A METHOD TO OPTIMIZE THE SIZE OF EMPTY CONTAINER BUFFERS IN PORT

by

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ABSTRACT

In order to cushion the impact of the daily demand of exporters for empty container vans, extra empty containers are kept in or near the port as a buffer. The sizing of these empty container buffers involves trade-offs which are here identified. Lost revenue cost decreases while storage cost increases with buffer size. Lift and transit costs for replenishment increase with buffer size. For shipping away excess empties at a constant rate, lift and transit costs decrease with buffer size. The major random variables affecting buffer size are pointed out: cargo volumes, time for an importer to unload a container and time for an exporter to load a container. A method to find the optimum buffer size, based on discrete event simulation modelling, is developed. Various replenishment schemes are considered.

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I. Introduction

An operational problem that is encountered by shipping companies on a regular basis is the provision of extra empty containers at the various ports in order to cushion the impact of the daily demand of exporters for these empty containers. These extra containers are here referred to as the empty container buffer at the port. To maintain an acceptable if not optimal level of the inventory of these empties, it is necessary to balance their supply in a multiport itinerary based on a repositioning strategy. Thus a twofold problem exists: the determination of optimal buffer size at each port and the determination of a strategy of repositioning empties in an itinerary to keep the buffer sizes at near optimal level.

The problem of empty container management is very important because of the high cost of acquiring, maintaining, handling and transporting containers. Also the opportunity cost of cargo lost to other carriers due to an inadequate supply of containers can be very high.

To give a measure of the acquisition costs involved, Edmond and Wright (1976) show that in the case of a 1200 TEU ship with three sets of containers, annual capital charges are 28% containers and 72% ship. Since the determination of optimal buffer sizes and the optimal repositioning strategy directly affects the decision on the number of containers to maintain, this research can prove to be valuable in an economic sense.

The problem of empty equipment management exists not only in ocean shipping but also in the rail and truck industries. While extensive literature exists in the case of the rail and truck industries, very little has been written about the problem in the case of container shipping. Dejax and Crainic (1987) in a survey paper, find it "surprising" that the latest methodologies for the rail and truck modes have not been employed in ocean shipping.

Potts (1970) solves the problem for the movement of empty containers in Australia using the standard out-of-kilter algorithm. White (1972) builds a space-time network (a dynamic transshipment network) and solves it using the out-of-kilter algorithm also. Ermol'ev, Krivets and

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* TEU is the acronym for twenty equivalent units or the standard 20 ft long container. A 40 ft long container is equal to two TEU's. Thus a 1200 TEU ship can carry 1200 X 20 ft long containers or 600 X 40 ft long containers or any combination of 40 footers and 20 footers that is equivalent to 1200 TEU's.

Petukhov (1976) build a dynamic model and propose a solution by means of a network optimization algorithm. Florez (1986) builds a dynamic transshipment network solved by two alternative linear programming algorithms. All of the above work do not consider the stochastic nature of the flow of containers in an itinerary and do not shed light on the question of optimal buffer sizes.

In a very recent work, Ireland (1991) uses discrete event simulation to compare various strategies of repositioning empty containers in a simple mutiport container service. He uses arbitrarily chosen sizes of empty container buffers and acknowledges that "a method must be found to optimize the size of these buffers." The optimization of buffer sizes is a gap that this research aims to bridge.

Section II of this paper describes the simulation model that was constructed to solve the optimization problem. Section III discusses an illustrative example of the application of the model. Section IV gives the conclusions of the study. References are given at the end. All Tables and Figures are placed at the end.

II. Simulation model

A. Assumptions

This section discusses the assumptions behind the model. It describes container flows in a port as a basis for the model. The system is defined and the basis of optimization is laid out in terms of cost elements. A flowchart is presented along with some program details.

1. A . port in which the average number of export containers exceeds that of import containers is here referred to as a "sink" port in the sense that they tend to swallow up empty containers. If an opposite situation exists, the port is referred to as a "source" port. It is here assumed tnat no empty containers are ever exported from a sink port and no replenishments of empties are received by source ports. These assumptions should be valid where the difference of the averages of the exports and imports is significantly large.

