. AGV. The AGV system was designed to operate throughout the CBC. The guidepath of the AGV system would extend to every building. Additionally, each building in the bin and bulk areas would have many pick-up and deposit stands (P & D stands). The P & D stands would be located as follows:

In the bin area:

Buildings 59 and 66--along the West Wall.
Buildings 60 and 65--along the East Wall.

In the bulk area:

Building 7--along the West Wall
Building 10--along the East Wall
Building 11--along the West Wall

Building 14--along the East Wall
Building 15--along the West Wall

There would also be P & D stands, as well as induction and discharge conveyor interfaces located throughout LTL packing and receiving. These provisions enable the AGV system to perform any point to point movement of pallets or modules almost anywhere in the CBC.

2. Alternative Equipment. In order to make comparisons between the proposed AGV system and alternative types of equipment, it was first necessary to design operational procedures for the alternate types of equipment. These operational procedures would ensure that the alternative equipment would in fact be capable of fulfilling the functions of the AGV system.

a. Towveyor.

A towveyor is a conveyance system which consists of a vehicle that is pulled by a mechanism installed along a path in the floor. The mechanism in the floor is generally a series of sprockets and chains which are driven by electric motors. The vehicle itself has no propulsion system, only a lever or rod which can be set to direct it into particular spurs off of the main path. Towveyor vehicles will follow a path similiar in layout to the AGV guidepath. The vehicles will be staged on spurs in the same general locations as the AGV P & D stands throughout the bin and bulk areas.

In the bin area stock pickers will place modules on the towveyor vehicle and activate it. The vehicle will transport the module to the induction conveyor in bin packing. The vehicle would then pick up an empty module and return it to one of the spurs in the bin area. Towveyer vehicles would also transport modules from bin receiving to the staging spurs in the bin area, where stock pickers will remove the modules and store the items.

In the bulk area stock pickers will place pallets on towveyor vehicles and activate the vehicle. The vehicle will transport the pallet to the induction point at the pallet conveyor in Section A of CBC. Pallets from LTL receiving will be transported by pallet conveyor to Section A where a towveyor vehicle will pick up the pallet and transport it to a spur in the bulk area. Once in the bulk area a stock picker will remove the pallet and store it.

The towveyor system would operate for the most part automatically in regard to traveling. It may be necessary to have operators activate and direct vehicles coming from the receiving areas.

b. Transporters.

A transporter is a single axle flatbed truck that has powered rollers across the entire bed. This truck works in conjunction with a special roller dock.

A transporter can load and unload modules or pallets from these docks at the rate of ten at a time. Transporters currently operate throughout DDRV on established routes. Inbound and outbound transporter docks are already in place in the existing buildings.

In the bin areas stock pickers will place modules on outbound docks. When a dock is full a transporter will be dispatched to remove the modules and take them to a transporter dock in bin packing. In the bin packing area a fork lift will unload modules from the inbound dock and place them on an induction conveyor. In bin receiving, a forklift will place modules on an outbound dock and a transporter will take the modules to an inbound dock in the bin storage area. Stock pickers will then remove the modules from the dock for storage.

In the bulk storage areas stock pickers will stage pallets on outbound transporter docks. Pallets can also be staged in staging areas inside the building immediately behind the docks. When the outbound docks become full, a transporter is dispatched to pick up the pallets and deliver them to less than truck load (LTL) packing. In LTL packing the inbound docks are designed to interface with the pallet induction conveyors. The flow of pallets from the inbound transporter docks to LTL packing would be essentially continuous. In LTL receiving the dock and conveyor system would be basically the same, so that pallets could flow directly from the receiving area to the outbound docks. A transporter would then take the pallets from an outbound dock in the bulk storage area. In the bulk storage area stock pickers will remove the pallets from the dock and place them into storage.

c. Mule Trains.

A mule train is a series of carts which are towed one behind the other by a small tractor called a tug. They can operate inside or outside the warehouse buildings. Mule trains are currently in use at DDRV.

In the bin area empty mule train carts will be staged in locations similiar to the AGV P & D stands. Stock pickers will place modules on the carts and tugs will cycle through the area and tow the carts to the bin packing area. In bin packing a forklift will offload modules from the carts onto the induction conveyor. In bin receiving modules will be placed on mule train carts by forklift and a tug will tow the carts back to the staging area in bin storage, where stock pickers will remove the modules and store the items.

d. Forklifts.

Forklifts are currently used extensively at DDRV. Forklifts could be used extensively throughout the CBC as the sole means of conveying modules and pallets. In the bin storage area stock pickers will stage modules on the floor in locations similiar to the P & D stands. In the bulk area, the same procedure would be followed. Forklifts would then retrieve staged pallets and modules from the floor areas and transport them to the proper induction point. The forklifts would also transport the pallets and modules from the LTL and bin receiving areas to the floor staging areas in bin and bulk storage.

B. Equipment Capabilities and System Requirements.

The next phase of the analysis involved integrating the capabilities of each equipment type with the actual system requirements. These system requirements are dependent on two basic factors, the distances the equipment will travel and the workload levels. The operational procedures provided a fundamental framework for the routes that vehicles would have to travel. From these routes we calculated round trip distances for modules and pallet movements. Figure 2 is a diagram of the CBC annotated with the lengths of the main sections.

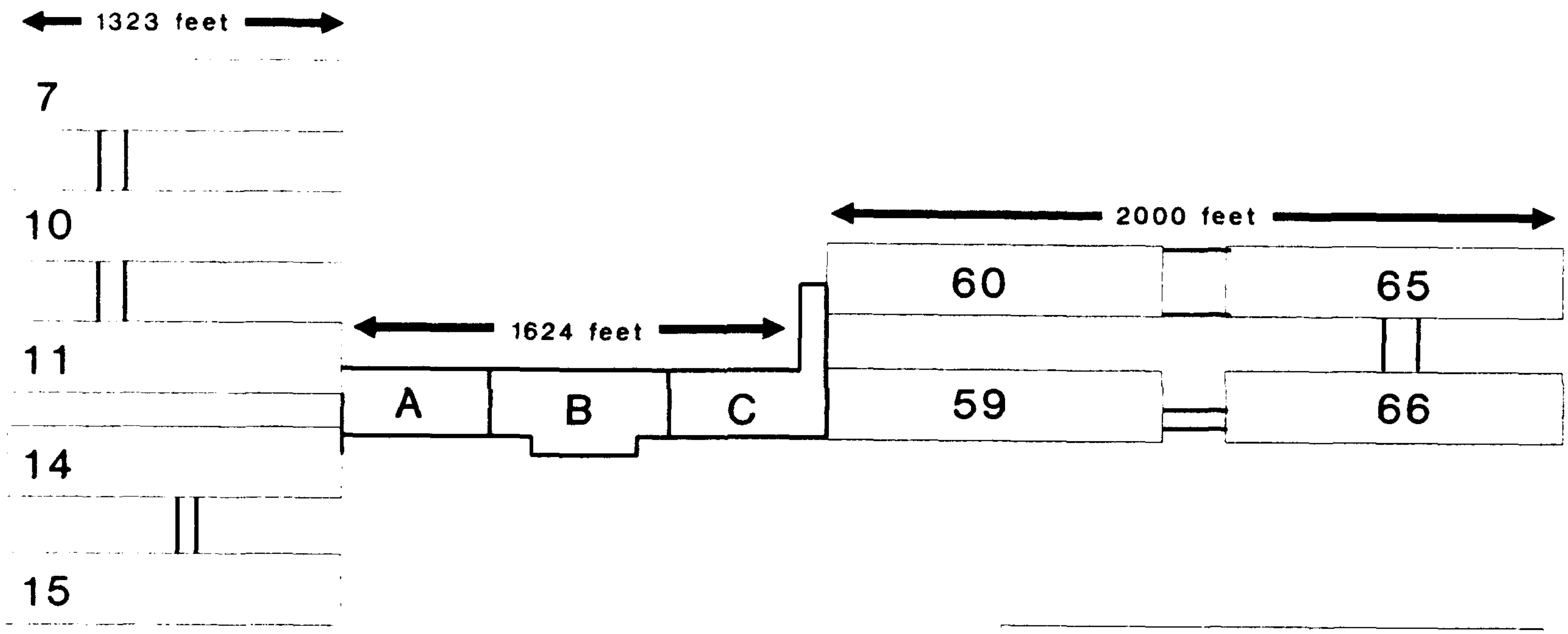
The essential component in evaluating the capabilities of each alternative type was the individual equipment characteristics. These characteristics consist of speed, capacity and specific travel distances. Speed refers to the average speed in miles per hour at which vehicles travel. Capacity refers to the number of modules or pallets that the equipment will handle as a single load. Specific travel distances refer to the exact route a particular type of equipment would use. These routes may vary because of the varying nature of the equipment. For example, a transporter travels on the road system outside and around the CBC, traveling exterior to the building adds distance to the transporter routes. A mule train can travel through the interior of the CBC, this reduces the travel distance over an exterior route. The mule train, however, has restrictions even other interior vehicles do not have. A mule train requires wide aisles and open floor space to turn around. It is very likely that a mule train would have to travel some distance past the intended pick-up point in order to find a suitable place to turn around and begin the return trip. Other interior vehicles such as a forklift can turn and maneuver in much less space, shortening their travel distances. The AGV and towveyor vehicles follow a predetermined guidepath that is usually in the form of a large loop. This loop is often not a direct route and lengthens the travel distances.

