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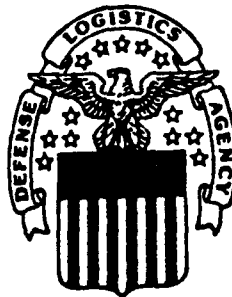
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DLA-93-P20147

RED RIVER DEPOT OPERATIONS CENTER DESIGN SIMULATION ANALYSIS

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DLA-93-P20147

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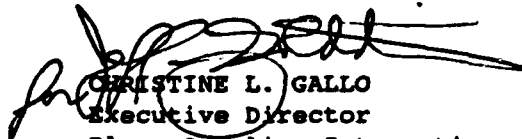


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FOREWORD

The Depot Operations Support Office (DOSO) has project lead on the construction of a Depot Operations Center (DOC) at Defense Depot Red River near Texarkana, Texas. The DOC will aggregate the currently separated functions of receiving, preservation and packaging, and packing and shipping. It will also provide additional internal storage space. DOSO design engineers developed blueprints for the DOC's new material handling equipment. Afterwards, Material Management Distribution tasked us to evaluate DOSO's proposed plan by simulating the operation of the DOC. This Red River DOC Design Simulation Analysis project examined DOSO's design from the dynamic operation perspective, searching for potential bottlenecks and improvements. We thank DOSO for their guidance throughout this undertaking, especially Mr. Jerry Beasley, Mr. Paul Wind, Ms. Amy Kasdorf, and Mr. Don Garrett.


CHRISTINE L. GALLO
Executive Director
Plans & Policy Integration

EXECUTIVE SUMMARY

The Defense Logistics Agency is in the process of creating a Depot Operations Center (DOC) at Defense Depot Red River, Texas. The DOC will consolidate the areas of receiving, preservation and packaging, and packing and shipping. Currently those functions are dispersed about the post. In addition, the new DOC, due for completion by 1997, will house new material handling equipment and provide additional internal storage. The Depot Operations Support Office (DOSO) has overall project responsibility for the new DOC. Accordingly, they developed the engineering design for consolidating the different functions within the DOC. They were able to appraise the value of the design in many areas. However, we were asked to assess the capabilities of DOSO's design in a dynamic environment by simulating the timing of items flowing through the material handling equipment.

The objective of this study was to test DOSO's proposed DOC design in a dynamic environment to identify potential problems and enhancements. The methodology was to 1) analyze historical data over the past 2 years to capture throughput estimates; 2) create a simulation model of the DOC to assess DOSO's design against expected workload; 3) collaborate with DOSO personnel while building the simulation model; 4) identify bottlenecks and other inefficiencies; and 5) recommend improvements/changes where appropriate. The scope was largely limited to the material handling equipment inside the DOC, particularly in the receiving, towveyor, and packing and shipping areas.

Generally, the receiving area met desired expectations. Recommendations for that area included increasing contract pull resources and decreasing module-load personnel for the multipack breakdown/small parcels area. In addition, the lone recommendation for the mechanized pallet area was to ensure quick pallet off-loads from the accumulating conveyors.

The towveyor section was well designed also. The only recommendation for this area was to increase the spur lengths at three awaiting transportation points to accommodate the prepositioning of extra carts.

Although not one of DOSO's major concerns, the picking process from the DOC storage area was evaluated. The principal finding from analyzing the pick/issue process was that 29 pickers are necessary to perform the expected volume of issues over the desired 5-hour period.

The preservation and packaging area was also assessed. Recommendations here were to add two more pallet-line, package stations and two more vacuum bag machines to serve both the pallet and tote lines. Additional recommendations included the choice of enlarging existing stations/spurs, installing additional stations, or controlling the material's arrival rate at the incheck stations for both the pallet and tote lines.

Packing and shipping was the last area to be evaluated. Here, we found the conveyor spur, intended to accommodate the backlog of pallets waiting for placement onto pallet racks, to be too small. Recommendation here was using some combination of additional personnel to work

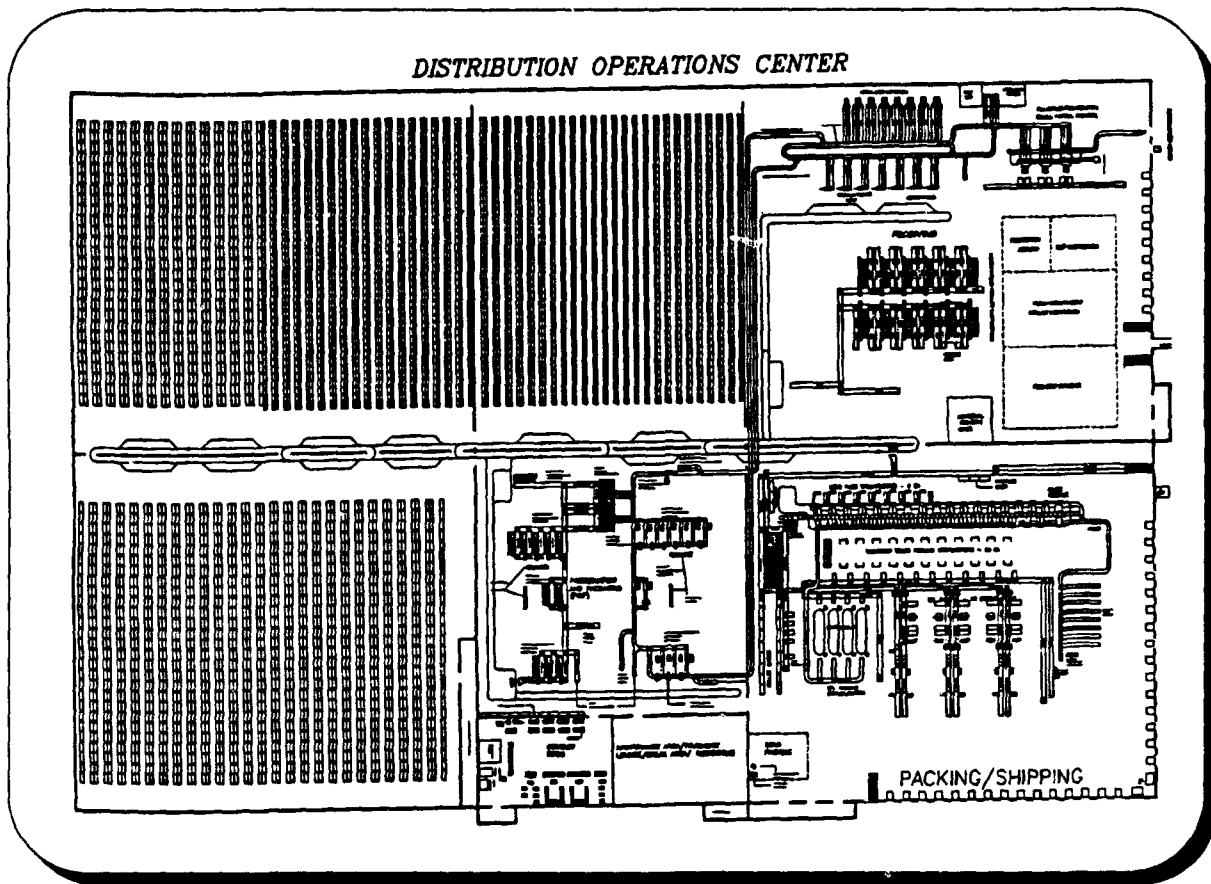
this area as needed, enlarging the existing spur, installing additional spurs, and/or controlling the arrival of material. The same findings and recommendations apply to the pack-sort, work station. Other recommendations for this area included keeping the mix of lines in the less-than-truckload area flexible. The final suggestion was to ensure the computer software governing the carousels give precedence to off-loading completed shipping units over on-loading of newly arrived material.

Purpose

Evaluate the Depot Operations Support Office's (DOSO) design of Red River's new Depot Operations Center for bottlenecks and other inefficiencies.

DORO

Welcome. I am Capt. Yielding; together with Mr. Greiner we have completed this project entitled Depot Operations Center (DOC) Design Simulation Analysis. The purpose was to evaluate the Depot Operations Support Office's (DOSO) proposed DOC design, to be built at Red River, Texas, for any bottlenecks that would hinder flow of materials through the Center. In addition, while evaluating the system for major problems, we checked for inefficiencies that might exist and recommended improvements where possible.



The layout of the proposed structure is shown above. The receiving area is located at the top right while the packing and shipping area is positioned directly below the receiving area at the bottom right. The preservation and packaging area is situated to the packing and shipping area's left, the middle-bottom part of the diagram. The rest of the DOC is devoted to storage. We will discuss each area in more detail when we present the simulation results for that area.

Overview

- **Approach**
- **Limitations/Scope**
- **Historical Data Analysis**
- **Model Development**
- **Scenario Simulations**
- **Conclusions/Recommendations**

DORO

For this briefing, Mr. Greiner and I will follow the above specified format as we report our findings. Since the analytical approach provides the framework for the study, we will begin with it.

Approach

- **Analyze historical data**
- **Use SLAM II**
- **Collaborate with DOSO**
- **Apply statistical measures**

DORO

With any problem-solving project, a plan is developed to show the steps proposed for solving the problem. For our methodology we analyzed historical data to get average throughputs for Red River's proposed DOC. We then used a simulation language, specifically SLAM II, to code the model. In the process DOSO advised us on the material's logical flow through the DOC. Finally, we applied statistical measures, e.g., queue lengths, utilization rates, etc., to evaluate and display the effectiveness of DOSO's engineering plan. In order to properly evaluate the main elements of the engineering plan we needed to define the scope of the system to be studied.

Scope

- **Inside vs outside**
- **Mainly Receiving, Towveyor, and Packing/Shipping Areas Modeled**
- **Conveyor/Towveyor associations**

DORO

Besides developing the problem-solving methodology we also had to set boundaries on what we would and would not model. This was determined by the objectives for this project and the time available to us. First, we limited our efforts to the operations that would occur inside the DOC building itself versus outside. Second, we then limited our work to the three areas DOSO was most concerned with. If other areas would affect one of the main areas, we did model those areas sufficiently to capture their influence. Third, within those three major areas we limited most of the coding to the mechanics of moving an item along the conveyor or towveyor, i.e., we didn't model outload staging, floor pack, etc.

Historical Data

- Receipts: Jun 90 to Sep 92
- 1455 receipts/5-day work week
- Issues: Aug 90 to Sep 92
- 5875 issues/5-day work week
- Additional data input usage
- Assumes future = past

DORO

To determine estimates of workload, we used the average throughput for both receipts and issues that had flowed through Red River over the 2-year period indicated. Eliminating weekends and holidays we computed the average on a 5-day work week.

We were also able to use the data in other areas of the model: receipt breakout, cube and weight percentages for picks, etc. [NOTE: "picks" are those items pulled from storage and destined for shipment]. However, using the historical data as input to our model assumes future demand equals past. DOSO provided guidance that this was the best estimate of future workload that could presently be obtained. In addition, the historical data provided us with real input for the model.

Model Development/ Scenario Simulations

- **Receiving**
 - **Multipack Breakdown/Small Parcels**
 - **Mechanized Pallet Inspection**
- **Towveyor**
- **Packing/Shipping**
 - **DOC Storage**
 - **P&P**

DORO

When we were through with most of the historical analysis we proceeded to develop the model. We quickly discovered the model as a whole was too large for the computer. So, we decided to break the model into three parts using the areas DOSO was concerned about as a guide. [NOTE: We were able to preserve system integrity between the separate models by capturing the relevant output from one area, in the form of data or distributions, and using it as input to another area(s) of need].