2. The demand for and the movement of 40-footers and 20-footers are independent. One 40-footer cannot be

substituted for two 20-footers and vice-versa. This assumption implies that the model can be run either for 40's or for 20's but not simultaneously.

3. The ships call on each port on a weekly basis. This is the current practice of major container lines.

4. The replenishment requirements of sink ports can always be satisfied. The source ports always have the required number of empty containers to give to the sink ports and the ships always have room to carry these replenishments. This assumption creates an ideal situation for each port. The compromises that have to be dealt with will come with the consideration of the entire itinerary in the latter part of this report.

5. The replenishments arrive a week after the requirement is determined. This assumption can be satisfied if the ship can arrive at the port within seven (7) days from the farthest port from which a part of the replenishment is to come. For purposes of demonstration, this assumption will not change the basic nature of the results. In a particular operation, however, the schedule of replenishments will have to be factored in.

6. Import containers always return to port empty, i.e., no shippers unload and load a container van in a single round trip from port to hinterland and back to the port. If this assumption were not true in a certain application, the accomodation of such a situation into the simulation model can be simply done if the percentage of the shippers who unload and load in the same trip can be estimated fairly accurately.

7. All import containers are full container loads, i.e., they are not devaned at the container freight station (CFS). If this were not the case, the simulation model may be articulated further. As in assumption 6, if the percentage of containers that pass through the CFS is known, then this situation can be easily accomodated in the model.

8. If there is a demand of an exporter for an empty container that cannot be satisfied, a situation termed "stockout" exists. In this research "stockout" is used to mean the number of orders that are not filled. In this case it is assumed that the customer is lost

to the competition. Conceivably, it may happen that the customer waits for next week's sailing. Such a possibility is not considered here. Neither is the possibility of leasing a container to fill an order.

9. Seasonality of cargo volumes is not considered here although such can be very readily accomodated in a discrete-event simulation model.

B. Container flows

Figures 1 and 2 show schematically the flow of containers at a sink and a source port, respectively.

For a sink port, a ship comes in bearing imports and replenishments of empty containers. The replenishments immediately go to the buffer upon arrival. The imports get unloaded by the importers and are sent back empty to the buffer. This movement of the container takes a random amount of time and is here called the "emptying time". Prior to the ship's arrival, empty containers are ordered by exporters from the buffer in a random fashion. They may get back to port long before the ship's arrival and be stored in the port along with the other export containers.

In contrast to the sink port, the source port does not receive any replenishments. In fact it ships away excess empty containers from the buffer.

If the loaded containers are tracked individually, each container will go through the following process:

1. arrives at the port
2. waits in storage
3. is transported to the importer
4. is unpacked by the importer
5. is returned empty to the buffer
6. leaves buffer to be transported to exporter
7. is packed by exporter
8. is returned to export storage
9. catches the next sailing

Items 1 to 5 may be said to constitute the "emptying time" as defined before while items 6 to 9 may be said to constitute the "filling time". Both empying and filling times are affected by the physical and economic conditions of the country in which the port is located. They may be influenced by management policy.

C. System definition

The system may be taken as the ship, the containers, the port, including the buffer and the hinterland.

In such a system, the input random variables are: the number of import containers, the number of export containers, the emptying time and the filling time.

The state of the system is completely determined by the buffers size. Thus the events that change the state of the system are:

1. a ship calling at the port with its load of empties
2. an import container coming back empty from an importer
3. an empty container leaving the buffer upon order of an exporter.

D. Cost items

System costs include storage cost, lift cost, transit cost and lost revenue cost. Capital cost is not considered. According to Ireland (1991) the capital cost of containers is small compared with lost revenue cost and lift cost. The discussions below detailing each cost item are based on Ireland (1991).

1. Storage cost

This is the cost incurred to the system by the storage on empty containers in the terminal. If the shipping company does not own the yard, this item can be quantified as a daily rate for each container.