Because of the many differences in equipment capabilities, each type of equipment was evaluated separately. A summary of the characteristics of all the alternative equipment is shown in Table 2.

Maximum distance to travel and maximum travel time refer to the longest round trip cycle a vehicle travels. The data for the equipment was obtained by observing and timing the equipment currently in use at DDRV. For equipment not currently in use at DDRV, specifically the towveyor and the AGV, industry standard data was used.

Figure 2

CONNECTOR BUILDING COMPLEX



Bldgs 7,10,11,14,15 - Bulk

Bldgs 59,60,65,66 - Bin

A - RFCC

B - LTL Packing/Receiving

C - Bin Receiving/Packing

Table 2

EQUIPMENT CHARACTERISTICS

AGV
Speed-1.76 MPH
Capacity-1 module or 1 pallet

Bin Area

Maximum distance to travel	-5,000 feet
Maximum travel time	-32 minutes

Bulk Area

Maximum distance to travel	-3,500 feet
Maximum travel time	-23 minutes

TOWVEYOR
Speed-20 MPH
Capacity-1 module or 1 pallet

Bin Area

Maximum distance to travel	-5,000 feet
Maximum travel time	-32 minutes

Bulk Area

Maximum distance to travel	-3,500 feet
Maximum travel time	-23 minutes

TRANSPORTER
Speed-20 MPH
Capacity-10 modules or 10 pallets
Load and unload time-1 minute

Bin Area

Maximum distance to travel	-10,000 feet
Maximum travel time	-6 minutes

Bulk Area

Maximum distance to travel	-15,000 feet
Maximum travel time	-9 minutes

MULE TRAIN
Speed-5 MPH
Capacity- 1 module or 1 pallet

Bin Area

Maximum Distance to travel	-4,500 feet
Maximum travel time	-11 minutes

Bulk Area

Maximum distance to travel	-3,300 feet
Maximum travel time	-8 minutes

It is important to note certain aspects of the data. The speeds for the transporters, mule trains and lift trucks represent average speeds and are somewhat conservative. The speeds for the AGV and towveyor are more precise as those systems can be set to operate at an exact and constant speed. There are time factors associated with the transporter and the mule train that involve the acquisition and discharge of the load. For the transporter this is the load and unload time or the time it takes to roll pallets or modules from the dock to the transporter and vice versa. For a mule train this is the time required to attach and detach the cart from the tug. With the other forms of equipment, the transfer times are not as distinct of an operation and their transfer times are factored into the overall travel time. As an example, a forklift delivering a pallet deposits that pallet in almost a simultaneous action without stopping to turn around. In any case, we have included all the time elements required for the equipment to complete its function, either as a discrete time element or part of a continuous travel time period.

C. Performance Throughput. Based on the capabilities and operational procedures for the alternative equipment, it was possible to model the performance of each type of equipment. Each type was evaluated on the basis of throughput for a single 8-hour shift. This throughput was then compared to the various workload levels required in an 8-hour shift.

1. AGV System. The AGV system was evaluated using a computer simulation model written in the SLAM language. The AGV system was the only alternative evaluated in this way. The reason for this was twofold. The AGV system is a dynamic system which continuously readjusts itself to make the optimum use of all its vehicles. The other equipment follows set routes and schedules. Also, every individual AGV vehicle is very expensive. It was very important to define exactly how many vehicles were required for each workload scenario. So, where mule trains, transporters and forklifts could be evaluated on a component by component basis, the AGV system had to be evaluated as a whole, taking into consideration the synergistic effects of all vehicles working together. The simulation of the AGV system was designed using 8 full hours per shift and using the number of vehicles as an input variable. Several iterations of the model were run using different workloads and varying the total number of vehicles within the same workload framework. We reviewed the results of the model runs and identified the least number of vehicles which could handle a given workload.

2. Towveyors. The towveyor system operates similiar to the AGV system. However, there are two major differences. The towveyor carts are not dynamically allocated; rather they are set in motion to a particular destination, and must complete a round-trip cycle before they can be re-assigned. The other difference is that the carts are relatively inexpensive, so that increasing the number of carts does not signifigantly increase cost. Because of these differences the towveyor system could be evaluated using a mathematical model. The main output variable to the model was, as with the AGV system, the number of vehicles or carts. The towveyor system was modeled with all of the workload scenarios and generally required more carts as the workload increased. The towveyor also requires two operators to activate the

carts and send them to their destination. The towveyor system like the AGV system was modeled to operate 8 hours in a shift.

3. Transporters, Mule Trains and Forklifts. Transporters, mule trains and forklifts do not operate as a unified system in the same way that an AGV system or a towveyor system does. For this reason it was only necessary to model a single unit of equipment from each of the types. This was done using a simple mathematical model. Once the performance capabilities of one unit were identified, it was a simple matter of calculating what two or more units would do. In this way, the equipment could be matched rather easily to the workload requirements.

Transporters, mule trains and forklifts have to be manned by operators at all times. It was therefore necessary to apply Personal, Fatigue and Delay (P.F. and D) factors to the 8-hour shift time. The P.F. and D. factor used was 12.6 percent. This figure represents a conservative approach to estimating productive time as it is at the high end of factors used for standards with depot operations. Reducing the 8-hour shift by 12.6 percent yielded slightly less than 7 hours of productive time per shift. This 7-hour time, and the throughput capacity of each type of equipment were input into the models. The results are summarized in Table 3.

VII. COST ANALYSIS

A. General.

Using the previously developed data we projected three cost configurations over a 10-year life cycle. These cost configurations covered the baseline workload scenario, the low workload scenario, and the high workload scenario. The baseline workload scenario consisted of the baseline workloads for both the bin and bulk areas. The low workload scenario consisted of the 30 percent of baseline workload for the bin area and the 75 percent of baseline workload for the bulk area. The high workload scenario consisted of the 120 percent workload for the bin area and the 125 percent workload for the bulk area.

The projection included all costs for systems, vehicles maintenance and personnel. The personnel costs are based on the current wage grade pay scale for DDRV and include an 18 percent factor for leave and a 29.55 percent factor for benefits. The mid-range of each pay grade was used as the hourly wage. The annual maintenance cost for the AGV system was 11 percent of the purchase price. The factor for all other equipment was 7 percent annually. The AGV is somewhat higher due to the higher costs for parts.

Several of the alternative types of equipment are already in place at DDRV, but for the purpose of this analysis all equipment required for every alternative was purchased as new. The cost factors for each alternative are shown in Table 4.