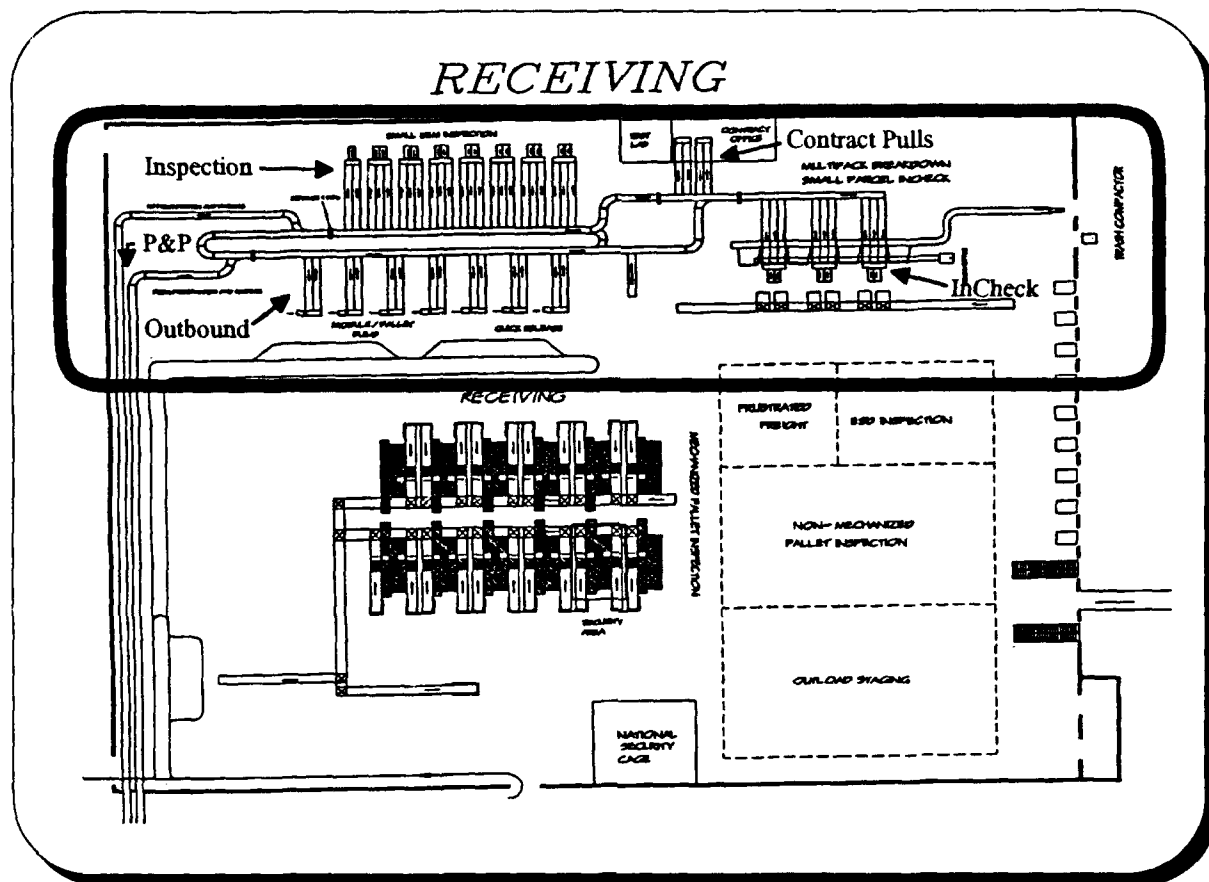
Consequently, the rest of this briefing follows the format shown above. I will explain the model developments, scenario simulation results, and recommendations together for the receiving and towveyor areas. As shown, I further break the receiving area into two parts: the multipack breakdown/small parcels and mechanized pallet sections. After the receiving and towveyor accounts, Mr. Greiner will then report on the packing and shipping area. Included with Mr. Greiner's presentation will be results from modeling the necessary parts of the DOC storage and preservation and packaging (P&P) areas.

Receiving

Multipack Breakdown/ Small Parcels

DORO

First, receiving, more explicitly, the multipack breakdown/small parcels area.



The small parcels are those items that are able to fit into a tote measuring 30 by 30 by 24 inches. They tend to arrive to the DOC via a small parcels' truck, e.g., United Parcel Service, or bunched together in triwalls which are large boxes measuring less than 48 by 48 by 60 inches.

These small items will enter the DOC through the receiving area, in particular, that part of receiving as highlighted above by a rectangle. As shown, the items first flow to the incheck stations for early identification and other minor processing. From there, they are put in totes and the totes onto conveyors. Before the final destination of outbound is reached there are three possible departures along the way. The first is the contract office where contract pulls are executed for those items requiring one. Next, most items will divert to an inspection station for a complete examination. Third, about 20% of the previously inspected items will be sent to preservation and packaging. Eventually, though, all receipts will arrive at outbound where they are placed on modules for either quick release, located at packing/shipping, or for internal storage.

Multipack Breakdown/Small Parcel Area Modeling Techniques/Assumptions

- **8-hour shift**
- **620 receipts per day**
- **60/40 arrival split**
- **Constant inter-arrival input rate**

DORO

As I proceed to describe the modeling of the small parcels area I'll first discuss the baseline scenario. I do this by delineating the model's construction, i.e., the techniques, assumptions, data assignments, and station numbers/time standards applied. Next, I'll display the results of simulating the baseline and subsequent scenarios. Finally, I'll list any conclusions and recommendations from the analysis.

The above chart is the first of four describing the baseline scenario. This chart begins listing the assumptions taken to model the small parcels area. The second assumption above shows DOSO's computed average of 620 small parcel receipts per day. DOSO calculated this norm from the average throughput we supplied them. The third assumption manifests DOSO's guidance that most of the receipts arrive in the morning. Consequently, 60% arrive within the first 4 hours. For the last assumption, I used a constant inter-arrival time to ensure items arrive over a full 8-hour shift.

At this point we know in gross terms the amount of work arriving into this receiving area. To determine the adequacy of the design we need to next see how this work is distributed to the specific stations.

Multipack Breakdown/Small Parcel Area Modeling Techniques/Assumptions (Continued)

- One receipt per tote
- Plentiful supply of totes
- Cyclic station assignments
- One person per station
- No Contract Pulls from
pallet area modeled

DORO

The assumption of one receipt per tote needs some explanation. DOSO's guidance was that a receipt could consist of up to three multi-totes. However, using the IMC study¹ for a multi-tote percentage breakout and station times along with some "back-of-the envelope" computations, multi totes had minimal influence on overall results. Thus, given the time constraint for completing the simulation analysis, I assumed one receipt per tote.

"Cyclic station assignments" is a way to control how items arrive at the different stations along the route. "Cyclic" means a tote travels to the first available station starting from the last station that was selected. No "contract pulls" from the pallet areas were modeled because it is assumed that personnel from the pallet areas perform the contract pulls themselves without affecting the personnel at the contract pull stations. In other words, contract pull personnel only pull contracts for small parcels in totes.

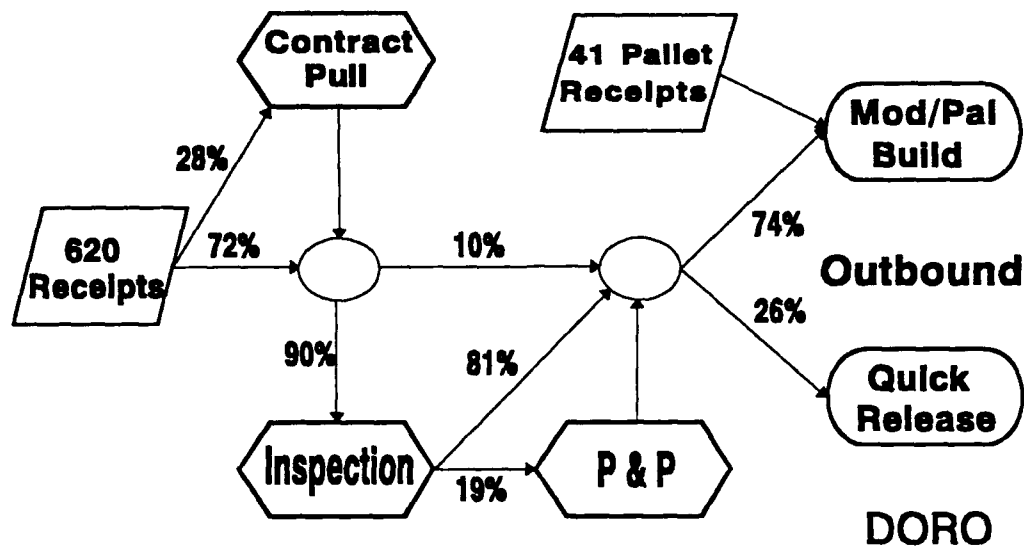
These assumptions all relate generally to how work arrives in this area. We now need to discuss the specific assumptions concerning the actual operations at the workstations.

¹ INTEGRATED MATERIEL COMPLEX EQUIPMENT DESIGN, Mar 1987, DORO, by Dr. Dennis A. Hopkinson and Mr. James M. Russell

Multipack Breakdown/Small Parcel Area

Modeling Techniques/Assumptions

Data Assignments



This chart shows the flow of the materials through the small parcels area. After the receipts enter the DOC, 28% will require a contract pull; 90% require an inspection. For those that are inspected, 19% need preservation and packaging. All items ultimately end up at outbound where 74% go to the module/pallet build stations, which also receive 41 pallet receipts throughout the shift. The remaining 26% go to the quick release stations. The module/pallet build stations construct modules filled with items for internal DOC storage. The quick release stations predominantly assemble modules with items for immediate, on post shipment. However, the quick release stations also build modules from split receipts for internal DOC storage. [NOTE: A split receipt is one whose items are split between DOC storage and quick release].

Multipack Breakdown/Small Parcel Area

Modeling Techniques/Assumptions

Station Numbers/Time Standards

- **Incheck(6): Triag(3.0,3.2,5.0) mins/receipt**
- **Contract Pull(2): Triag(4.8,5.0,5.3) mins/tote**
- **Inspection(15): Triag(8.9,9.8,10.3) mins/tote**
- **Module/Pallet Build(4): 30 secs/tote**
- **Quick Release Build(3): 3.2 mins/tote**
- **Conveyor Speed: 90 ft/min**

DORO

Since processing times for a particular operation exhibit variability, the most reasonable technique for estimating the variability is with the minimum, normal, and maximum times to perform the task. A triangular distribution (TRIAG in the above chart) is an appropriate statistical function to use with these estimates to determine the time to process a particular tote as it enters the workstation. The processing times at the various stations and the conveyor speeds were provided by DOSO and identical to those used in the IMC study. The numbers enclosed within parentheses for the triangular distribution represent the minimum, normal, and maximum values.

The number shown in parenthesis to a station's immediate right represents the number of stations of that type. Outbound has seven stations split between module/pallet build and quick release as shown. In reality, though, outbound's breakup between quick release and module/pallet build is dependent on the number of quick release items received and processed through small parcels. Although this number changes somewhat on a daily basis, we split the workstations into the two areas based upon the average work expected for each.

This completes an overview of the requirements and capabilities of these areas. We will next see how capabilities matched requirements in the dynamic environment represented by the simulation.

Multipack Breakdown/Small Parcel Results

Baseline Scenario

12-Day Continuous Simulation

Station	(#)	Utilization Rate	Queues (totes)	Wait Times (seconds)
Incheck	(6)	79.9%	0.0	15.3
Contract Pull	(2)	88.8%	2.3	764.1
Inspection	(15)	74.5%	0.0	6.5
Outbound	(7)	25.0%	0.0	6.0

Throughput: 620 receipts/day
 Balked Contract Pulls: 0/day
 Conveyor System: No congestion

DORO

This chart and the preceding three now constitute the baseline scenario. This baseline and subsequent scenarios were simulated over 12 continuous days. I use the word "continuous" to mean items left in the system after a shift is complete remain there for the start of the next shift.