2. Lift cost

Lift cost is the cost of unloading containers from and loading containers onto a ship. Most terminals charge the same for each lift regardless of container weight or size.

3. Transit cost

Transit cost refers to the sum of daily fixed operating costs and fuel costs. This cost is quantified as the cost of transporting one tonne, one mile. In transporting an empty container, "fully allocated costs" must be applied when the empty container displaces a loaded container. If it does not, marginal costs are applied. In this study marginal costs are invariably applied. More specifically, this is taken to be the marginal fuel costs of the vessel for one additional empty container per mile.

4. Lost revenue cost

Lost revenue cost is the cost incurred due to the inavailability of an empty container when ordered by an exporter. It is the opportunity cost of not being able to earn revenue from shipment of cargo. According to Ireland (1991), this cost depends upon "the type of container, what the customer would have been willing to pay to ship the cargo, if the customer is willing to wait a short amount of time for one to become vailable, how often the customer has been made to wait and the demand for empty containers in other locations." Obviously, this cost is not easy to calculate. This cost is here assumed to be the average revenue earned by a full container.

E. Optimization

The optimization of the buffer size is based on the goal of minimizing the total system cost.

The existence of an optimum may be deduced from the variation of the cost elements with buffer size. In the case of a sink port, as buffer size increases storage cost, lift cost and transit cost increase while lost revenue cost decreases. Lift cost and transit cost increase because the increased buffer size can come about only through higher levels of replenishment. In the case of a source port, if the number of empty containers shipped away per week is constant, the average buffer size increases as less excess empties are sent away. Therefore in this case lift cost and transit cost decrease with buffer size.

F. Flowcharts

Figure 3 to 6 show the flowcharts for the main program and the three event routines. One iteration consists of a simulation run in which a certain length of simulated time determines the termination of the run. For each iteration a total annual cost is determined. For a number of iterations the average and variance of total annual cost is updated. The variance becomes the basis of the stopping rule for the simulation. Specifically, a certain level of confidence that the mean of the total annual cost is within plus or minus a certain value of the sample mean is prescribed.

The flow of a single iteration itself follows traditional practice for the conduct of discrete event simulation.

The simulation begins at time zero with the setting of the clock to zero, the initialization of system state and statistical counters. In this case, buffer size as the system state variable is set to an initial value and the area under buffer size, total stockouts and total replenishments - as statistical counters - are set to zero.

The timing routine is then called. This routine determines which type of event is most imminent and advances the simulation clock to the next event.

As stated earlier, in this model there are three event types:

1. A ship calling on the port;

2. Return of import containers to the buffer;

3. Customer orders for empty containers.

If an event of type i is the next to occur, the routine for event i is called. Three activities generally happen in the event routines:

1. Updating of system state (buffer size);

2. Updating of statistical counters (area under buffer size, stockouts, replenishments);

3. Generating the times of occurence of future events and updating the time to the next event of type i.

After control is returned to the main program, a check is made whether the simulated time has exceeded the prescribed length of simulation. If the simulation has to proceed, the timing routine is called again. If the simulation run has to stop, the average and variance of total annual costs and the average of each cost item are updated. The stopping rule is then applied. If not staisfied, another iteration is executed. If satisfied, the results are printed out. This consists of the cost items, average buffer size, annual stockouts and average weekly replenishments.

G. Program details

1. Statistical counters

The average buffer size is determined by dividing the area under the plot of buffer size vs. time by the total length of simulation. It is evident that the tracking of the residence of individual containers in the buffer is not necessary in order to determine the average buffer size.

The annual stockout is approximated by getting the total number of stockouts throughout the length of simulation, dividing this by the length of simulation in days and multiplying by 365.

The average weekly replenishment is determined by accumulating the total number of replenishments and dividing by the total number of weeks in the simulation. To get the annual replenishment, this quotient is multiplied by 52.

2. Cost items

The following formulae are used to calculate the items of annual cost:

storage cost = ave buffer size X storage cost/day X 365

lift cost = annual replenishment X lift cost/container

transit cost = annual replenishment X transit cost/container

lost revenue = annual stockout X ave revenue/container

The total annual cost is the sum of all the above cost items.