Table 3

PALLET AND MODULE MOVEMENT CAPABILITIES

Transporters (per vehicle)
Bin area-410 modules per shift
Bulk area-370 pallets per shift

Mule Trains (per tug with 4 carts)
Bin Area-160 modules per shift
Bulk Area-160 pallets per shift

Forklifts (per vehicle)
Bin Area 69 modules per shift
Bulk Area-59 pallets per shift

Vehicles required for each workload scenario.

Bin Area	Workload			
	30 Percent	60 Percent	Baseline	120 Percent
Transporters	1	1	1	1
Mule Trains	1	1	2	2
Forklifts	2	3	4	4

Bulk Area	75 Percent	Baseline	125 Percent
Transporters	2	2	2
Mule Trains	3	4	5
Forklifts	8	10	13

Table 4

COST FACTORS

	System	Vehicle (each)
AGV	$2,961,190	$64,110
Towveyer	$2,244,420	$1,500
Transporter	$368,000	$110,000
Mule Trains	$0	$15,000
ForkLift	$0	$24,000

The system cost for the AGV system includes the computer hardware and software which control the system, the guidepath and the battery charging equipment. The system cost for the towveyor includes the motors, the towline and the spurs. The transporter alternative does not have a system cost as such; however, a cost factor has been included here to insure that all docks will be in proper working order and to cover the cost of new modules for the bin area which would be required if transporters are used. Mule trains and forklifts have no system cost. The total cost for a 10-year life cycle for the low, baseline and high workload scenarios is shown in Table 5 in undiscounted and discounted dollars. Figure 3 is a graphical representation of this data.

Table 5

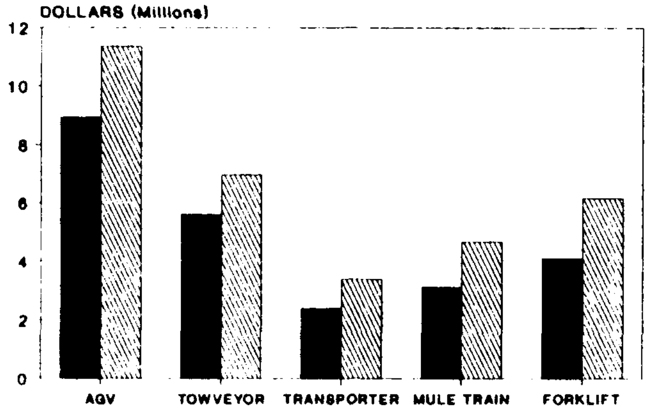
TOTAL COST 10-YEAR LIFE CYCLE

Low Workload Scenario	Discounted	Undiscounted
AGV	7,337,148	9,345,708
Towveyer	5,321,178	6,570,491
Transporter	2,170,600	3,020,808
Mule Train	1,837,931	2,734,589
Forklift	2,404,337	3,614,771
Baseline Workload Scenario	**Discounted**	**Undiscounted**
AGV	8,403,336	10,692,020
Towveyer	5,553,897	6,918,561
Transporter	2,411,034	3,382,286
Mule Train	2,856,246	4,257,377
Forklift	3,366,072	5,060,679
High Workload Scenario	**Discounted**	**Undiscounted**
AGV	8,936,430	11,365,170
Towveyer	5,591,838	6,964,461
Transporter	2,411,034	3,382,286
Mule Train	3,124,197	4,656,359
Forklift	4,087,373	6,145,110

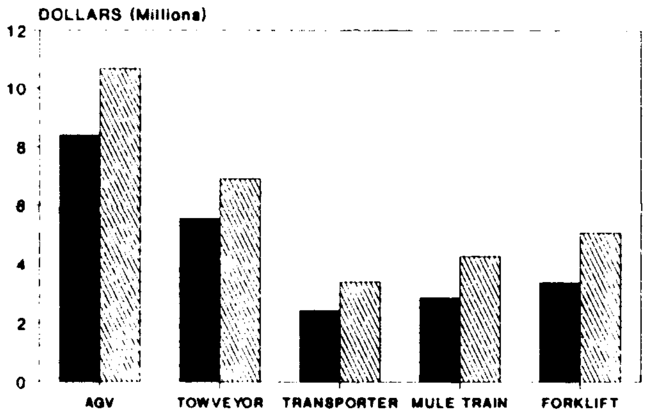
Figure 3

TOTAL COST/10-YEAR LIFE CYCLE

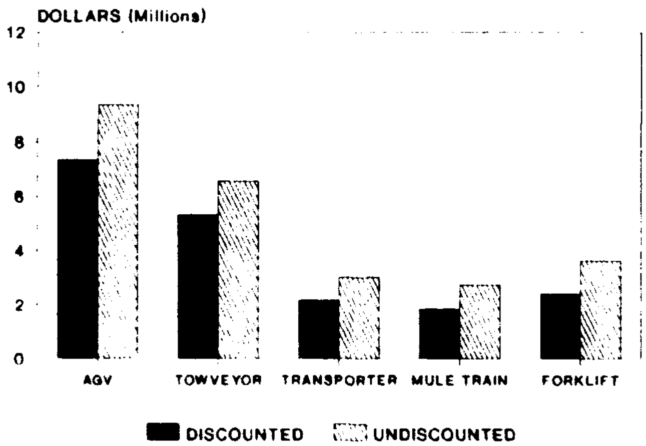
HIGH WORKLOAD LEVEL



BASELINE WORKLOAD LEVEL



LOW WORKLOAD LEVEL



Two significant things are evident from the graphs. The first is that the cost of each alternative increases and decreases as the workload level increases and decreases. The second is that the AGV system is not cost effective at any of these levels.

The reason that the AGV is so costly is twofold. The initial cost for the system is very high and the individual vehicle cost is very high. It is true that there are not any direct labor costs involved with the operation of an AGV system, but the savings in labor is not sufficient to offset the other high costs.

Figure 4 is a line graph showing the cumulative discounted costs for all the alternatives under a baseline workload scenario. This graph shows that even though the slope of the lines is similiar, the high initial costs are the predominant factor.