Referring to the chart above I list the type of station at the extreme left with the number of that type station immediately to its right. The next three columns show averages for selected statistics. Each of these latter three statistics is on a per station basis. The first statistic entitled utilization rate refers to the percentage of time that station, or more specifically that person since I'm assuming one person per station, is busy throughout the shift. Contract pull personnel appeared to be the busiest while outbound personnel seemed to be underused. The length of queues measured in totes is the next statistic shown. Here, only contract pull had any kind of queue length. There are similar results for wait times for each tote in a queue. Here, again, only contract pull had any significant numbers.

At the bottom of the chart are three footnotes. The first displays the average output per day from the system. The next footnote depicts the number of average balked contract pulls per day over the simulation. A balked contract pull is defined as a receipt that required a contract to be pulled but could not receive one because the queue length for the contract pull station was completely full. Consequently, instead of allowing the tote to wait for an opening, thus blocking

incoming totes, the tote was allowed to proceed on without a contract. There were no balked contracts for the baseline scenario. Although, in a later slide, I address the conveyor system in more detail, the final footnote indicates that when looking at the traffic and the flow of totes through the conveyor system, there was no congestion. Everything flowed smoothly.

Overall, for the baseline scenario, results looked good. The only two possible concerns were at outbound and contract pull. Outbound's utilization rate was very low. First thought would be to cut back on the number of this type station. However, remember, this statistic measures the station's personnel and not the station itself. This station also has another role that cannot be measured by the utilization rate statistic: storage zoning. Storage zoning refers to moving carts with empty modules around a module/pallet build or quick release station. Each cart represents a zone, i.e., so many contiguous rows in DOC storage. Before a tote arrives to a module/pallet build or quick release station, the item in the tote will be assigned a DOC storage location. Upon arrival to outbound, the tote is diverted to that station which has the properly zoned module for that item. This practice takes more time up front but is justified based on very efficient DOC storage times. So, even though outbound's utilization rate was low, a number of these stations are required just for the zoning. However, the assumption of one person per station might be relaxed here to allow one person for every two or three stations.

The contract pull stations are a different story. Their utilization rates of 85 to 90 percent are at the maximum acceptable, allowing for a certain safety level. In addition, these stations are the only ones with significant queues and wait times. Consequently, there may be a problem with this type station, but the evidence from only one scenario is not conclusive. So, I modified the baseline scenario to further test these stations and to stress test the system as a whole. The alteration involved changing the 60/40 arrival split to 80/20 to get a greater surge of receipts during the first four hours. We next examine how well the system responds under these stress conditions.

Multipack Breakdown/Small Parcel Results

80/20 Input Scenario

12-Day Continuous Simulation

Station	(#)	Utilization Rate	Queues (totes)	Wait Times (seconds)
Incheck	(6)	79.9%	6.3	1749.2
Contract Pull	(2)	87.0%	3.6	1256.3
Inspection	(15)	74.3%	0.0	20.6
Outbound	(7)	25.3%	0.0	6.8

Throughput: 620 receipts/day
 Bailed Contract Pulls: 2.6/day
 Conveyor System: No congestion

DORO

The inspection and outbound station statistics remained about the same. However, incheck's queues and wait times increased dramatically, but this was to be expected given 80% of the items now arrived within the first 4 hours. Overall, however, their utilization rate remained the same. So, incheck had to work harder during the morning but they were still able to process all receipts. Further, the system as a whole performed well since we still achieved the desired throughput for this scenario and there was no congestion in the conveyor system.

Contract pull's queues increased by a little over one tote each per station for this 80/20 input scenario. In conjunction, the wait times for these totes almost doubled. The utilization rate did drop by almost two percentage points but that's because, if you'll notice the middle footnote, there are now bailed contracts of almost three per day. Thus, the utilization rate dropped since there were fewer items to pull contracts on.

Therefore, considering all three statistics, contract pull does have a slight problem. To further test this station and the entire system I, again, altered the baseline scenario. I derived the maximum number of receipts incheck could accomplish (776) and used that as input to the system. This maximum number represents a 25.2% increase from the baseline. [NOTE: I arrived at the 776 receipt number by backing into it from incheck's time standards].

In addition, I eliminated the constant inter-arrival spacing and forced all results to enter at time zero. Although, this is unrealistic, I wanted to create a worst-case, maximum input scenario. If the system could handle this extreme it would definitely manage a more normal situation.

Multipack Breakdown/Small Parcel Results

Maximum Input Scenario 12-Day Continuous Simulation

Station	(#)	Utilization Rate	Queues (totes)	Wait Times (seconds)
Incheck	(6)	99.8%	8.3	1838.3
Contract Pull	(2)	100.0%	7.0	2327.6
Inspection	(15)	93.5%	0.0	28.9
Outbound	(7)	30.1%	0.0	7.0

Throughput: 775 receipts/day
 Balked Contract Pulls: 18.8/day
 Conveyor System: No congestion

DORO

The small parcels system is designed very well because output was only one less than input (775) and there was still no congestion in the conveyor system for this maximum input scenario. The incheck statistics were higher but that was to be expected when all 776 receipts arrive at once. The outbound stations' utilization rate did increase but was hardly noticeable. And, the inspection station statistics also increased, that is, all except for the queue statistic; there was still no backlog here. But, there were backlogs at the contract pull stations (7), enough to create almost 19 balked contracts per day. The utilization rate was now full and the wait times per queue per station had doubled. So, this maximum input scenario shows that although the system, in general, accommodated 776 receipts per day the contract pull area is a problem.

With the contract pull stations identified as a problem area, the next simulation scenario attempted to remedy it. Once more I took the baseline scenario and changed it, this time by assigning two people per contract pull station giving a total of four contract pull personnel in all; the remaining baseline assumptions, standards, and modeling techniques remained firm.

Multipack Breakdown/Small Parcel Results

4-Contract Pull Personnel Scenario

12-Day Continuous Simulation

Station	(#)	Utilization Rate	Queues (totes)	Wait Times (seconds)
Incheck	(6)	79.9%	0.0	15.3
Contract Pull	(4)	45.1%	0.0	5.5
Inspection	(15)	74.2%	0.0	9.4
Outbound	(7)	25.3%	0.0	6.3

Throughput: 620 receipts/day
 Balked Contract Pulls: 0/day
 Conveyor System: No congestion

DORO

And, indeed, contract pull's problem was solved. Again, recall the utilization rate statistic is per person and not per station. It is per station only when the assumption of one person per station is holding. Since we allotted two people per contract pull station in this scenario the 45.1% utilization rate is per person. The overall station rate would be double that. The other station statistics remained about the same as those on the baseline scenario, including outbound's low utilization rates.

Multipack Breakdown/Small Parcel Recommendations/Observations

- **Increase Contract Pull resources**
- **Decrease Outbound personnel**

DORO

Thus the recommendations for the small parcels area are listed above. The contract pull resources can either be personnel or stations. And, for outbound, one person may be able to operate two or three stations.

Multipack Breakdown/Small Parcel Results

All Scenarios

12-Day Continuous Simulation

Station/Resource	(#)	Utilization Rate	Queues (totes)	Wait Times (seconds)
Conveyors	(74)	5.1%	—	—
Conveyor Junctions	(21)	7.6%	0.0	0.1

No Congestion!!!

DORO

Earlier I pointed out that the conveyor system experienced essentially no congestion. Now I would like to discuss that in more detail.

I modeled the conveyor system as resources composed of 74 separate smaller conveyors with 21 junctions. The conveyor sections were to and from junctions and stations. The statistics shown are for the highest that occurred from all the previous scenarios. The utilization rate statistic refers to the amount of time a resource was busy, e.g., how often totes were present on a conveyor section or at a conveyor junction. The queues and wait time statistics for the conveyor junctions are negligible.

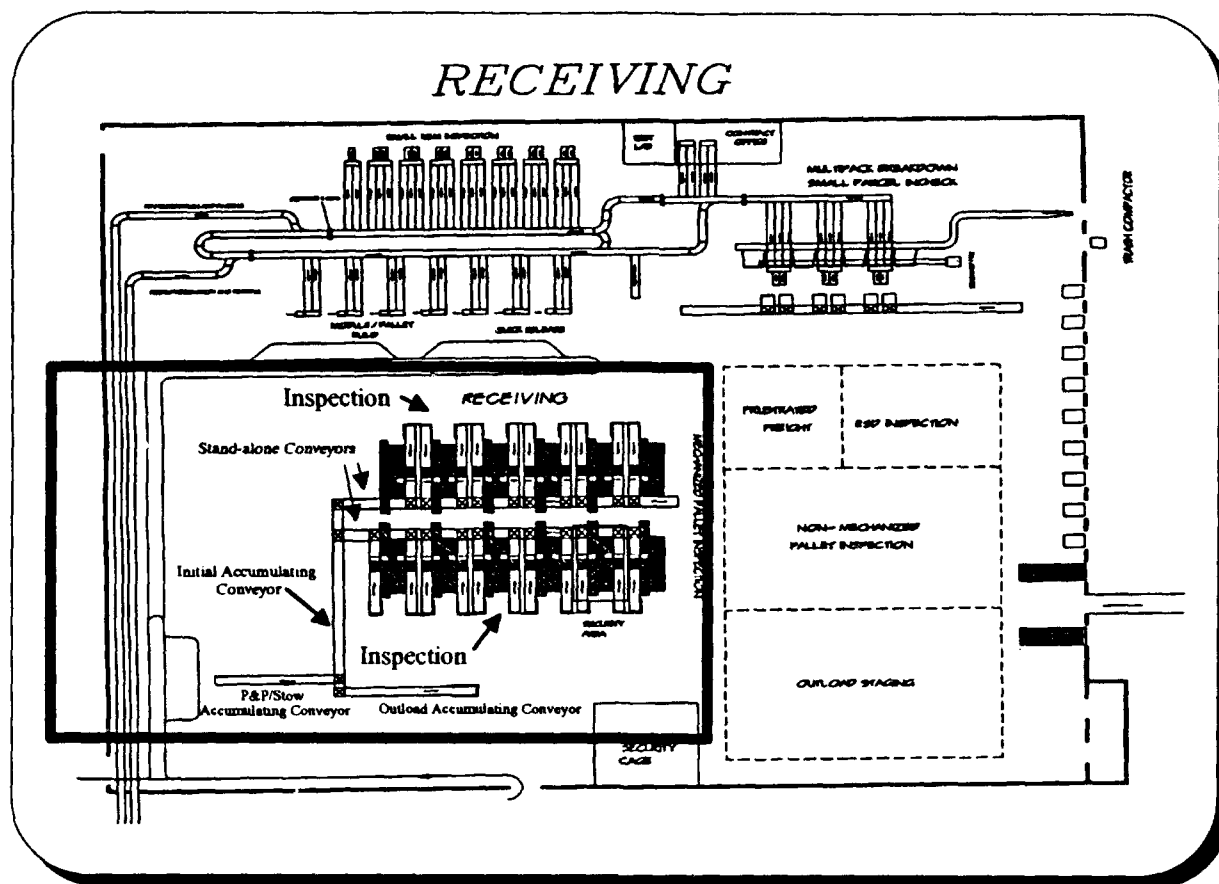
Queue and wait time statistics were not appropriate for the method we used to represent conveyor sections. The number of totes per conveyor section was monitored throughout the simulated scenarios. We were able to calculate utilization rates and note the number of occasions a section's tote capacity was surpassed. In view of the low utilization rates coupled with infrequent occurrences of exceeded capacity, we concluded the conveyor system performed admirably with no congestion.