H. Replenishment schemes

Ireland (1991) uses target buffer levels to determine the replenishment requirements for sink ports. He takes replenishment as a fraction of the difference between the target level and the current level or the average level over an immediately preceding duration of time. This taking of the average is meant to detect any trends in changes in the size of the buffer.

For a simulation where the probability distributions of the random variables do not change over the entire length of the simulation, an approach using average buffer size values appears to have no basis. For this study the replenishment is taken to be the difference between the target level and the current level. If the latter exceeds the former then the replenishment is taken to be zero.

The replenishment arrives a week after the need is determined, at which time the level of the buffer could have significantly changed. Still, there is some merit to the above approach in that relatively speaking a lower level of buffer now more probably implies a lower level a week from now.

For comparison purposes two other schemes are considered for this study:

1. Constant values of weekly replenishment. This is based on the supposition that over time the average of the buffer size will tend to settle to a smaller interval of values.

2. Replenishment equals the number of export containers minus the number of import containers. This is meant to keep the total number of containers, full and empty, constant in a port and its hinterland. The problem of a one-week lag also exists in this case.

III. Numerical example

Two examples are worked out - one for a sink port and the other for a source port.

A. Input data

1. Cargo

The data for the levels of export and import containers are taken from Ireland (1991), who did some statistical fitting on cargo data from American President Lines' (APL) Singapore-Jakarta-Surabaya service.

For the sink port:

number of import containers = 96.846 + 19.860 N(0,1)

number of export containers = 126.86 + 25.487 N(0,1)

where N(0,1) represents the unit normal distribution.

For the source port:

number of import containers = 55.385 + 17.800 N(0,1)

number of export containers = 47.923 + 19.410 N(0,1)

These distributions are shown in Figures 8 and 9.

2. Container emptying and filling time

The probability distribution of time for an import container to be emptied and for an export container to be filled by a shipper is based on data from Edmond and Wright (1976). They give a mean turnaround (arriving in port and leaving port) of 19 days for short sea services. It is here assumed that half of this is used for emptying and the other half for filling. Thus an average emptying time of 9 days and an average filling time of 9 days are here adopted. For emptying time an additional day is tacked on. This is the assumed time when the containers sits in storage waiting to be picked up. Thus the average is pushed up to 10 days.

Based on Edmond and Wright (1976), the probability distributions for emptying and filling time are here taken to be 2-Erlang.

For the filling time, all the containers leaving at a certain ship sailing are assumed to arrive in port a day before the scheduled departure. The distribution of time that they are filled is also assumed to be 2-Erlang.

While the Erlang distribution is here used, it may be noted that in some other applications the generation of emptying and filling times may be based on histograms of actual observed times.

3. Cost items

Data on costs are also taken from Ireland (1991). If X is one unit of cost, then:

yard cost per container :	1.0 X
lift cost per lift:	37.0 X
transit cost per voyage leg per container :	0.7 X
lost revenue per container:	111.0 X

The fact that the costs are only relative values does not change the optimum. Note that transit costs are very small. It shall here be merged with lift cost in the graphs of results since both are involved with the movement of empty containers as replenishments or as excess being shipped away.

Ireland (1991) gives per diem capital cost as 1.4 X. Because of its relatively small relative magnitude, leaving this item out is not expected to materially affect the results.

B. Simulation particulars

The length of simulation is taken to be 2 years.

The initial buffer size is set to zero. Initial experimentation shows that this parameter is insignificant in the determination of the average buffer size. The reason for this is that the train of values of buffer size gets reset when a stockout is encountered since the negative buffer sizes cannot occur and thus the buffer size is set to zero.

The simulation is carried out such that there is 95% confidence that the mean of total annual costs is within plus or minus 20,000 units of the sample mean. The confidence interval is much smaller for some data points. On the whole for adjacent points in a graph there is to be no overlap of the confidence intervals.