B. <u>Least Cost Alternatives</u>.

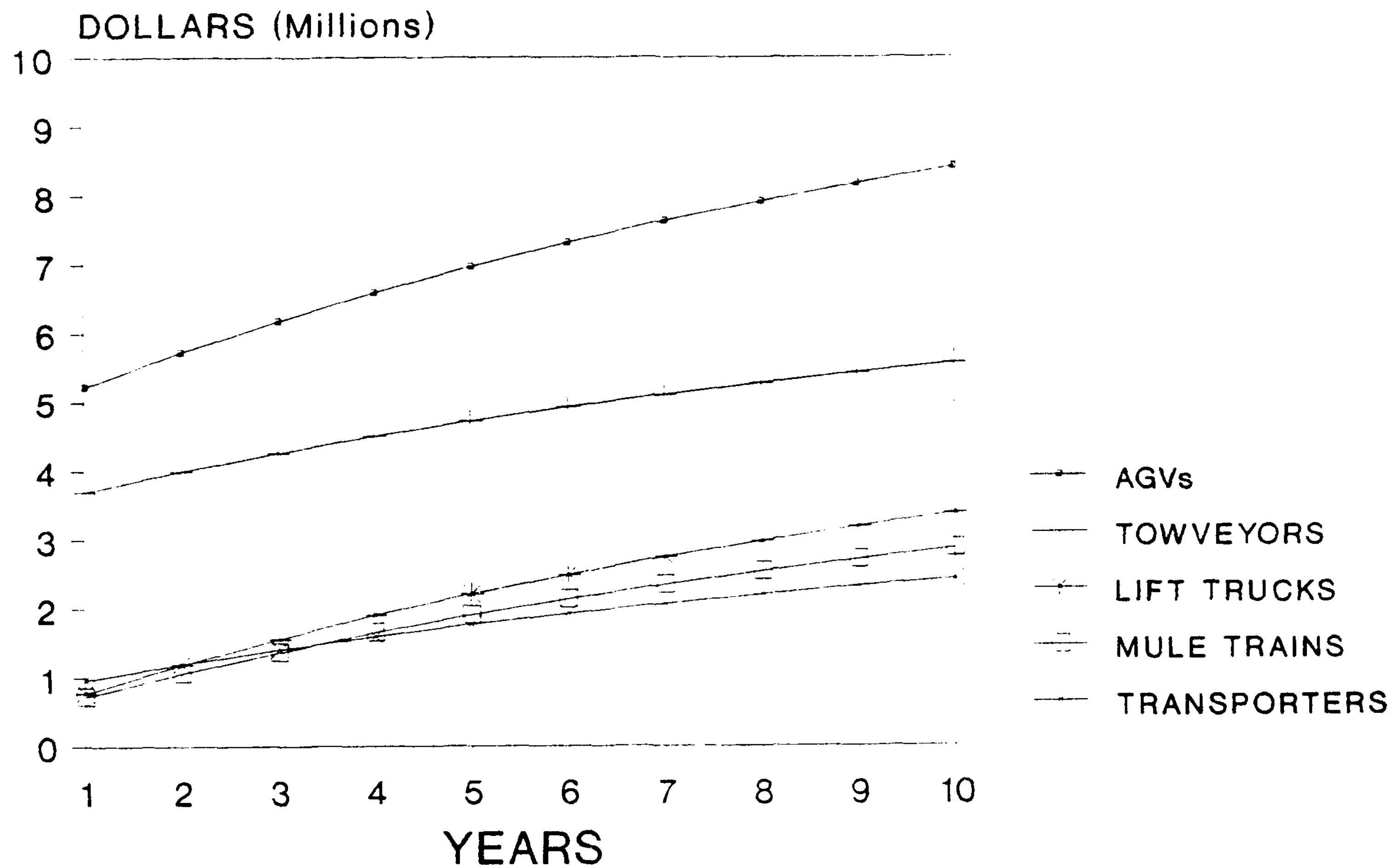
The initial cost comparisons in this analysis viewed each alternative as a single system to be used throughout the CBC. The bin and bulk areas serve as natural divisions within the CBC. In order to identify a least cost alternative for bin and bulk it was necessary to isolate these areas and examine the differences in each. To some extent the equipment that is an integral part of the bin and bulk operations dictated the least cost alternatives. As an example, in bin packing there is no established link between the dock area and induction conveyors. If a transporter were used in this area, some other type of equipment would still be required to move modules from the dock to the induction point. The degree to which equipment interfaced became an important factor in identifying the least cost alternative. The bin and bulk areas have some similarities but have enough differences to require different equipment. The manner in which the proprietary equipment in bin and bulk interfaced with the alternative equipment ultimately dictated the least cost equipment for that area.

Figure 5 illustrates the cost of the alternative equipment, for bin and bulk, for a 10-year life cycle under the baseline workload scenario. The least cost alternatives are forklifts in the bin area and transporters in the bulk area. The total cost of the combination of these two alternatives is shown in Table 6, as well as the difference in cost between the least cost alternative combination and the AGV system. The difference in discounted dollars of using the least cost combination verses the AGV system is $6.2 million. This difference would vary under different workload scenarios.

Also, the least cost alternative equipment would vary for different workload scenarios in the bin area. The transporter alternative remains the least cost alternative in the bulk area under all workload scenarios as its degree of efficiency in that area is far superior to the other alternatives. In the bin area, the difference in the alternatives is not that pronounced among the forklifts, mule trains and transporters. An exhaustive look at all possible combinations is not appropriate for this study. In any case, the alternatives presented as least cost are for cost comparison purposes and not intended to

Figure -

CUMULATIVE COST - DISCOUNTED
BASELINE WORKLOAD



be specific operational recommendations. It is important to note that with the costs shown in Figure 5 for the AGV system the towveyor system in bin and bulk add up to a cost which is greater than the cost previously shown for the total system. This is because the AGV and the towveyor system have high fixed costs which are not proportionally reduced by reducing the size of the system. The other alternative equipment can be reduced in somewhat of a constant ratio.

C. Additional Alternative.

When we briefed our findings to DDRV, they requested that we consider one additional alternative. DDRV expressed reservations about operating the bin area with mule trains, transporters or forklifts. Their recommendation was to use a package conveyor and a module tug system in the bin area. As previously discussed in the analysis, a conveyor system which traversed the entire CBC was absolutely cost prohibitive. However, the DDRV recommendation was for a very limited, basic conveyor system in the bin area, that would operate in one direction only. This conveyor would carry the picked bin items to bin packing. Items from bin receiving would be brought to the bin storage area in modules towed by a special module tug. DDRV felt that this alternative was operationally the most efficient and safe.

DOSO completed a basic design for the requested alternative in June 1991. The cost for implementing the package conveyor alternative over a 10-year life cycle for the baseline workload is $1.3 million in discounted dollars. This would be approximatley $300,000 more over 10-years than the forklift alternative. A comparison of this cost is shown on the graph in Figure 6. A comparison of the cost of the combination of the transporters in the bulk area/package conveyor in the bin area, and the other alternatives, is shown in Figure 7.