Receiving

Mechanized Pallet Inspection

DORO

The second part of Receiving I modeled was the Mechanized Pallet area. Recall that this area manages those receipts that arrive to the DOC by pallet which are able to travel on the conveyor, i.e., pallet items don't weigh more than 3000 pounds and are not oversized.



The mechanized pallet area is outlined above by the thick solid rectangle. Items for this area arrive to the DOC mainly on pallets and are forklifted over. All items are inspected. There are 21 inspection stations to choose from, 10 on one side and 11 on the other. After inspection, the items exit the area via a set of conveyors. The P&P/stow accumulating conveyor, shown at bottom left, is the exit point for items to be stowed in the DOC and the outload accumulating conveyor, shown at bottom right, is the exit point for items to be sent to outload staging or to outbound in the small parcels area.

Mechanized Pallet Area Modeling Techniques/Assumptions

- 8-hour shift
- 320 receipts per day
- 60/40 arrival split
- Constant inter-arrival input rate
- Pallets inspected as a whole

DORO

I use the same discussion format to portray the mechanized pallet area as was used previously with the small parcel area. I first describe the ingredients used in constructing the baseline scenario. These elements are the modeling methods, assumptions, data assignments, and station numbers/time standards. Next I will report the different scenarios and show their results and then complete this section with recommendations.

Most of the assumptions listed here and on the next chart are the same as those specified for the small parcels area. I used an 8-hour shift with a 60/40 split between arriving receipts. The receipts entered the area with a constant inter-arrival time. The 320 pallet receipt average is DOSO's estimate obtained from using the average throughput numbers garnered from the historical data analysis. The last assumption on this chart implies that all items on the pallet are the same type.

Mechanized Pallet Area Modeling Techniques/Assumptions (Continued)

- **Cyclic station assignments**
- **Stand-alone vs accumulating conveyors**
- **No constraint on forklift resources**
- **No Contract Pulls modeled**

DORO

There are two types of conveyors for the mechanized pallet area: stand-alone and accumulating. The stand-alone conveyor is the type where only one pallet can be on the conveyor at any one time. The accumulating conveyor allows pallets to amass. There are two stand-alone and three accumulating conveyors. A stand-alone conveyor accepts a pallet exiting an inspection station and ferries it to what I dubbed the initial accumulating conveyor. There is one stand-alone conveyor for each of the two sections of inspection stations. Then, depending on the pallet's destination, it is transported via the initial accumulating conveyor to either the P&P/stow accumulating or outload accumulating conveyor.

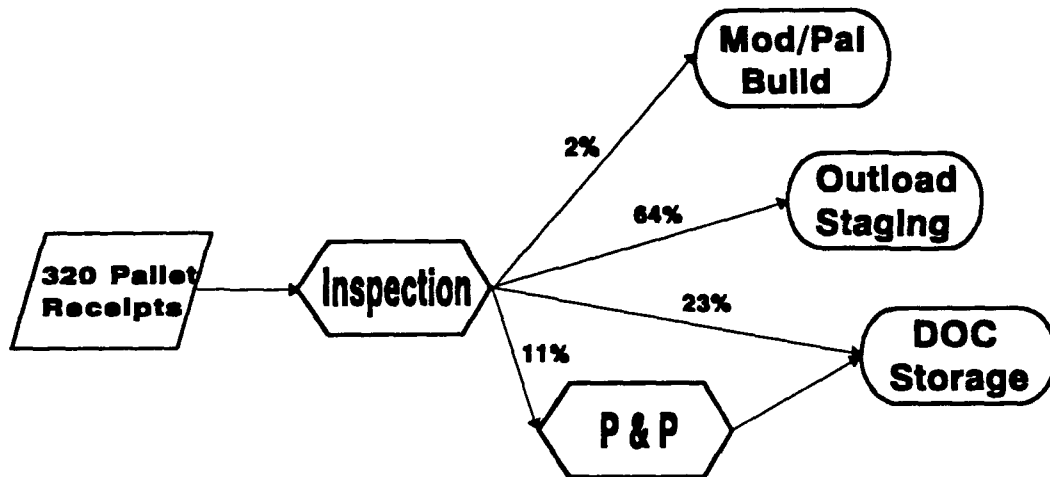
At the end of the outload accumulating conveyor, a forklift is required to off-load the pallet. Since the scope of this project doesn't include forklift modeling I do not allow the absence of forklifts to affect flow of pallets through this area.

For the last assumption the dynamics of pulling a contract are not specifically modeled. We assume that while the contract pull is in process, either by a "runner" or pneumatic tube system, the inspector can perform other parts of the pallet inspection or move on to another pallet.

Mechanized Pallet Area

Modeling Techniques/Assumptions

Data Assignments



DORO

The flow of materials through this area was simpler than for the small parcels area. All items entering this area are inspected. From there the pallets proceed to one of the two outgoing accumulating conveyors. Those items designated for module/pallet build or outload staging proceed to the outload accumulating conveyor. The rest advance to the P&P/stow accumulating conveyor to be off-loaded for DOC storage. Part of those pallets will be diverted to preservation & packaging before being stowed.

Mechanized Pallet Area

Modeling Techniques/Assumptions

Station Numbers/Time Standards

- **Inspection(21): Triag(16.2,17.8,18.7) mins/pallet**
- **Off-load by forklift: Unfrm(10,50) secs/pallet**
- **Automatic off-load: 10 secs/pallet**
- **Pallet conveyor speed: 45 ft/min**

DORO

Again, the numbers shown on this chart were given to me by DOSO. There are 21 inspection stations. The triangular distribution was used to introduce variability into the model. The numbers enclosed within parentheses represent the minimum, average, and maximum values, respectively, for the triangular distribution.

The off-load numbers are the times required to take a pallet off the conveyor. The outload accumulating conveyor requires a forklift for off-loading. The off-load time was modeled as a uniform distribution demanding 10 to 50 seconds per pallet. The P&P/stow accumulating conveyor has an automatic off-load diverter that takes only 10 seconds.

With the system parameter definitions completed, we will next examine the system performance during the simulation.

Mechanized Pallet Results

Baseline Scenario

15-Day Continuous Simulation

Station/Resource	(#)	Utilization Rate (percent/pallets)	Queues (pallets)	Wait Times (seconds)
Inspection	(21)	72.4%	0.0	0.0
Initial Accumulating Cnvyr	(17)	1.2 pallets	0.0	0.0
P&P/Stow Accumulating Cnvyr	(10)	0.3 pallets	—	—
Outload Accumulating Cnvyr	(11)	0.6 pallets	—	—

Throughput: 320 receipts/day
Conveyor System: No congestion

DORO

The preceding three charts and this one form the baseline scenario. This baseline and subsequent scenarios are simulated over 15 continuous days. "Continuous" means the same here as with the small parcel scenarios, that is, items left in the system after a shift remain there for the start of the next.

Referring to the chart above, the type station or resource is listed at the far left with the number of stations/resources immediately to its right. The resources are the three accumulating conveyors. For the resources, the number to the conveyors right is the maximum number of pallets that can accumulate on it.

The next three columns display the same type statistics as those from the small parcels results. Consequently, their meanings are the same. However, the meaning for the utilization rate statistic does change somewhat when reported for the conveyors. In this case the utilization rate is defined as the average number of pallets on the conveyor at any point in time.

The last two conveyors do not have queue or wait time statistics. If a pallet arrives to one of these conveyors and the conveyor is full the system will start backing up and become congested. For example, if the outload accumulating conveyor has 11 pallets on it when a pallet arrives that pallet remains on the initial accumulating conveyor, because this conveyor feeds the

latter two accumulating conveyors, until an opening occurs. If the pallet off-load times for the outload accumulating conveyor become greater than the rate of incoming pallets the initial accumulating conveyor will eventually clog. This in turn will cause both stand-alone conveyors to back up into the inspection stations; thus, a congested system.

There was no congestion for this baseline scenario; the system operated very well. Utilization rates were very good with no queues or wait times. Also, we achieved our desired throughput with no congestion, as manifested by the two bottom footnotes.

Given the excellent results we could have been through with this area, but I was curious as to how well this system could handle a heavier load of receipts. So, I backed into the maximum number of receipts this area could process just as I did with small parcels. That number was 444. So, I used the baseline scenario but changed input to be 444 receipts. Likewise, as with the maximum input scenario for small parcels area, I changed the inter-arrival time to zero, i.e., all enter the system at the start of the shift.

Mechanized Pallet Results

Maximum Input Scenario

15-Day Continuous Simulation

Station/Resource	(#)	Utilization Rate (percent/pallets)	Queues (pallets)	Wait Times (seconds)
Inspection	(21)	99.8%	1.4	25.2
Initial Accumulating Cnvyr	(17)	1.2 pallets	0.0	0.0
P&P/Stow Accumulating Cnvyr	(10)	0.4 pallets	—	—
Outload Accumulating Cnvyr	(11)	1.0 pallets	—	—

Throughput: 444 receipts/day
Conveyor System: No congestion

DORO

Maximum input was no problem for the mechanized pallet area. Even with the inspection personnel's utilization rate nearly at 100% the average queue was very small with inconsiderable wait times. In addition, we realized the desired throughput and had no congestion.

With the exception of the outload conveyor, the conveyor resource statistics hardly altered. There were no queues or wait times. The utilization rate practically remained the same for the first two conveyors; not so for the outload accumulating conveyor. Even though its rate was still small, it nearly doubled.

Because of this, I devised another simulation scenario to analyze the sensitivity of the pallet off-load time. I again used the baseline scenario but changed the pallet off-load time for the outload accumulating conveyor to be from 90 to 150 seconds with a uniform distribution.

Mechanized Pallet Results

Increase Pallet Off-load Scenario

15-Day Continuous Simulation

Station/Resource	(#)	Utilization Rate (percent/pallets)	Queues (pallets)	Wait Times (seconds)
Inspection	(21)	67.3%	8.9	13156.7
Initial Accumulating Cnvyr	(17)	17.0 pallets	1.0	75.6
P&P/Stow Accumulating Cnvyr	(10)	0.3 pallets	—	—
Outload Accumulating Cnvyr	(11)	11.0 pallets	—	—

Throughput: 293 receipts/day
Conveyor System: Congested!!!

DORO

The system completely bogged down. As you can see from the utilization rate column , the outload accumulating conveyor became overloaded. The average number of pallets accumulated (11) equalled the conveyor's capacity. Pallets then saturated the initial accumulating conveyor creating a one-pallet queue on the stand-alone conveyors. Each queue had an average wait time of approximately 76 seconds. Since the stand-alone conveyors each had pallets on them, the inspection personnel could not release inspected pallets. Thus, their utilization rate decreased causing them to have larger queues with excessive wait times. This led to a throughput lower than desired.