C. Results

The results for the sink port are shownin Tables 1 and 2. These data are graphed in Figures 11 to 15. The results for the source port are shown in Table 3, on which are based Figures 16 and 17.

For the sink port Table 1 and Figures 11 to 13 show the results corresponding to the use of a target buffer level. Table 2 and Figures 14 and 15 correspond to a constant level of weekly replenishments. The last row of Table 2 also shows the results if the replenishment scheme is to equate replenishment to the difference of export and import containers as discussed in Section II.H.

Attention is first focused on the sink port using a target buffer level. Note that all graphs are very smooth. As expected, average buffer size increases with target buffer while stockout exhibits the opposite trend. Beyond a target buffer of 100 containers the graph for weekly replenishments becomes essentially flat. This coincides with the region where the graph of average buffer size becomes bigger and essentially constant. Thus with the bigger increases in average buffer the increase in replenishments also drops off. Also as can be seen in Figure 12, the stockouts also decrease dramatically beyond a target level of 100.

All these trends are reflected in Figure 13. Storage cost follows the shape of the average buffer curve. Lift and transit costs follow the shape of the replenishment curve. The lost revenue curve follows the shape of the stockout curve.

Looking at Figure 13, the increase in the storage cost dominates the trend of the total cost beyond a target level of 100, while the decrease in stockout cost dominates the total cost curve for target levels below 100. Table 1 shows the optimal target level at about 100, corresponding to an average buffer size of 54 containers, an average weekly replenishment of 24 containers and a total cost of 91,055 units.

For a constant level of weekly replenishment, the optimal level is 25 containers per week corresponding to an average buffer size of 65 containers and a total cost of 111,322 units.

From Tables 1 and 2 it may be deduced that for the same average buffer size the total cost is consistently lower for the "target buffer" strategy than for the "constant replenishment" strategy.

It may thus be seen that a policy of using target levels is significantly more economical than the use of constant weekly replenishments.

Note also that the use of exports-minus-imports policy, the results for which are shown in the last row of Table 2, gives the highest cost - 146,719 cost units. This is 61% higher than that for the optimum of the "target buffer level" strategy or scheme. Note that the "exports-minus-imports" policy results in very high average buffer sizes.

In Figure 15, the total cost curve increases at a faster rate to the right of the optimum as the the total cost curve of Figure 13. This is due to the fact that replenishment for the "target buffer" strategy is held down by being tied to the current buffer size.

In Figure 11 note that the average buffer size is consistently lower than the target level although beyond a target of 80 containers the relationship is essentially linear. In a sense, "target level" then may be a misnomer.

In Figure 13 it appears that setting a target which is lower than the optimal level can result in a much higher total cost than if the target were set to the right of the optimum. This is due to the relatively high level of stockouts and the very high cost of lost revenue compared with the other cost items.

From Table 2, beyond a target level of 180 the stockout remains the same. This means that it is pointless to show data beyond this point in as much as the object of avoiding stockouts by increasing buffer size is no longer at work.

The results for the source port show a well defined optimum and very clear trends in the graphs. The slopes for the storage and lost revenue curves shown in Figure 17 are now the reverse of those of Figures 13 and 15. The slope of the lift and transit costs curve remains the same in all curves since these costs are a function of containers moved regardless of whether it is towards or away from the port.

The graph of Figure 17 levels off beyond 15 containers per week, the optimum number of empty containers to be shipped away. In this region there are a lot of cases when the buffer is zero or below the desired number of empty containers to be shipped away. This means that there is a trend towards the equalization of actual number of containers shipped away.

IV. Conclusions

This study has identified a basic trade-off involved in the optimization of the size of an empty container buffer at a port. In the case of a sink port a bigger buffer leads to smaller lost revenue cost but requires higher transit, lift and storage costs. In the case of a source port a bigger buffer leads to less lost revenue, transit and lift costs but requires a higher storage cost.

The most significant random variables affecting the buffer size have been pointed out: import and export volumes and the emptying and filling times for the containers.