Figure 5

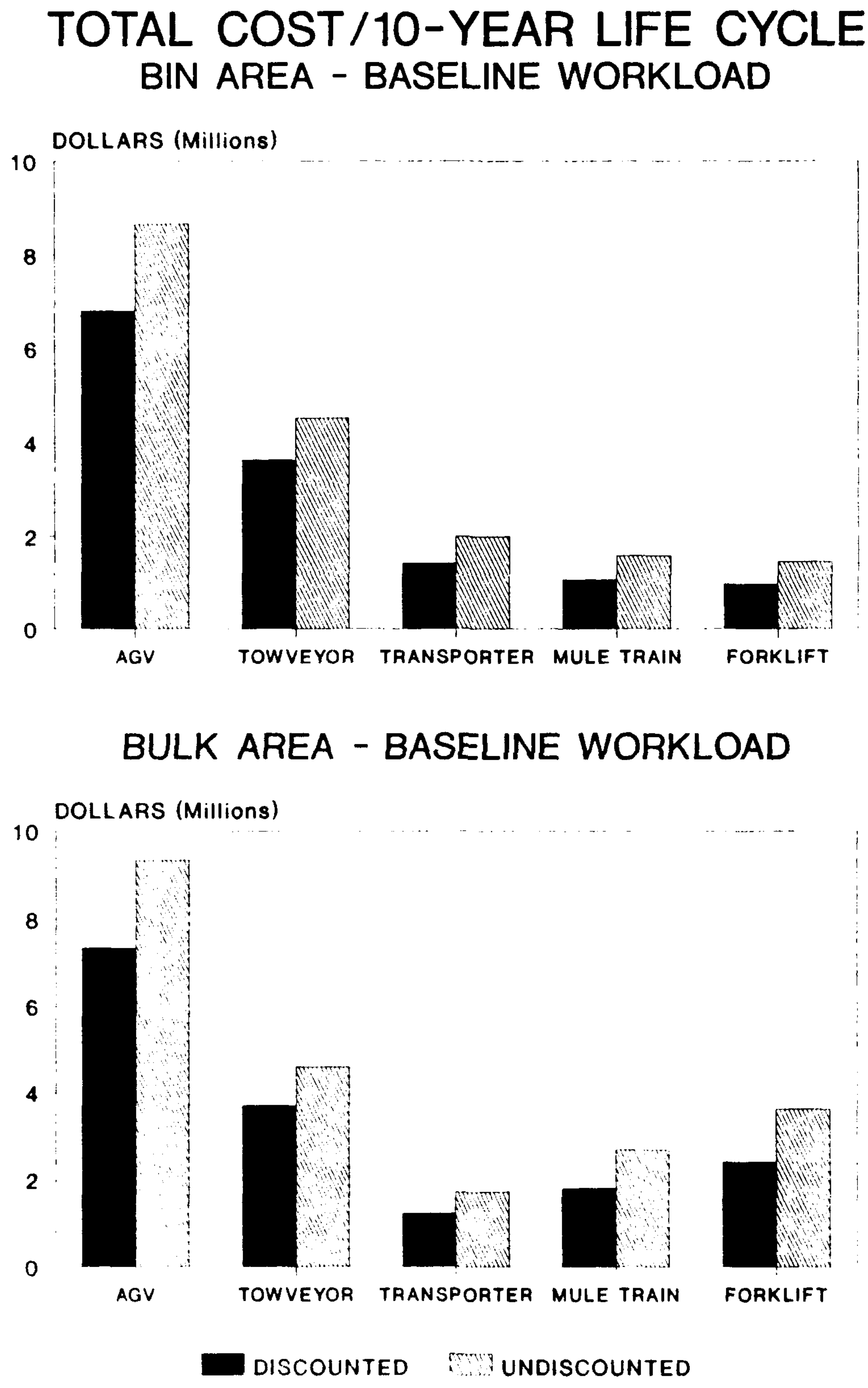

TOTAL COST/10-YEAR LIFE CYCLE
BIN AREA - BASELINE WORKLOAD
DOLLARS (Millions)
10
8
6
4
2
0
AGV
TOWVEYOR
TRANSPORTER
MULE TRAIN
FORKLIFT
BULK AREA - BASELINE WORKLOAD
DOLLARS (Millions)
10
8
6
4
2
0
AGV
TOWVEYOR
TRANSPORTER
MULE TRAIN
FORKLIFT
DISCOUNTED
UNDISCOUNTED

Table 6

LEAST COST COMBINATION
10-YEAR LIFE CYCLE

	COST UNDISCOUNTED	COST DISCOUNTED
BIN AREA - FORKLIFTS	1,445,908	961,735
BULK AREA - TRANSPORTERS	1,723,301	1,225,318
TOTAL	3,169,209	2,187,053

LEAST COST COMBINATION VERSES AGVs

	COST UNDISCOUNTED	COST DISCOUNTED
AGVs	10,692,018	8,403,336
LEAST COST ALTERNATIVE	3,169,209	2,187,053
DIFFERENCE	7,522,809	6,216,283

Figure [illegible]

TOTAL COST/10-YEAR LIFE CYCLE
BIN AREA - BASELINE WORKLOAD

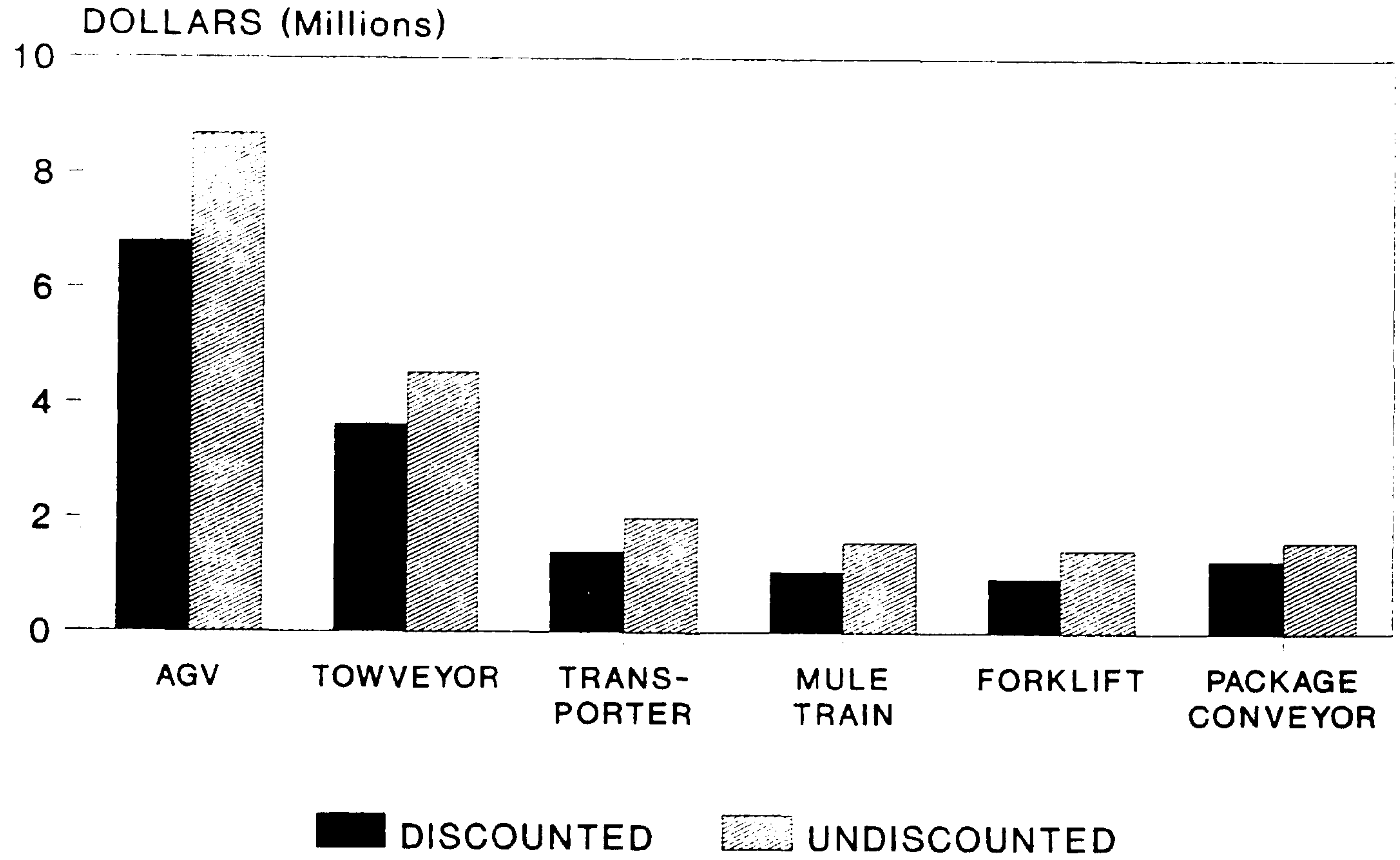
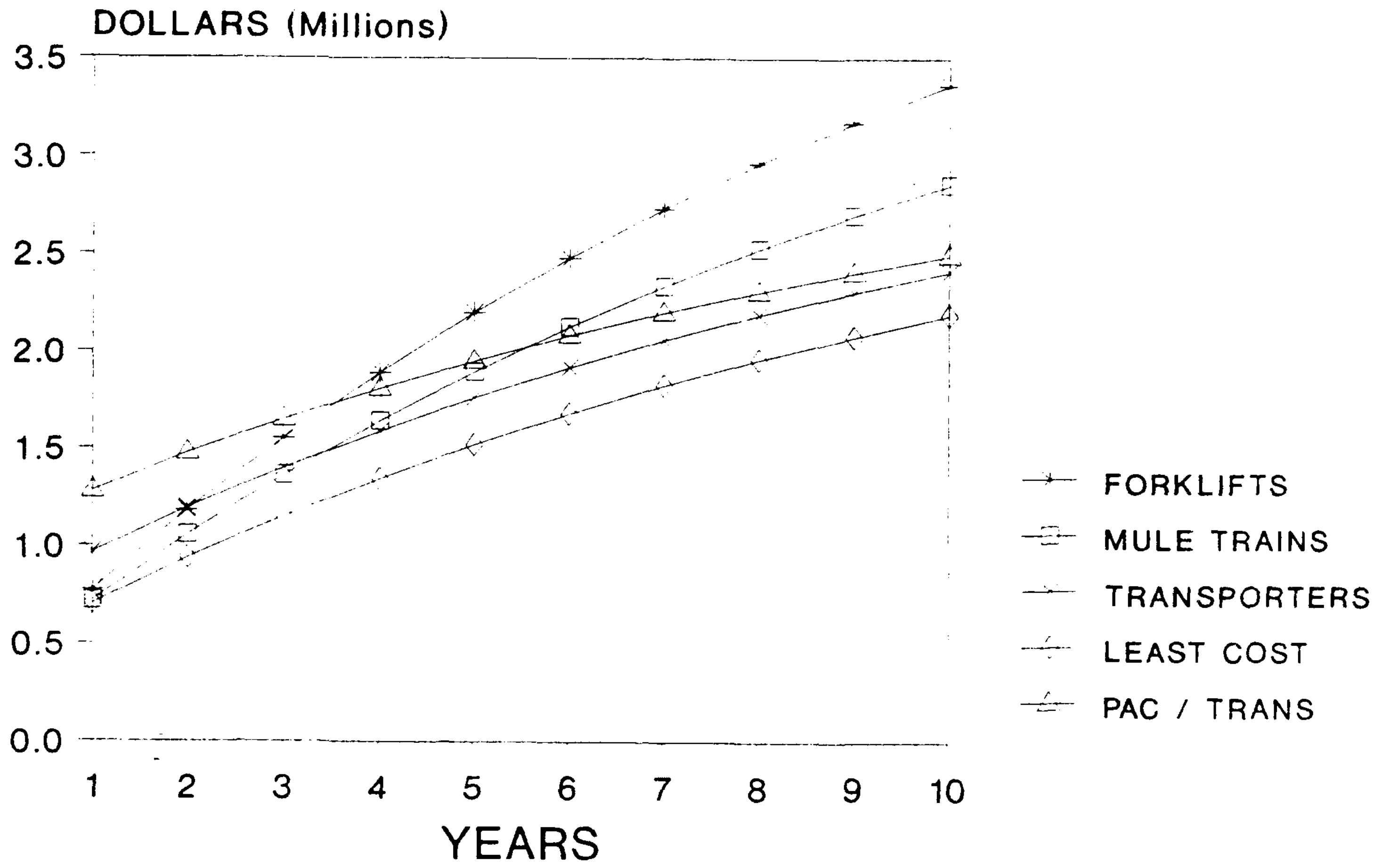