Mechanized Pallet Area Recommendations/Observations

Insure quick pallet off-loads

DORO

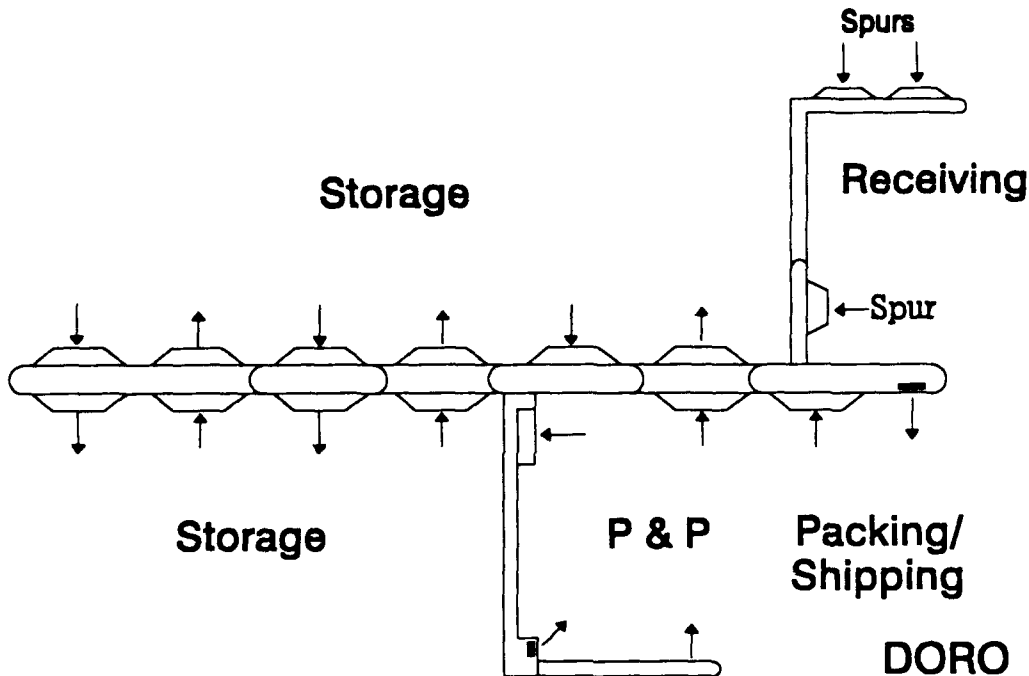
Hence, changing the pallet off-load time dramatically affected the flow of receipts through the mechanized pallet system. Other than that, though, the system functioned properly under the baseline scenario. Therefore, the only recommendation for this area is to insure quick pallet off-load procedures.

Towveyor

DORO

The towveyor is the critical transit system that links all parts of the DOC. First, we will review the overall design of the system and then present our analysis.

Towveyor Layout



Traversing the towveyor are carts that pick up the modules and pallets from different points called input spurs, identified above with arrows pointing inward. These modules and pallets are then channeled by cart to predetermined destinations called output spurs or points, displayed above with arrows pointing away. As shown above there are three input spurs in the receiving area for carts to seize the modules and pallets released by the small parcel and mechanized pallet areas. Depending on their destination the carts convey their load to either packing/shipping for the quick release items; P&P for those items requiring preservation and packaging before DOC storage; or straight to the internal DOC storage area.

Packing/shipping also has an input spur to upload empty modules onto the towveyor. Preservation and packaging has four towveyor input/output points. The two output points shown at the bottom of the diagram off-load pallets and modules respectively to P&P, viewing left to right. Once past P&P the pallets and modules exit via the top two towveyor input spurs, pallets accessing the left and modules the right. DOC storage has ten spurs used in tandem: every other one is an output spur for off-loading pallets and modules sent here for storage with the rest used as input spurs for releasing the modules containing picks onto the towveyor system.

All these cart movements are not occurring at the same time. So to assess the system capability we want to examine the requirements as they occur over time.

Towveyor Input Areas

From Receiving (200)

From P&P (175)

From Packing/Shipping (130)

From DOC storage (100)

0

9-Hour Shift

9

DORO

The picks from the DOC storage area are the first items requiring towveyor transportation. The first picks become ready for on-load about 10 to 20 minutes into the towveyor's shift. About 20 to 40 minutes later the P&P and packing/shipping areas start off-loading items onto the towveyor system. Finally, roughly 90 minutes into the shift, the modules and pallets from the receiving area become available for passage. The pickers in the DOC storage area usually require 4 to 6 hours to complete all picks. After that, the towveyor is not required in the DOC storage area except to off-load the items that require storage. However, the other three areas are different. Once started, the other areas continually place modules and pallets onto the towveyor system for the entire shift.

Towveyor

Modeling Techniques/Assumptions

- **9-hour shift**
- **75 carts used**
- **Carts prepositioned**
- **Tandem spurs in DOC storage area**
- **DOC off-loads are Unfrm(1.5,2.5) mins**
- **Towveyor speed: 60 ft/min**

DORO

As you probably noticed from the previous chart the shift is assumed to be nine hours in duration. That's because receiving personnel start work 1 hour after packing and shipping personnel do. Accordingly, the towveyor is required for 9 hours.

The second assumption employed in modeling the towveyor is to initially use 75 carts. I derived this figure by calculating the total number of carts all the input, not output, spurs could hold. This was done by dividing the aggregated length of the input spurs by the length of a cart.

After determining the number of carts, I developed a routine to pre-position them. The routine would determine where the most likely use for an empty cart was. It did so by comparing the number of open slots at all applicable input spurs and sending the empty cart to the input spur with the most empty slots available.

Although the time used to estimate the off-loading of a towveyor cart loaded with a stow might be overly optimistic, this off-load time has no effect on the towveyor system congestion or efficiency. This is because it does not influence the number of cart movements required. It will, however, modify the project number of carts needed in the system. The carts will stack up in the storage area input spurs and will not be available to service other requests. Sufficient space exists on the input spurs to accomodate these carts waiting off-load. So although this chart shows 75

carts used, it underestimates the total required because of the off-load time estimation. A rough estimate for the number of additional carts needed is seventy five carts , bringing the total one hundred and fifty. So although the number of carts used in the simulation may be understated, the results for the efficiency statistics we present next are accurate.

Towveyor Results Baseline Scenario 15-Day Continuous Simulation

Awaiting Transportation Point	Queue Lengths	Wait Times (seconds)	Spur Capacity (carts)
Receiving (modules)	0.0	0.0	16
Receiving (pallets)	0.6	122.5	4
Packing/Shipping	0.1	31.2	4
P&P (modules)	0.0	0.0	8
P&P (pallets)	157.8	44310.9	3
DOC Storage	0.0	0.0	40

Carts used: 75
Towveyor System: No congestion

DORO

Just like the small parcels and the mechanized pallet areas the previous charts define the baseline scenario. The chart on this page reveals the results of simulating the baseline scenario over 15 continuous days.

Viewing the chart above, those points on the towveyor system awaiting transportation are shown in the first column. The next two columns display queue lengths and wait times per object for those queues. The final column depicts the number of carts that can be pre-positioned at those spurs. The 16 carts for receiving (modules) were evenly distributed between two spurs and the 40 carts for DOC storage were equally rationed among five spurs. Summing this column gives the total number of carts, shown at the bottom, used for this scenario.

The towveyor system itself wasn't congested but P&P (pallets) had a major problem: a queue of 157.8 pallets each with unacceptable waiting times. Packing/shipping and receiving (pallets) also had problems but to a lesser extent. So, I created another scenario by increasing the length of some input spurs to accommodate more carts and reapportioning the carts from the baseline scenario. In addition, I reduced the total number of carts used. How well this revised system responded is what we will discuss next.

Towveyor Results

Modified Cart & Spur Length Scenario

15-Day Continuous Simulation

Awaiting Transportation Point	Queue Lengths	Wait Times (seconds)	Spur Capacity (carts)
Receiving (modules)	0.0	8.4	6
Receiving (pallets)	0.1	13.6	6
Packing/Shipping	0.0	8.3	6
P&P (modules)	0.0	10.8	4
P&P (pallets)	1.2	245.2	9
DOC Storage	0.0	1.8	20

Carts used: 51

Towveyor System: No congestion

DORO

Before looking at the simulation results, notice that the specific cart reassignments and changes in spur lengths can be seen by comparing the figures in the last column between the previous chart and this chart. Those points which had no queues from the previous chart lost carts: the two spurs in receiving (modules) lost ten; the one spur in P&P (modules) lost four; and the five spurs in DOC storage lost a total of twenty. Conversely, the remaining three points received additional carts: the spur in receiving (pallets) and the spur in packing/shipping both received two extra carts while the spur in P&P (pallets) received six more. Overall, the number of carts used for this modified cart & spur length scenario was 51.

From the results shown above, there was still no congestion, which you'd expect with fewer carts, and the statistics were much better. Five of the awaiting transportation points had no noticeable queue and their waiting times were trivial. Even the P&P (pallets) statistics were drastically lower: queue of one with about a 4 minute wait time per pallet. However, I still didn't want even a small queue. So, I took this scenario one step further by adding four more carts to the group.

Towveyor Results

Modified Cart & Spur Length Scenario, Part 2

15-Day Continuous Simulation

Awaiting Transportation Point	Queue Lengths	Wait Times (seconds)	Spur Capacity (carts)
Receiving (modules)	0.0	3.1	6
Receiving (pallets)	0.0	0.7	7
Packing/Shipping	0.0	1.1	7
P&P (modules)	0.0	1.6	4
P&P (pallets)	0.2	40.0	11
DOC Storage	0.0	0.3	20

Carts used: 55

Towveyor System: No congestion

DORO

Two carts were added to P&P (pallets) and one cart each was added to receiving (pallets) and packing/shipping. Observing the chart above, there were no queues and, essentially, no waiting times. The total carts now employed was 55 and there still wasn't any congestion.

Towveyor System Recommendations/Observations

Increase spur lengths

DORO

Thus, just by increasing spur lengths to accommodate more carts, fewer carts were needed and exceedingly better results were derived. Consequently, that is the recommendation for the towveyor system. More specifically, increase the P&P (pallets) spur length by a factor of four and double the receiving (pallets) and packing/shipping spur capacities.

Towveyor Results
All Scenarios
15-Day Continuous Simulation

Station/Resource	(#)	Utilization Rate
Sections of towveyor	(57)	8.7%

No Congestion here either!!!

DORO

There is one remaining point to address in this section. On the previous chart and others prior to that we indicated that there was no congestion in the towveyor system. As with the small parcels area, the towveyor was dissected into 57 smaller sections. Again, for all the scenarios, the utilization rate for the most traveled piece of towveyor was very small, leading to the conclusion that there was no congestion.

Packing/Shipping

DORO

With the receiving and towveyor areas complete, Mr. Bob Greiner will now explain his modeling efforts for the packing and shipping area.

Defense Depot Red River, Texas (DDRT)

Storage Area (Issues)

Preservation and Packaging (P&P)

Packing and Shipping

Now that we have covered the receiving area and the towveyor system, we are ready to turn our attention to the three remaining warehouse areas: storage (in particular, issues); preservation and packaging; and packing and shipping.

Before we address each area individually, it is first necessary to discuss some overarching assumptions applicable to all areas.

Defense Depot Red River, Texas (DDRT) Issuing, P&P, and Packing/Shipping Model General Assumptions

- **Support equipment availability**
- **Indicators of system problems**
- **Work station assignments**
- **Floor pack & outload**

Ancillary support equipment such as pallets, modules and forklifts are assumed to be available whenever and wherever they are needed. The primary purpose of the project is to analyze system capacity and bottlenecks, not to determine equipment requirements. However, in the course of the analysis we do attempt to estimate requirements for certain major end items such as pick/issue vehicles and pallet racks.

Utilization rates and queue lengths are used as measures of the adequacy of the system's capacity. Utilization rates above 90% and queue lengths that exceeded the designed capacity for more than a few minutes are considered indications of system problems.

When material can be processed at one of several locations (e.g., four carousels), work stations are randomly assigned in advance to enable consolidation of multi-line shipping units (SU). This realistically reflects the random way material will arrive.

Once material is removed from the conveyor system, it is outside the scope of this study. Consequently, floor pack and out-load areas are not modeled.