A simulation model of container flow in a port that takes account of the abovecited random variables has been developed and applied successfully to a numerical example. The numerical results are reasonable and clearly demonstrate the cost trade-offs pointed out above.

It has been shown via the example that a replenishment scheme using a target buffer level is more desirable than one with a constant value for replenishments.

The output of the above method, a graph of total costs vs. average replenishment or excess, can conceivably be used in the optimization of the flow of empties in a single multiport container service. Within the constraint of the source ports being able to supply the sink ports in a service, a mathematical program may be formulated to determine the balance of replenishments and excesses that minimizes total system cost. This approximate optimal may be the starting point for a search for better configurations. The above can be the subject of future research as a novel approach to the problem of empty container management.

For a specific application the above method can be easily extended to account for the following:

1. The seasonality of cargo volumes;
2. The handling of import volumes from several upstream ports and export volumes to several downstream ports;
3. The generation of random variables from histograms;
4. The inclusion of the devanning and packing of containers at a freight consolidation station.

REFERENCES

Dejax, P.J. and T.G. Crainic, "A Review of Empty Flows and Fleet Management Models in Freight Transportation", Transportation Science, Vol. 21, No. 4, November 1987.

Potts, R.B., "Movement of Empty Containers Within Australia", paper presented before Operations Research Society of Victoria, Melbourne, Australia, 1970.

White, W.W., "Dynamic Transhipment Network: An Algorithm and Its Application to the Distribution of Empty Containers", Networks, 2, 211-236, 1972.

Ermol'ev, Y.M., T.A. Krivets and V.S. Petukhov, "Planning of Shipping Empty Seaborne Containers", Cybernetics, 12, 664-646, 1976.

Florez, H., "Empty Container Repositioning and Leasing: An Optimization Model", Ph.D. Dissertation, Polytechnic Institute of New York, 1986.

Ireland, P., "Systematic Control Techniques for Repositioning Empty Equipment Within a Maritime Transportation System", M.S. Thesis, University of California at Berkeley, 1991.

Edmond, E.D. and A.J. Wright, "Estimating the Number of Sets of Containers for Containerships", Trans., RINA. 1976.

Table 1

RESULTS FOR A SINK PORT
USING TARGET BUFFER LEVEL

200	0.00	3.77	1627	0	0	1,376	180,615	181,991	5395	30
200	8.12	7.28	1206	15,661	296	2,658	133,860	152.476	4899	30
200	15.77	14.05	809	30,434	576	5,129	89,885	126,025	4249	30
200	22.08	24.15	486	42,589	805	8,815	54,003	106,214	3454	30
200	26.58	37.53	257	51,280	970	13,702	28,637	94,601	2550	30
200	29.30	53.81	124	56,529	1069	19,642	13,813	91,055	1821	30
200	30.72	71.98	60	59,276	1121	26,271	6,621	93,290	1393	30
200	31.37	91.20	36	60,515	1144	33,289	3,955	98,905	1232	30
200	31.68	110.86	29	61,126	1156	40,463	3,226	105,972	1205	30
200	31.88	130.66	28	61,511	1163	47,690	3,180	113,545	1193	30
200	32.08	150.47	28	61,881	1170	54,920	3,180	121,153	1193	30

Table 2

RESULTS FOR A SINK PORT
WITH CONSTANT REPLENISHMENT
AND EXPORT-IMPORT SCHEME

0	3.76	1627	0	0	1,376	180,615	181,991	5,395	30
5	5.55	1362	9,712	183	2,028	151,175	163,100	4,920	36
10	9.72	1104	19,425	367	3,550	122,577	145,920	5,186	30
15	16.79	844	29,137	551	6,129	93,700	129,518	4,895	30
20	30.24	587	38,850	735	11,038	65,124	115,747	4,190	30
25	65.05	343	48,562	918	23,744	38,097	111,322	2,999	30
30	150.00	152	58,275	1102	54,820	16,860	131,058	9,950	35
35	319.00	71	67,987	1286	116,605	7,842	193,721	14,919	42
40	539.00	49	77,700	1470	196,909	5,390	281,468	19,840	36
45	794.00	38	87,412	1653	289,994	4,250	383,311	19,991	34
33.28	199.00	61	65,905	1246	72,793	6,774	146,719	6,225	30