Figure 7

PACKAGE CONVEYOR/TRANSPORTER
BASELINE WORKLOAD



APPENDIX A

Figure A-1, A-2 and A-3 provide the annual cost amounts for the 10-year life cycle for each major cost element within the different alternatives. These figures represent the baseline, high and low workload scenarios respectively. Figures A-4, A-5 and A-6 show the annual cost totals and cummulative costs for each alternative under the same scenarios in both discounted and undiscounted dollars.

Figure A-1

DETAILED COST INFORMATION

BASELINE WORKLOAD LEVEL

	COST/DATA ELEMENTS	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10	TOTAL
AGVS												
EQUIPMENT COSTS												
SYSTEM COST	$2,961,190	2961190										2961190
VEHICLE COST	$64,110											0
REQUIRED VEHICLES	30	1923300										1923300
MAINTENANCE COST	0.11	537294	537294	537294	537294	537294	537294	537294	537294	537294	537294	5372939
PERSONNEL COSTS												
VEHICLE OPERATORS												
OTHER OPERATORS												
GRADE/PAY RATE												
MAINTENANCE PERSONNEL	1	43459	43459	43459	43459	43459	43459	43459	43459	43459	43459	434589
GRADE/PAY RATE	WG11/17.62											
												$10,792,018
[illegible]												
EQUIPMENT COSTS												
SYSTEM COST	$3,370,000	3370000										3370000
CART COST	$1,500	166500										166500
REQUIRED CARTS	111											
MAINTENANCE COST	[illegible]	247555	247555	247555	247555	247555	247555	247555	247555	247555	247555	2475550
PERSONNEL COSTS												
VEHICLE OPERATORS	0											
OTHER OPERATORS	3	90651	90651	90651	90651	90651	90651	90651	90651	90651	90651	906511
GRADE/PAY RATE	WG4/9.47											
												$6,918,5[illegible]
TRANSPORTERS												
EQUIPMENT COSTS												
SYSTEM COST	$368,000	368000										368000
TRANSPORTER COST	$110,000	330000										330000
FORKLIFT COST	$24,000	48000										48000
REQUIRED TRANSPORTERS	3											
REQUIRED FORKLIFTS	2											
MAINTENANCE COST	[illegible]	52220	52220	52220	52220	52220	52220	52220	52220	52220	52220	522200
PERSONNEL COSTS												
TRANSPORTER OPERATORS	[illegible]	113529	113529	113529	113529	113529	113529	113529	113529	113529	113529	1135291
GRADE/PAY RATE	WG8/11.86											
DISPATCHER	[illegible]	37744	37744	37744	37744	37744	37744	37744	37744	37744	37744	377439
GRADE/PAY RATE	GS[illegible]											
FORKLIFT OPERATOR	2	64135	64135	64135	64135	64135	64135	64135	64135	64135	64135	641354
GRADE/PAY RATE	WG5/[illegible]											
												$3,382,286
MULE TRAINS												
EQUIPMENT COSTS												
SYSTEM COST	0											
TUG COST	$15,000	90000										90000
CART COST	$1,100	151800										151800
FORKLIFT COST	$24,000	120000										120000
REQUIRED TUGS	6											
REQUIRED CARTS	138											
REQUIRED FORKLIFTS	5											
MAINTENANCE COST	0.07	25326	25326	25326	25326	25326	25326	25326	25326	25326	25326	253260
PERSONNEL COSTS												
TUG OPERATORS	6	203893	203893	203893	203893	203893	203893	203893	203893	203893	203893	2038932
GRADE/PAY RATE	WG6/10.65											
FORKLIFT OPERATOR	5	160339	160339	160339	160339	160339	160339	160339	160339	160339	160339	1603385
GRADE/PAY RATE	[illegible]											
												$4,257,377
FORKLIFTS												
EQUIPMENT COSTS												
SYSTEM COST	[illegible]											0
FORKLIFT COST	$24,000	336000										336000
REQUIRED FORKLIFTS	14											
MAINTENANCE COST	[illegible]	23520	23520	23520	23520	23520	23520	23520	23520	23520	23520	235200
PERSONNEL COSTS												
FORKLIFT OPERATORS	14	448948	448948	448948	448948	448948	448948	448948	448948	448948	448948	4489479
GRADE/PAY RATE	WG5/10.75											
												$5,060,679