Defense Depot Red River, Texas (DDRT)

Storage Area

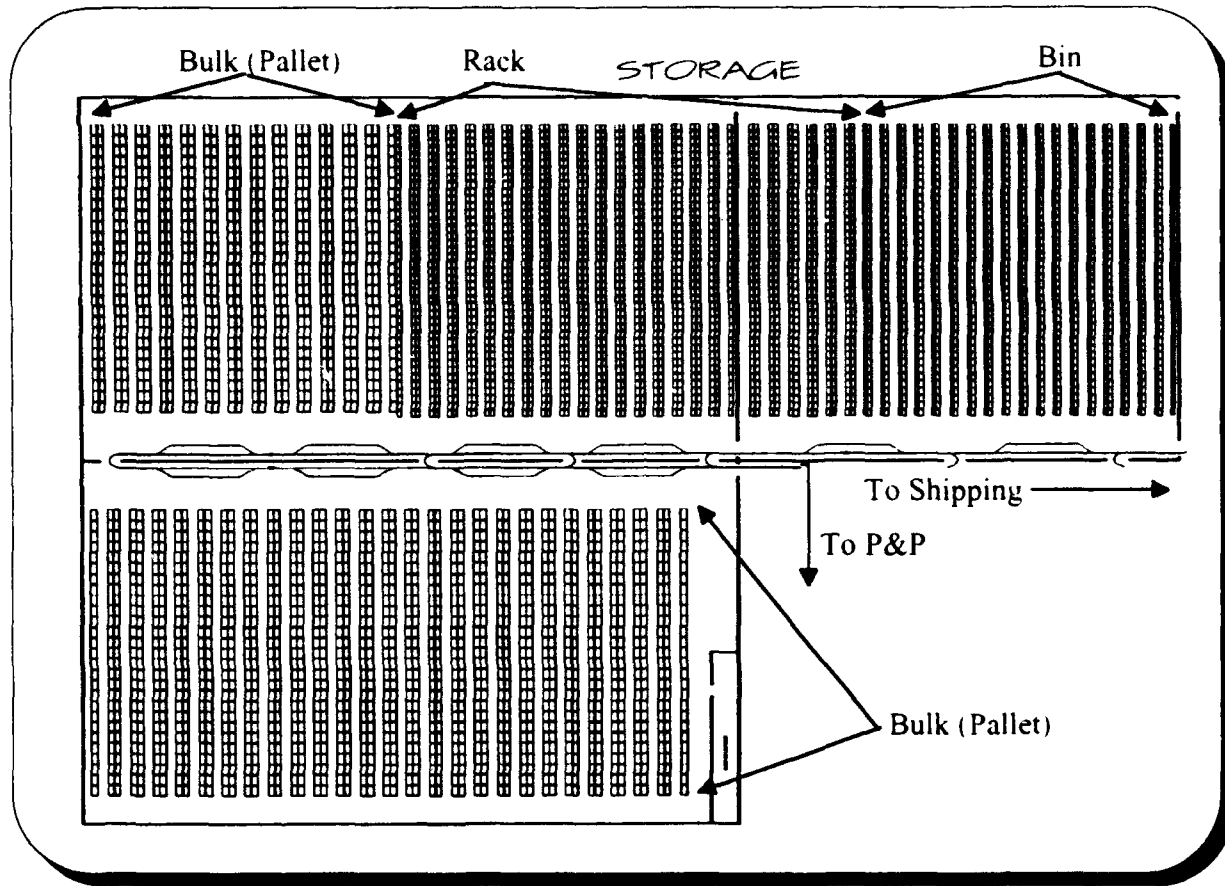
Bin

Rack

Bulk (Pallet)

With that overview in mind, we are now ready to examine specific areas within the distribution operations center (DOC). The first area of consideration is the storage area, where material is picked for issue based on Material Release Order (MRO) documents.

This analysis is based on a projected workload of approximately 1.05 million MROs per year. This figure represents only those MROs picked from the storage area; it does not include another 100,000 quick release MROs filled from the receiving process.



The storage area is the repository of material from which issues are made. Material is stored in bins, on racks or on pallets as indicated above.

Through the center of the storage area runs a towveyor system which transports pallets and modules of material on towveyor carts. This towveyor system delivers material either to the preservation and packaging (P&P) area, if necessary, or else directly to the packing and shipping area.

Defense Depot Red River, Texas (DDRT) Storage Area Pick/Issue Procedures Modelled

- **Module build**
- **Pick policy**
- **Pick early**
- **Material from outside**

The number of MROs that fit onto a single module are based on actual MRO weight and cube data from DDRT over a 545-day period.

Material is picked by issue group (i.e., three passes) and within issue group, by location (randomly assigned).

Pickers perform issues first before starting to stow material from receiving. That is, issues are dispensed early in the pickers' 8-hour shift.

Similarly, most material from outside the DOC arrives early in each work day.

Defense Depot Red River, Texas (DDRT) Storage Area Pick/Issue Results

Pick Location	Number Assigned	Average Pick Utilization	Begin Stow
Bin	11	6.75 (61%)	3.9 hours
Rack	13	8.45 (65%)	4.7 hours
Bulk	5	3.01 (60%)	4.5 hours
	--	-----	
Total	29	18.21 (63%)	

Note 1: Target volume = 4,183 MRO (model: 4,150 MRO)

Target volume = 94 modules; model built 109

Note 2: Worst time for last module: 6.8 hours (average: 6+)

Results of preliminary unconstrained runs indicate that 19 vehicles (18.21 in the chart) are needed to complete the given volume of issues.

The stated goal is to complete issues in 5 hours, or 62.5% of the 8-hour shift. Therefore 29 vehicles should be assigned to pick issues to produce a utilization rate approximating 62.5%. The slide displays results with 29 vehicles.

The column at the far right indicates the number of hours into the pickers' 8-hour shift when the first of the 29 vehicles is no longer needed for issues; that is, the time to begin stowing receipts.

Footnote 2 indicates that on average, the last picker finishes about 6 hours into the 8-hour shift. At this point, all of the 29 vehicles are now available for stowing receipts.

Defense Depot Red River, Texas (DDRT)

Preservation and Packaging (P&P)

Pallet Line

Tote Line

Common Stations

Not all material that is picked for issue is immediately available for release to customers; some must first be properly preserved and/or packaged. Similarly, material issues originating from outside the DOC might also require repackaging. In addition, a certain portion of newly arrived receipts requires packaging before being stowed.

The preservation and packaging (P&P) area consists of two separate conveyor lines: one line for palletized material and a separate line for items small enough to fit in tote pans. Both lines contain work stations for in-check/process planning, prefabrication, packaging, and out-check functions.

In addition, there are two work stations that serve both lines: namely, vacuum bagger and case sealer work stations.

Defense Depot Red River, Texas (DDRT) Preservation and Packaging (P&P) Area Procedures Modelled

- **Module implies tote line**
- **When is a pallet not a pallet?**
- **The contact room as black box**
- **Release from P&P**

All MROs arriving in modules are presumed to fit into tote pans. Furthermore, all MROs arriving at P&P that can fit into a module are placed into tote pans even if they arrive via pallet.

The contact room is modeled only to emulate time delays between the in-check and prefab stations. However, work station utilization rates and queue lengths within the contact room are not monitored because the contact room is not an immediate part of the conveyor system in question.

Issue group 1 and 2 material that has completed P&P flows immediately to the next destination. On the other hand, issue group 3 material is consolidated for release every hour on one module (tote line) and/or one pallet (pallet line).

Defense Depot Red River, Texas (DDRT) Preservation and Packaging (P&P) Area Pallet Line Utilization

Work Station	Number of Stations	Average Utilization	Maximum In Use
Incheck	3	1.95 (65%)	3
Prefab	2	0.80 (40%)	2
Packager	6 (vice 5)	5.31 (89%)	6
Outcheck	1	0.51 (51%)	1

Note: Projected volume = 145 pallets; model volume = 154 pallets.

With that background in mind, we are now ready to examine the results of the simulation pertaining to P&P.

Pallet line utilization for in-check, prefab and out-check stations were well within target. Notice, however, that the designed 5 packaging stations were not enough: 5.31 packagers were required. A sixth station must therefore be added to accommodate the anticipated volume of work.

Even with a sixth station, utilization approaches the upper limits of acceptability at 89%. A seventh work station might even be worthwhile.

Defense Depot Red River, Texas (DDRT) Preservation and Packaging (P&P) Area Pallet Line Backlog

Work Station	Number of Stations	Average Backlog	Maximum Backlog	Maximum Allowed	% Time > Allowed	Average Wait
Incheck	3	8.6	22	3	55%	1.4 hours
Prefab	2	0.03	2	3	0%	11 seconds
Packager	6 (vice 5)	2.4	7	3	41%	44 minutes
Outcheck	1	0.13	2	3	0%	24 seconds

Note 1: Projected volume = 145 pallets; model volume = 154 pallets.

Note 2: Backlogs represent the average per individual station

In the pallet line, no appreciable backlogs develop at either the prefab or out-check work stations.

Significant backlogs accumulate at the in-check stations. Not only did the maximum backlog observed (22) exceed the maximum allowed (3) by the conveyor capacity, but the average backlog at any one time (8.6) also exceeded the capacity. This excess persisted throughout 55% of the simulation. However, this problem is not quite as serious as it first appears. If no room exists at the in-check stations, pallets can circulate around the towveyor until such time as room does become available (provided, of course, that enough carts are available and that the towveyor does not become overloaded).

Such is not the case with the package stations. Although the average backlog at any one package station (2.4) is below the maximum capacity (3), queue length does exceed available capacity during 41% of the shift. The absence of an alternative holding pattern for these pallets poses a problem. Possible solutions will be addressed in a later chart (P&P recommendations).

Defense Depot Red River, Texas (DDRT) Preservation and Packaging (P&P) Area Tote Line Utilization

Work Station	Number of Stations	Average Utilization	Maximum In Use
Incheck	4	2.03 (51%)	4
Prefab	2	0.84 (42%)	2
Packager	7	5.56 (79%)	7
Outcheck	1	0.53 (53%)	1

Note: Projected volume = 172 totes; model volume = 161 totes

On the tote line, all utilization rates are well within tolerance. The number of work stations in the design will adequately handle the anticipated work load.

Defense Depot Red River, Texas (DDRT) Preservation and Packaging (P&P) Area Tote Line Backlog

Work Station	Number of Stations	Average Backlog	Maximum Backlog	Maximum Allowed	% Time > Allowed	Average Wait
Incheck	4	5.7	26	6	34%	1.1 hours
Prefab	2	0.1	3	6	0%	51 seconds
Packager	7	2.2	7	6	1%	45 minutes
Outcheck	1	0.3	3	10	0%	57 seconds

Note 1: Projected volume = 172 totes; model volume = 161 totes

Note 2: Backlogs represent the average per individual station

Tote line backlogs present another story. While virtually no backlogs occur at the prefab or out-check stations, significant backlogs develop at the in-check area. While the average queue length (5.7) is less than the queue capacity of 6, queues do at times build to a length of 26. In fact, queue length exceeds the maximum capacity fully 34% of the time, and unlike the pallet line, there is no provision for tote pans to re-circulate around the conveyor system until space becomes available at the in-check stations.

Backlogs also exceed queue capacity at the packaging work stations but not by very much (a maximum queue of 7 compared to a queue capacity of 6) and not for very long (1% of the time).

Defense Depot Red River, Texas (DDRT) Preservation and Packaging (P&P) Area Common Station Utilization

Work Station	Target Volume	Model Volume	Number of Stations	Average Utilization	Max In Use
Vacuum Bag	39	40	2 (vice 1)	2.00 (100%)	2
Case Sealer	54	57	1	0.20 (20%)	1

Note: Increase in vacuum stations assigned reflects increased workload of 40 per day vice original design standard of 15 per day.

The projected daily work load for the vacuum bag is 40 items; based on a capacity of 20 items per day per vacuum bag, at least two vacuum bag machines are required. Only one machine is contained in the design drawing, a reflection of an earlier estimate of only 15 items per day. Notice that even with two machines, utilization is virtually 100% and therefore is not in accordance with the desired goal.

One case sealer is more than enough to handle expected throughput.