Table 3

RESULTS FOR A SOURCE PORT
WITH CONSTANT NUMBER OF EXCESS EMPTIES
SHIPPED AWAY EACH WEEK

0	412.75	33	0	0	150,656	3,667	154,322	17,266	30
5	201.35	56	9,228	174	73,493	6,199	89,095	13,187	30
10	72.08	123	16,792	317	26,310	13,699	57,119	4,551	30
15	27.16	214	21,088	398	9,915	23,715	55,118	1,391	30
20	15.33	269	23,275	440	5,598	29,910	59,225	1,244	30
25	10.68	300	24,411	461	3,899	33,275	62,048	1,284	30
30	8.85	314	24,946	471	3,232	34,852	63,503	1,190	30
35	8.00	320	25,187	476	2,921	35,549	64,134	1,208	30

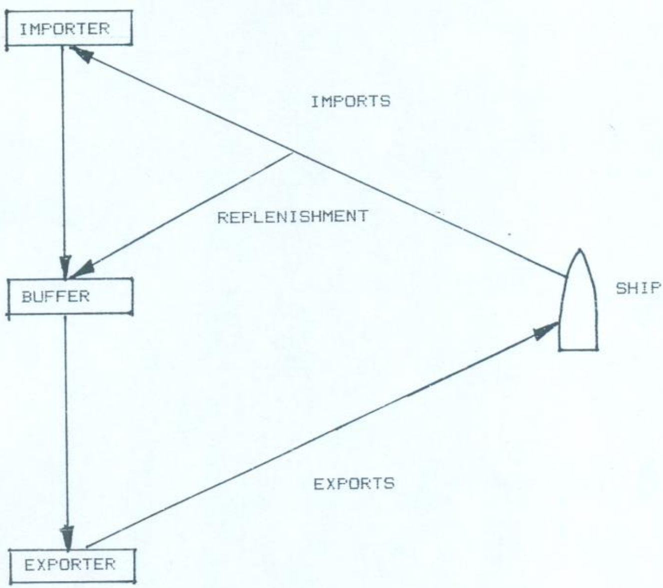


Figure 1