Figure A-2

DETAILED COST INFORMATION

HIGH WORKLOAD LEVEL

	COST DATA ELEMENTS	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10	TOTAL
AGVS												
EQUIPMENT COSTS												
SYSTEM COST	$2,961,190	2961190										2961190
VEHICLE COST	$64,110											
REQUIRED VEHICLES	35	2243850										224385
MAINTENANCE COST	0.11	572554	572554	572554	572554	572554	572554	572554	572554	572554	572554	5725540
PERSONNEL COSTS												
VEHICLE OPERATORS	0											
OTHER OPERATORS												
GRADE/PAY RATE	0											
MAINTENANCE PERSONNEL	1	43459	43459	43459	43459	43459	43459	43459	43459	43459	43459	434590
GRADE/PAY RATE	WG11/13.62											
												$11,365,173
CONVEYORS												
EQUIPMENT COSTS												
SYSTEM COST	$3,370,000	3370000										3370000
CART COST	$1,500	193500										193500
REQUIRED CARTS	129											
MAINTENANCE COST	0.07	249445	249445	249445	249445	249445	249445	249445	249445	249445	249445	2494450
PERSONNEL COSTS												
VEHICLE OPERATORS	0											
OTHER OPERATORS	[illegible]	90651	90651	90651	90651	90651	90651	90651	90651	90651	90651	906510
GRADE/PAY RATE	WG4/9.47											
												$6,964,4[illegible]
TRANSPORTERS												
EQUIPMENT COSTS												
SYSTEM COST	$368,000	368000										368000
TRANSPORTER COST	$110,000	330000										330000
FORKLIFT COST	$24,000	48000										48000
REQUIRED TRANSPORTERS	3											
REQUIRED FORKLIFTS	2											
MAINTENANCE COST	0.07	52220	52220	52220	52220	52220	52220	52220	52220	52220	52220	522200
PERSONNEL COSTS												
TRANSPORTER OPERATORS	3	113529	113529	113529	113529	113529	113529	113529	113529	113529	113529	1135290
GRADE/PAY RATE	WG8/11.86											
DISPATCHER	1	33744	33744	33744	33744	33744	33744	33744	33744	33744	33744	337440
GRADE/PAY RATE	GS6											
FORKLIFT OPERATOR	2	64135	64135	64135	64135	64135	64135	64135	64135	64135	64135	641350
GRADE/PAY RATE	WG5/10.05											
												$7,282,[illegible]
MULE TRAINS												
EQUIPMENT COSTS												
SYSTEM COST	0											
TUG COST	$15,000	105000										105000
CART COST	$1,100	171600										171600
FORKLIFT COST	$24,000	120000										120000
REQUIRED TUGS	7											
REQUIRED CARTS	156											
REQUIRED FORKLIFTS	5											
MAINTENANCE COST	0.07	27762	27762	27762	27762	27762	27762	27762	27762	27762	27762	277620
PERSONNEL COSTS												
TUG OPERATORS	7	237875	237875	237875	237875	237875	237875	237875	237875	237875	237875	2378754
GRADE/PAY RATE	WG6/10.65											
FORKLIFT OPERATOR	5	160339	160339	160339	160339	160339	160339	160339	160339	160339	160339	1603385
GRADE/PAY RATE	WG5/10.05											
												$4,656,[illegible]
FORKLIFTS												
EQUIPMENT COSTS												
SYSTEM COST	0											
FORKLIFT COST	$24,000	408000										408000
REQUIRED FORKLIFTS	17											
MAINTENANCE COST	0.07	28560	28560	28560	28560	28560	28560	28560	28560	28560	28560	285600
PERSONNEL COSTS												
FORKLIFT OPERATORS	17	545151	545151	545151	545151	545151	545151	545151	545151	545151	545151	5451510
GRADE/PAY RATE	WG5/10.05											
												$6,145,110

Figure A-3

DETAILED COST INFORMATION

LOW WORKLOAD (F.F)

	COST/DATA ELEMENTS	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10	TOTAL
AGVS												
EQUIPMENT COSTS												
SYSTEM COST	$2,961,190	2961190										2961190
VEHICLE COST	$64,110											0
REQUIRED VEHICLES	20	1282200										1282200
MAINTENANCE COST	0.11	466773	466773	466773	466773	466773	466773	466773	466773	466773	466773	4667729
PERSONNEL COSTS												
VEHICLE OPERATORS	0											
OTHER OPERATORS												
GRADE/PAY RATE	0											
MAINTENANCE PERSONNEL	1	43459	43459	43459	43459	43459	43459	43459	43459	43459	43459	434589
GRADE/PAY RATE	WG11/13.62											
												$9,345,708
CONVEYORS												
EQUIPMENT COSTS												
SYSTEM COST	$3,370,000	3370000										3370000
CART COST	$1,500	139500										139500
REQUIRED CARTS	93											
MAINTENANCE COST	0.07	245665	245665	245665	245665	245665	245665	245665	245665	245665	245665	2456653
PERSONNEL COSTS												
VEHICLE OPERATORS	0											
OTHER OPERATORS	2	60434	60434	60434	60434	60434	60434	60434	60434	60434	60434	604341
GRADE/PAY RATE	WG4/9.47											
												$6,570,491
TRANSPORTERS												
EQUIPMENT COSTS												
SYSTEM COST	$363,000	362000										368000
TRANSPORTER COST	$110,000	330000										330000
FORKLIFT COST	$24,000	24000										24000
REQUIRED TRANSPORTERS	3											
REQUIRED FORKLIFTS	1											
MAINTENANCE COST	0.07	50540	50540	50540	50540	50540	50540	50540	50540	50540	50540	505400
PERSONNEL COSTS												
TRANSPORTER OPERATORS	3	113529	113529	113529	113529	113529	113529	113529	113529	113529	113529	1135293
GRADE/PAY RATE	WG8/11.86											
DISPATCHER	1	33744	33744	33744	33744	33744	33744	33744	33744	33744	33744	337439
GRADE/PAY RATE	GS6											
FORKLIFT OPERATOR	1	32068	32068	32068	32068	32068	32068	32068	32068	32068	32068	320677
GRADE/PAY RATE	WG5/10.05											
												$3,020,808
MULE TRAINS												
EQUIPMENT COSTS												
SYSTEM COST	0											
TUG COST	$15,000	60000										60000
CART COST	$1,100	111100										111100
FORKLIFT COST	$24,000	72000										72000
REQUIRED TUGS	4											
REQUIRED CARTS	101											
REQUIRED FORKLIFTS	3											
MAINTENANCE COST	0.07	17017	17017	17017	17017	17017	17017	17017	17017	17017	17017	170170
PERSONNEL COSTS												
TUG OPERATORS	4	135929	135929	135929	135929	135929	135929	135929	135929	135929	135929	1359288
GRADE/PAY RATE	WG6/10.65											
FORKLIFT OPERATOR	3	96203	96203	96203	96203	96203	96203	96203	96203	96203	96203	962031
GRADE/PAY RATE	WG5/10.05											
												$2,734,589
FORKLIFTS												
EQUIPMENT COSTS												
SYSTEM COST	0											0
FORKLIFT COST	$24,000	240000										240000
REQUIRED FORKLIFTS	10											
MAINTENANCE COST	0.07	16800	16800	16800	16800	16800	16800	16800	16800	16800	16800	168000
PERSONNEL COSTS												
FORKLIFT OPERATORS	10	320677	320677	320677	320677	320677	320677	320677	320677	320677	320677	3206771
GRADE/PAY RATE	WG5/10.05											
												$3,614,771

Figure A-4

YEARLY COSTS
BASELINE WORKLOAD

COSTS PER YEAR - UNDISCOUNTED	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10	TOTAL
AGVS	5465243	580753	580753	580753	580753	580753	580753	580753	580753	580753	10692018
CONVEYORS	3874706	338206	338206	338206	338206	338206	338206	338206	338206	338206	6918561
TRANSPORTERS	1009629	263629	263629	263629	263629	263629	263629	263629	263629	263629	3382286
MULE TRAINS	751358	389558	389558	389558	389558	389558	389558	389558	389558	389558	4257377
FORKLIFTS	808468	472468	472468	472468	472468	472468	472468	472468	472468	472468	5060679

COSTS PER YEAR - DISCOUNTED	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10	TOTAL
AGVS	5213842	503513	457633	416400	378070	343806	312445	283969	258435	245205	8403336
CONVEYORS	3696470	293225	266506	242494	220172	200218	181955	165383	150502	136973	5553897
TRANSPORTERS	963186	228566	207739	189022	171622	156068	141832	128914	117315	106770	2411034
MULE TRAINS	716795	337747	306971	279313	257602	230618	209582	190494	173353	157771	2856246
FORKLIFTS	771278	409630	372305	338759	307577	279701	254188	231037	210248	191349	3366072

CUMMULATIVE COSTS - UNDISCOUNTED	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10
AGVS	5465243	6045996	6626748	7207501	7788254	8369007	8949760	9530513	10111265	10692018
CONVEYORS	3874706	4212912	4551118	4889324	5227530	5565737	5903943	6242149	6580355	6918561
TRANSPORTERS	1009629	1273257	1536886	1800514	2064143	2327771	2591400	2855028	3118657	3382286
MULE TRAINS	751358	1140915	1530473	1920031	2309589	2699146	3088704	3478262	3867819	4257377
FORKLIFTS	808468	1280936	1753404	2225872	2698339	3170807	3643275	4115743	4588211	5060679

CUMMULATIVE COSTS - DISCOUNTED	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10
AGVS	5213842	5717354	6174988	6591387	6969457	7313263	7625708	7909696	8158131	8403336
CONVEYORS	3696470	3989694	4256201	4498694	4718867	4919085	5101040	5266422	5416924	5553897
TRANSPORTERS	963186	1191752	1399491	1588513	1760135	1916203	2058035	2186949	2304264	2411034
MULE TRAINS	716795	1054542	1361513	1640826	1898428	2125046	2334628	2525122	2698475	2856246
FORKLIFTS	771278	1180908	1553213	1891972	2199549	2479250	2733437	2964474	3174722	3366072