Defense Depot Red River, Texas (DDRT) Preservation and Packaging (P&P) Area Common Station Backlog

Work Station	Target Volume	Model Volume	Number of Stations	Average Backlog	Maximum Backlog	Maximum Allowed	% Time > Max Queue	Average Wait Time
Vacuum Bag	88	48	2 (line 1)					
Pallet Line				0.8	2	8	0%	1.2 seconds
Tote Line				0.8	2	4	0%	0.7 seconds
Case Sealer	84	87	1					
Pallet Line				none	1	8	0%	19.2 seconds
Tote Line				none	1	4	0%	0.8 seconds

Backlogs reflect the amount at each individual station

Even though the vacuum bag machines are used virtually all of the time, the conveyor lines that feed the machines both on the pallet line and the tote line appear large enough to accommodate any backlogs likely to develop.

The case sealer machine, used far less often than the vacuum bag machines, has no backlog from either the pallet line or the tote line.

Defense Depot Red River, Texas (DDRT) Preservation and Packaging (P&P) Recommendations

- **Add 6th, and perhaps a 7th, package station to the pallet line**
- **Add a 2nd, and perhaps even a 3rd, vacuum bag machine**
- **Explore ways to alleviate or accommodate the peak backlog at the incheck and package stations; for example,**
 - ▶ **enlarge existing stations or spurs**
 - ▶ **add new stations**
 - ▶ **control flow of arriving pallets evenly throughout the shift**

The first two recommendations result directly from findings addressed in previous charts that not enough work stations were included in the original design to handle the expected volume of work at the pallet line package station and the vacuum bag station in P&P.

The final recommendation stems not from any inability of the work stations to process throughput in a timely manner but instead from lack of physical space on the conveyor system to contain the backlog of material that is likely to accumulate at the work stations indicated. There are several different ways to alleviate or accommodate such backlogs, and we would be more than happy to explore those different scenarios in future studies.

Defense Depot Red River, Texas (DDRT)

Packing and Shipping

Pallet Rack / Pack Sort Work Station

Light Pack

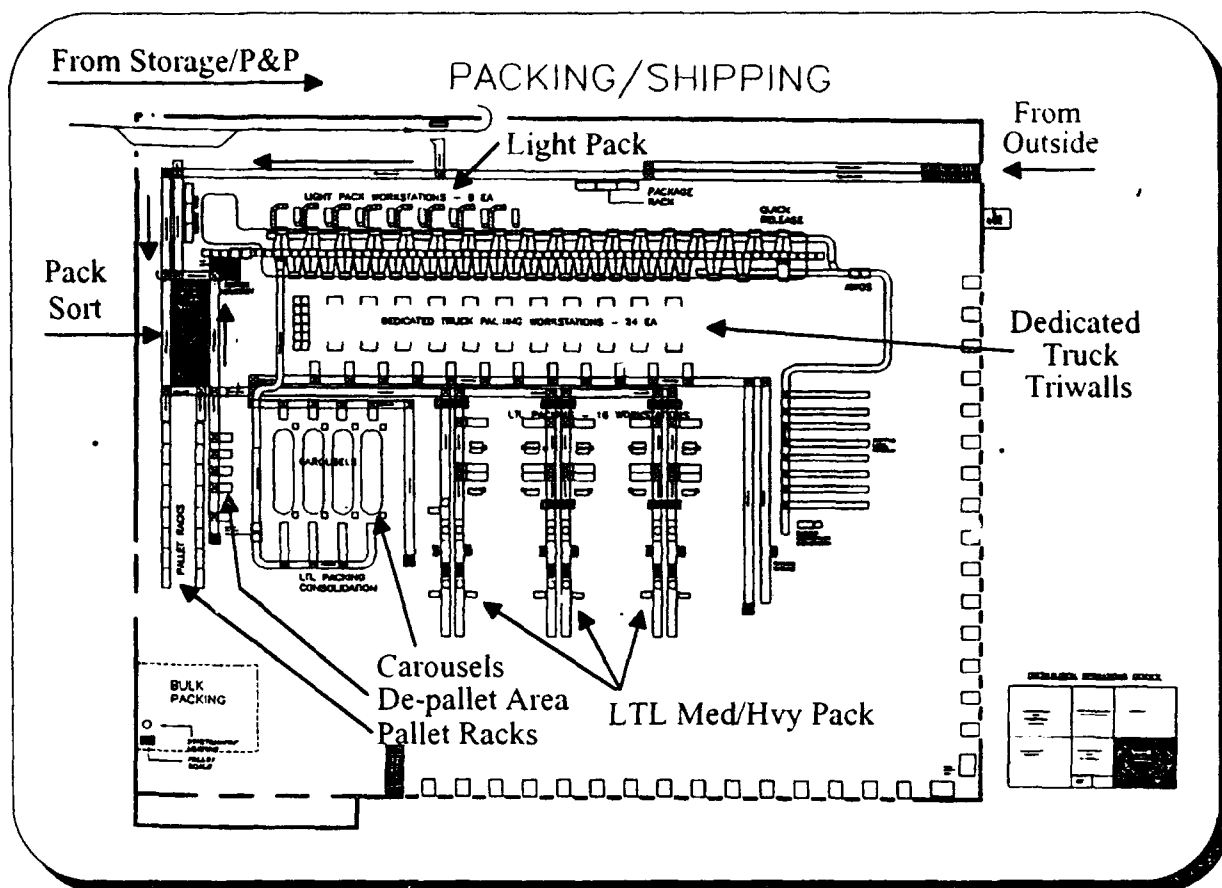
Dedicated Truck

Less Than Truck Load (LTL)

Perhaps the heart of the DOC is the packing and shipping area. Of key importance is the pallet rack and pack sort work station through which all material to be shipped must flow, whether the issue originates within the DOC or comes from external warehouses.

All material that finds its way onto the towveyor/conveyor system is ultimately packed for shipment in one of three areas:

- a. Light pack, a series of work stations fed by a tilt tray conveyor intended for small, light material destined for modes of shipment such as parcel post, UPS, Federal Express, etc. This area also processes quick release MROs as well as issues to local commands and material destined for the Property Disposal Office (PDO).
- b. Dedicated truck, an area also fed by the tilt tray conveyor and a series of chutes directing material to one of up to 24 work stations. Each work station holds 6 triwalls.
- c. Less than truck load (LTL), including 4 carousels for pre-pack consolidation of multi-line shipping units.



Material from P&P and issues from within the DOC storage area travel by towveyor (upper left) to a point where the material is transferred to a pallet conveyor. Issues from outlying warehouses are placed on the same pallet conveyor as soon as they enter the DOC (upper right). All material then flows to the pallet rack area (lower left).

Pallets with only a single line item that are part of a multi-pallet shipment are placed on the pallet racks for consolidation with all other pallets of the shipping unit. Once the shipping unit is completely assembled, the pallets are placed back on the conveyor and carried to the LTL medium/heavy pack area (center) for packing and shipment.

Modules and multi-line pallets bypass the pallet racks and continue up the right-hand side of the pack sort work station (large shaded area, far left). Material that is small enough is placed in the sorter inductor (shaded area to the upper right of the pack sort station). Light pack and dedicated truck material is carried by tilt tray conveyor and delivered down chutes to the appropriate work station. LTL issues are routed down the first chute beyond the sorter inductor for transport via package conveyor to the carousels and, after consolidation, to the LTL medium/heavy pack area.

LTL material that is too large for the sorter inductor is placed on pallets and conveyed to the de-pallet area, where it is transferred to the package conveyor feeding the carousels. Dedicated truck material that is too large for the sorter inductor is similarly placed on pallets and conveyed to the dedicated truck area for packing and shipment.

Defense Depot Red River, Texas (DDRT) Pallet Rack / Pack Sort Area Procedures Modelled

- **Pallet rack purpose**
- **Pack sort work station**
 - ▶ **P&P**
 - ▶ **Sorter inductor**
 - ▶ **Dedicated truck**
 - ▶ **LTL**

Having discussed the packing and shipping section in general, we are now ready to address specific areas in more detail. First, we will discuss procedures at the pallet rack, pack sort area.

There is no reason to expect all pallets of a multi-pallet MRO or shipping unit to enter the conveyor system together. Instead, they will almost certainly be interspersed with other material. Consequently, the purpose of the pallet rack area is to consolidate all pallets of a given multi-pallet shipment before the material is conveyed to its final packing destination for eventual release to the customer as a single shipping unit.

For all material on modules, the pack sort work station serves as the point of entry into the sorter inductor. From there, material is conveyed either by tilt tray conveyor to the light pack or dedicated truck areas or else by package conveyor to the LTL pre-pack consolidation area (i.e., carousels).

In addition, personnel at the pack sort station must sort and re-palletize all pallets bearing mixed material. A single pallet might contain material which requires preservation and/or packaging, in which case the material must be placed on a separate pallet for transfer to P&P. The same incoming pallet might contain LTL material too large for the sorter inductor, and that material must be placed on its own pallet for delivery to the LTL carousels. Similarly, dedicated truck material that is too large for the sorter inductor must be placed on yet another pallet for delivery to the dedicated truck area. Any remaining material that will fit in the sorter inductor must also be processed. Clearly there is potential for congestion at the pack sort station.

Defense Depot Red River, Texas (DDRT) Pallet Rack / Pack Sort Area Utilization

Work Station	Target Volume	Model Volume	Number of Stations	Average Utilization	Max In Use
Pallet Rack Personnel	—	545 PLT	1	0.57 (57%)	1
Pallet Racks	—		Unconstrained	82.5	191
Depallet	—	91 PLT	4	0.05 (1%)	2
Pack Sort	393 PLTS/ MODS	298 PLTS/ MODS	2 (Vice 1)	1.22 (61%)	2

Pallet rack personnel remove pallets as they arrive on the conveyor line and place them on pallet racks for consolidation with other pallets of the same shipping unit. One person is kept busy less than 60% of the time, well within the utilization goal.

Pallet rack slots themselves were modeled as unconstrained resources to see how many might be needed. An average of 83 pallets were stored on the pallet racks throughout the simulation with a peak of 191 pallets stored at any one time.

The de-pallet area is used to transfer LTL material that is too large for the sorter inductor from pallets on the pallet conveyor to the package conveyor leading to the LTL pre-pack consolidation carousels. From the extremely low utilization rate below 1% it is clear that 4 stations are more than enough to handle work load; in fact, at most 2 of the 4 stations were in use simultaneously.

At the sort pack work station, notice that it was necessary to add a second person, not necessarily a second station, to handle the work load. This addition was largely a result of the re-palletization of pallets with mixed material discussed earlier. With 2 people, utilization was a very reasonable 61%.

Defense Depot Red River, Texas (DDRT) Pallet Rack / Pack Sort Area Backlog

Work Station	Target Volume	Model Volume	Number of Stations	Average Backlog	Maximum Backlog	Maximum Allowed	% Time > Allowed	Average Wait Time
Pallet Rack	—	546 PLT	1	17.5	72	2	50%	8 minutes
Depallet	—	91 PLT	4	none	1	1	0%	none
Pack Sort	382 PLT/ MODS	296 PLT/ MODS	2 (plus 1)	3.8	18	11	30%	12 minutes

Backlogs represent the amount per individual station

Backlog at the pallet rack is a serious problem. The spur that holds pallets awaiting placement on pallet racks as presently designed holds only two pallets. The average number of pallets waiting to go onto the pallet racks (17.5) far exceeded that capacity, to say nothing of the peak queue length of 72 pallets. This was not a passing phenomenon, either: fully 50% of the time more than 2 were waiting.

One important caveat should be noted. These results are sensitive to the distribution used to assign the number of pallets per MRO. The only hard data available concerned the average number of MROs per pallet; however, there are numerous different distributions which can produce that same average. The distribution used in the simulation was a constructed estimate that seemed reasonable to DOSO functional experts involved in the project; we will gladly run additional scenarios with different estimates or even better yet, if firm distribution data become available.

The de-pallet area experienced no backlog problem at all.

The pack sort work station is another story. We saw previously that a second person was required based on workload; the backlog data reported above includes a second work station/accumulator conveyor to accommodate the second person. While the average backlog per station of 3.8 pallets/modules is within the capacity of 11 per station, the peak observed backlog of 18 per station exceeds the capacity, and the capacity is exceeded during 30% of the simulation.

Defense Depot Red River, Texas (DDRT) Pallet Rack / Pack Sort Area Recommendations

- **Pallet Rack**
 - ▶ **Erect enough racks to hold a peak of 200 pallets**
 - ▶ **Assign at least one person full time and...**
 - ▶ **Insure a second person is immediately available as needed**
 - ▶ **Devise a method to hold a peak backlog of 35 pallets (e.g., add new spurs, enlarge existing spurs) or...**
 - ▶ **Control arrival rates to minimize the backlog**
- **Pack Sort:**
 - ▶ **Insure that at least two people can work simultaneously**
 - ▶ **Allow enough space for a peak backlog of 36 pallets and/or modules or...**
 - ▶ **Control arrival rates to minimize the backlog**

To pursue the pallet rack backlog problem further, a test was simulated in which two personnel were assigned to the pallet rack area rather than just one. Not surprisingly, the maximum backlog was in fact cut virtually in half from 73 to 35. Hence the recommendations to insure the immediate availability of a second person as needed and the need to hold a backlog of 35 pallets rather than 72. Even more personnel could be assigned, but eventually a point will be reached when numerous people operating forklifts in a confined area will begin to get in each other's way. The fact remains that a 2-pallet holding spur is just not large enough. Options for resolving these problems can be analyzed in a follow-on study.

With regard to the pack sort area, even two accumulator conveyors able to hold 10-11 pallets each were not enough to handle the peak backlog of 36 pallets (18 pallets at each of the two stations). Enlarging the existing stations or providing additional stations are obvious alternatives. Perhaps less obvious is the possibility of controlling the arrival rates of material flowing to this station. The fact that the most problematic material at this station consists of pallets of mixed material was mentioned previously. All such pallets originate outside the DOC, and as we saw earlier, the model is predicated on the assumption that the bulk of material from outside the DOC arrives early in the 8-hour shift. However, DOC personnel could presumably exercise control over pallet arrivals to allow entry only when backlogs at the station are low enough to accommodate more pallets.

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Defense Depot Red River, Texas (DDRT) Light Pack Area Procedures Modelled

- **Two-level consolidation**
- **Small stuff (parcel post, UPS, etc.)**

Material at the light pack areas undergoes consolidation at two levels. First, multiple picks, sometimes called split picks, are consolidated into MROs. Secondly, MROs are then consolidated into shipping units.

Personnel at the eight designed light pack work stations process light, small items to be shipped via parcel post, UPS, Federal Express, or other similar modes of shipment. Further down the tilt tray conveyor line that feeds the light pack stations are additional stations that process quick release MROs as well as MROs for local commands and material destined for the Property Disposal Office (PDO).

Defense Depot Red River Texas (DDRT) Light Pack Area Results

Work Station	Target Volume	Model Volume	Number of Stations	Average Utilization	Max In Use	Average Backlog	Max Backlog	Average Wait Time
Light Pack	1,088 MRO	1,128 MRO	8	8.82 (89%)	8	25	68	1.2 hours
Labeler	888 BU	814 BU	8	8.82 (7%)	6	none	1	none
Quick Release	428 MRO	429 MRO	2	1.43 (72%)	2	74	204	2.7 hours
Local/PDO	558 MRO	550 MRO	2	1.80 (88%)	2	102	235	2.6 hours

Note 1: Backlogs represent the average per individual station

Note 2: Wait time reflects front end loading of work flow early in the 8-hour shift

From a utilization standpoint, only the local/PDO processors fail to meet the goal of 85-90%. However, if the quick release personnel are made available, utilization for the combined quick release/local/PDO processors would be approximately 83%. In this way the goal could be met without adding another local/PDO processor.

At the opposite end of the spectrum are the 8 package labeling stations at the very end of the light pack conveyor line. These stations are utilized only 7% of the time with at most 6 of the 8 stations in use simultaneously. This area might appear to a candidate for reduction in the number of stations. However, these stations are designated for each of the diverse shipment modes involved (parcel post, UPS, Federal Express, etc.).

At first glance, backlog figures for all but the labeling areas might appear to be excessively large. However, these numbers do not represent full pallets or modules but instead represent individual MROs at each station. Almost all of those MROs are small and light and are contained in chutes that can hold a large number of small MROs. These numbers are intended to provide an estimate of package rack requirements in this area.

Defense Depot Red River, Texas (DDRT) Light Pack Area Recommendations

- **Provide enough package racks to hold a maximum backlog of 800 combined quick release/local delivery and PDO MROs**
- **Permit quick release personnel to assist the local/PDO processors**

No major revisions are necessary in the light pack area. These recommendations constitute only minor modifications that stem directly from the simulation results presented on the previous chart.

Defense Depot Red River, Texas (DDRT) Dedicated Truck Area Procedures Modelled

- **One level consolidation**
- **Only triwalls on dedicated truck conveyor line**
- **Partially filled triwall disposition**

Unlike the light pack area, the dedicated truck area involves consolidation of material at only one level: consolidation of picks into single MROs. Consolidation of MROs into shipping units is not applicable to dedicated truck material.

Only triwalls generated from the dedicated truck packing area find their way onto the dedicated truck conveyor. Other pallets of dedicated truck material (i.e., those from outside the DOC) are sent down the LTL conveyor line for shipment.

Triwalls are released for shipment as they are filled throughout the dedicated truck packers' 8-hour shift. In addition, at the end of every day, the model picks another 20% of the 144 triwalls for shipment even if the triwalls are not yet full. This practice emulates departure of trucks for specific destinations with whatever material that happens to be ready at that time.

As we will see on the next display, the dedicated truck is probably the most trouble-free element in the entire packing and shipping area.

Defense Depot Red River, Texas (DDRT) Dedicated Truck Area Results

Work Station	Target Volume	Actual Volume	Number of Stations	Average Utilization	Max in Use	Average Backlog	Max Backlog	Average Wait Time
Dedicated Truck Packers	2,243 MRO	2,151 MRO	24	8.16 (99%)	24	0.5	7	2 minutes
Bander	83 Triwall	86 Triwall	1	8.97 (7%)	1	0.2	18	55 seconds

Backlogs represent the average per individual station

Notice that utilization rates for both the 24 packing stations and the one triwall banding station at the end of the dedicated truck conveyor line are well within target. Similarly, there are no appreciable backlogs at either place. Consequently, no improvements are needed for the dedicated truck operation.

Defense Depot Red River, Texas (DDRT) Less Than Truck Load (LTL) Area Procedures Modelled

- **Two level consolidation at carousel**
- **Shipping unit in one cell**
- **Carousel rotation: frequency, distance**
- **Carousel availability: one or the other, never both**
- **Carousel software: offload > onload**
- **Single container upon offload**

Unlike the dedicated truck area, but just like the light pack area, less than truck load material is consolidated at two levels: picks are consolidated into MROs, and MROs are then consolidated into shipping units.

The carousels are used for this pre-pack consolidation of LTL material. MROs of one shipping unit are place onto the same carousel position; any overflow is placed on an immediately adjacent slot.

A carousel is rotated once per arriving pick/MRO and once per off-load of a completed shipping unit . Distance rotated is randomly assigned not to exceed the length of the carousel (i.e., carousel rotation is bi-directional).

At any one time, a carousel is available exclusively to the on-loader or off-loader, but never to both at the same time. Furthermore, the model is structured so that carousel software gives precedence to off-loading of completed shipping units over on-loading of arriving MROs. Otherwise, the number of MROs accumulating on the carousels will quickly exceed the carousels' capacity.

Finally, it is assumed that each completed shipping unit fits into a single container when removed from the carousel.

Defense Depot Red River, Texas (DDRT) Less Than Truck Load (LTL) Area Utilization

Work Station	Target Volume	Model Volume	Number of Stations	Average Utilization	Max In Use
Carousels	528 MRO	680 MRO	4 (44 cells in each)	2.37 (58%) 7.6 cells in each	4 18.5 cells in each
LTL Med/Hvy	681 PLT	804 PLT			
1-2 PLT WS			12 (Max 15)	3.74 (31%)	12
3-9 PLT WS			2 (vice 1)	1.77 (89%)	2
Shrink Wrap	488 PLT	588 PLT	6	2.37 (40%)	6
Crating	100 PLT	108 PLT	6	0.50 (8%)	4

The only utilization difficulties occurred on the LTL medium/heavy pack stations. In the original design, one of the six conveyor lines was designated to handle MROs of 3 to 9 pallets. The other 5 lines, each with 3 stations, were designated for lot sizes of 1 and 2 pallets. Utilization results indicate that two lines (1.77) are needed for the 3-9 pallet lots. Even with two lines, the utilization rate of 89% pushes the desired limit. There appears to be enough slack in the 4 lines (12 stations) assigned to 1- and 2-pallet lots to have a 3/3 split if operations dictate.

Realize that the same caveat encountered previously in the discussion of the pallet rack area applies to this area as well. That is, the mix of pallets is sensitive to the distribution used to assign the number of pallets per MRO. Lacking detailed historical data, the model employed a distribution that was our best estimate constructed to preserve the 1.36 MROs per pallet data provided by DOSO.

Notice also that both the average and maximum utilization rates for carousel cells are well within carousel capacity. These results were obtained only after the model was revised to give precedence to off-loading completed shipping units. When on-loading was given priority, the carousels quickly overflowed.

Defense Depot Red River, Texas (DDRT) Less Than Truck Load (LTL) Area Backlog

Work Station	Target Volume	Model Volume	Number of Stations	Average Backlog	Maximum Backlog	Maximum Allowed	% Time > Allowed	Average Wait Time
Carousel	838 MRO	888 MRO	4	2.8	88	—	—	18 minutes
LTL Mod/Hvy	881 PLT	884 PLT						
1-2 PLT Ws			12 (Min 12)	none	1	3	0%	2 seconds
3-8 PLT Ws			2 (Min 1)	12.2	84	10	76%	48 minutes
Shrink Wrap	488 PLT	888 PLT	6	none	2	2	0%	8 seconds
Crating	188 PLT	188 PLT	6	none	1	1	0%	none

Backlogs represent the amount per individual station

Utilization results indicated that a second line should be devoted to shipping units of three or more pallets. These backlog figures suggest that two lines might not be enough: the average backlog at each of the two stations exceeds the maximum capacity, and that capacity is exceeded fully 76% of the simulation duration. However, these results must again be tempered by the realization that the distribution used to determine the number of pallets per MRO is a very soft estimate and is not based on hard data.

Defense Depot Red River, Texas (DDRT) Less Than Truck Load (LTL) Area Recommendations

- **Flexibility in assigning the mix of lines devoted to 1-2 pallet stations and 3-9 pallet stations
(Note: 6 total lines are sufficient to accommodate any mix likely to be required)**
- **Implementation of carousel software that gives precedence to offloading completed shipping units over onloading newly arrived material**

Given that the results of the LTL section depend heavily on a distribution which was estimated and not based on hard data, perhaps the most that can be said is that a certain amount of flexibility will be necessary in assigning the exact mix of lines devoted to processing lots of 1 and 2 pallets as opposed to lines devoted to processing 3 to 9 pallets. It is important to note, however, that six lines called for in the design appear to be sufficient to accommodate any mix likely to be encountered.

The second and last recommendation stems directly from the utilization results and has been addressed previously.

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