Figure A-5

YEARLY COSTS
HIGH WORKLOAD

COSTS PER YEAR - UNDISCOUNTED	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10	TOTAL
AGVS	5821053	616013	616013	616013	616013	616013	616013	616013	616013	616013	11765173
TOWVEYORS	3903596	340096	340096	340096	340096	340096	340096	340096	340096	340096	6964461
TRANSPORTERS	1009629	263629	263629	263629	263629	263629	263629	263629	263629	263629	3382286
MULE TRAINS	822576	425976	425976	425976	425976	425976	425976	425976	425976	425976	4456357
FORKLIFTS	981711	573711	573711	573711	573711	573711	573711	573711	573711	573711	6145110

COSTS PER YEAR - DISCOUNTED	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10	TOTAL
AGVS	5553285	534684	485418	441682	401525	364690	331415	301231	274126	249185	8536430
TOWVEYORS	3724031	294847	267976	243849	221403	201337	182972	166307	151223	137729	5571838
TRANSPORTERS	963186	228566	207739	189022	171622	156069	141832	128914	117315	106770	2411034
MULE TRAINS	784737	369321	335669	305425	277310	252178	229175	208302	189557	172520	3124197
FORKLIFTS	936552	497407	452084	411351	373486	339637	308657	280545	255071	232353	4087373

CUMMULATIVE COSTS - UNDISCOUNTED	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10
AGVS	5821053	6437067	7053080	7669093	8285107	8901120	9517133	10133147	10749160	11365173
TOWVEYORS	3903596	4243692	4583788	4923884	5263980	5604077	5944173	6284269	6624365	6963461
TRANSPORTERS	1009629	1273257	1536886	1800514	2064143	2327771	2591400	2855028	3118657	3382286
MULE TRAINS	822576	1248552	1674528	2100504	2526479	2952455	3378431	3804407	4230383	4656359
FORKLIFTS	981711	1555422	2129133	2702844	3276555	3850266	4423977	4997688	5571379	6145110

CUMMULATIVE COSTS - DISCOUNTED	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10
AGVS	5553285	6087968	6572787	7014468	7415993	7780173	8111588	8412819	8686945	8936430
TOWVEYORS	3724031	4018874	4286870	4530739	4752141	4953478	5136450	5302757	5454110	5591838
TRANSPORTERS	963186	1191752	1399491	1588513	1760135	1916203	2058035	2186949	2304264	2411034
MULE TRAINS	784737	1154059	1489728	1795152	2072463	2324640	2553815	2762118	2951677	3124197
FORKLIFTS	936552	1433960	1886044	2297395	2670881	3010518	3319174	3599719	3855020	4087373

Figure A-6

YEARLY COSTS
[illegible] WORKLOAD

COSTS PER YEAR - UNDISCOUNTED	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10	TOTAL
AGVS	4753622	510232	510232	510232	510232	510232	510232	510232	510232	510232	[illegible]
CONVEYORS	3815599	306099	306099	306099	306099	306099	306099	306099	306099	306099	6570491
TRANSPORTERS	951981	229881	229881	229881	229881	229881	229881	229881	229881	229881	[illegible]
MULE TRAINS	492249	249149	249149	249149	249149	249149	249149	249149	249149	249149	2734589
FORKLIFTS	577477	337477	337477	337477	337477	337477	337477	337477	337477	337477	[illegible]

COSTS PER YEAR - DISCOUNTED	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10	TOTAL
AGVS	4534955	442371	402063	365836	332161	302057	274505	249507	227053	206644	7337148
CONVEYORS	3640082	265388	241206	219473	199270	181211	164681	149682	136214	123970	5321178
TRANSPORTERS	908094	199307	181146	164825	149652	136089	123676	112412	102297	93102	[illegible]
MULE TRAINS	469605	216012	196329	178640	162196	147496	134042	121874	110871	100905	1837931
FORKLIFTS	550913	292593	265932	241971	219698	199786	181563	165026	150177	136678	2404337

CUMMULATIVE COSTS - UNDISCOUNTED	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10
AGVS	4753622	5263854	5774085	6284317	6794549	7304781	7815013	8325245	8835476	9345708
CONVEYORS	3815599	4121698	4427797	4733896	5039995	5346094	5652193	5958293	6264392	6570491
TRANSPORTERS	951881	1181762	1411643	1641523	1871404	2101285	2331166	2561047	2790928	3020808
MULE TRAINS	492249	741398	990547	1239696	1488845	1737993	1987142	2236291	2485440	2734589
FORKLIFTS	577477	914954	1252431	1589908	1927385	2264862	2602339	2939816	3277294	3614771

CUMMULATIVE COSTS - DISCOUNTED	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10
AGVS	4534955	4977326	5379389	5745225	6077386	6379443	6653948	6903451	7130504	7337148
CONVEYORS	3640082	3905469	4146675	4366148	4565419	4746630	4911311	5060993	5197207	5321178
TRANSPORTERS	908094	1107401	1288547	1453372	1603024	1739114	1862789	1975201	2077498	2170600
MULE TRAINS	469605	685618	881947	1060587	1222783	1370279	1504321	1626155	1737026	1837931
FORKLIFTS	550913	843506	1109438	1351409	1571106	1770893	1952455	2117482	2267659	2404337

APPENDIX B

Figure B-1 provides the detailed annual cost amounts for the major cost elements within the package conveyer alternative. Also, included are the annual cost totals and the cumulative costs in both discounted and undiscounted dollars.

Figure B-1

DETAILED COST INFORMATION

[illegible] CONVEYORS

EQUIPMENT COSTS

		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Total
SYSTEM COST	$[illegible]	630000										6[illegible]
TUG UNIT	$10,[illegible]	10[illegible]										
MODULE COST	$1,200	120[illegible]										120[illegible]
REQUIRED TUGS	1											
REQUIRED VEHICLES	[illegible]											
MAINTENANCE COST	[illegible]	44100	44100	44100	44100	44100	44100	44100	44100	44100	44100	441[illegible]
PERSONNEL COSTS												
VEHICLE OPERATORS												
TUG OPERATORS	1	32068	32068	32068	32068	32068	32068	32068	32068	32068	32068	3206[illegible]
GRADE/PAY RATE	WG5 10.05											
												$1,511,677

YEARLY COSTS
BASE LINE WORKLOAD

	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10	TOTAL
[illegible]	836168	76168	76168	76168	76168	76168	76168	76168	76168	76168	1521677
COST PER YEAR - DISCOUNTED	797704	66037	60020	54612	49585	45091	40978	37246	33895	30848	1216017
CUMMULATIVE COSTS - UNDISCOUNTED	836168	912335	988503	1064671	1140839	1217006	1293174	1369342	1445509	1521677	
CUMMULATIVE COSTS - DISCOUNTED	797704	863741	923762	978374	1027959	1073050	1114028	1151274	1185169	1216017	

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13. This study compares the cost of implementing an automated guided vehicle system to the cost of utilizing conventional equipment for the same functions in the Connector Building Complex (CBC) at Defense Depot Richmond, Virginia (DDRV). The original concept for the Connector Building Complex included an automated guided vehicle system to be installed throughout. Due to depot consolidation efforts in progress throughout DLA, the mission of DDRV may be changing. It was therefore necessary to perform an analysis to determine if an AGV system or an alternate type of equipment would be most cost effective for the CBC. The results of the study indicate that an AGV system system would not be cost effective at any foreseeable workload level. Implementation of a full scale AGV system, which would handle a workload similar to that which DDRV currently handles, would have a 10-year life cycle cost of $8.4 million in discounted dollars. This study recommends using forklifts and transporters to handle the same workload, at a cost of $2.2 million in discounted dollars, over the same life cycle. Selection of this alternative would result in a cost savings to DLA of $6.2 million in discounted dollars over the AGV system.

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