CONTAINER FLOW IN A SINK PORT

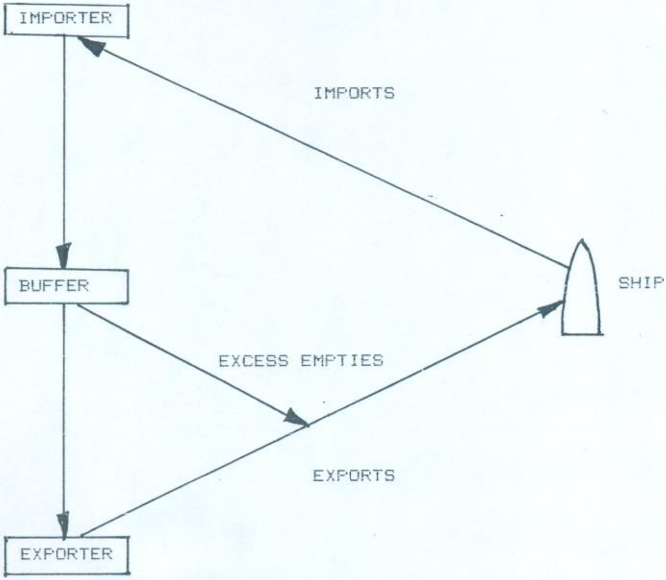


Figure 2

CONTAINER FLOW IN A SOURCE PORT

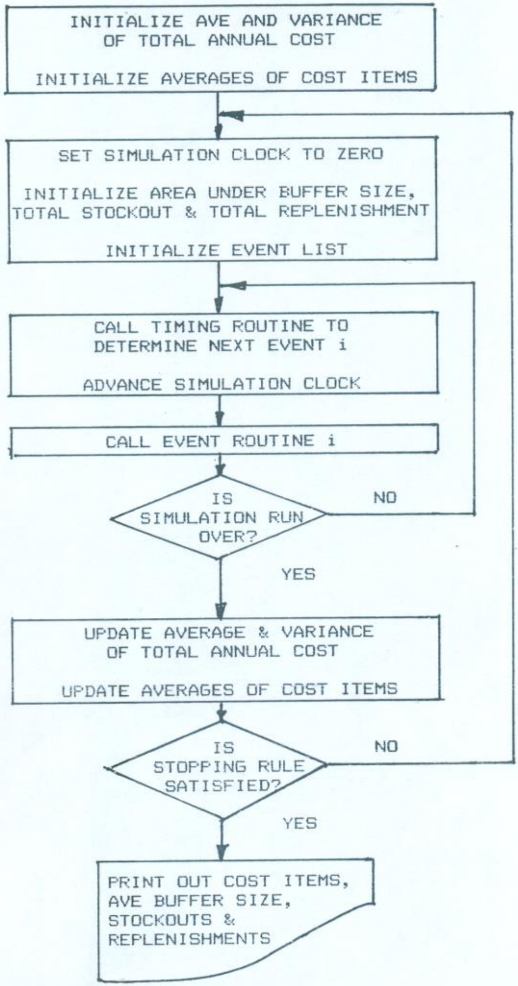


Figure 3

MAIN FLOWCHART

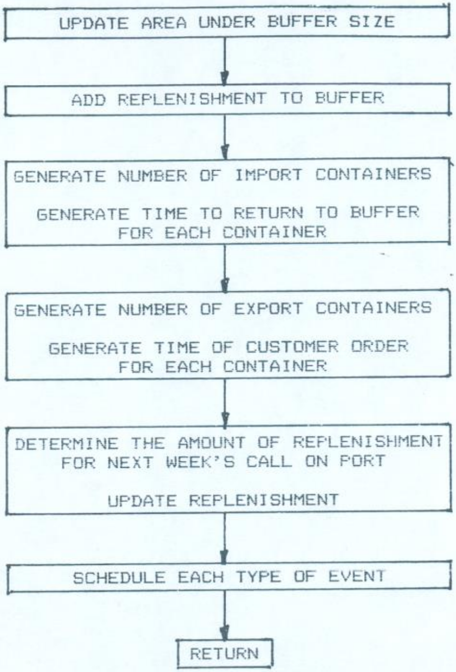


Figure 4

FLOWCHART FOR THE EVENT:
SHIP CALLING ON PORT

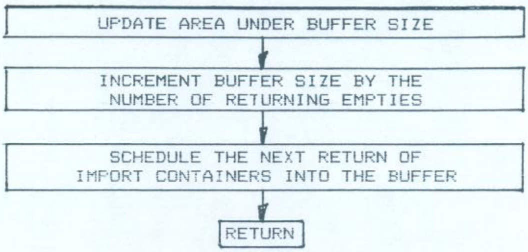


Figure 5

FLOWCHART FOR THE EVENT:
RETURN OF IMPORT CONTAINERS INTO THE BUFFER

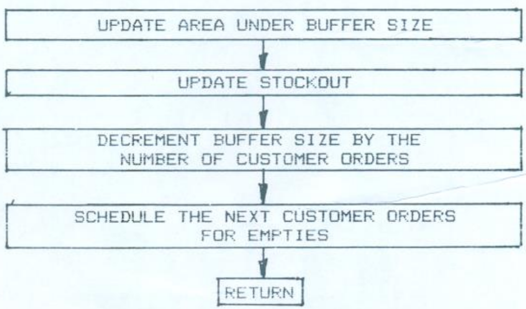


Figure 6

FLOWCHART FOR THE EVENT:
CUSTOMER ORDERS FOR EMPTY CONTAINERS

FIGURE 14

CONSTANT REPLENISHMENT—BUFFER/STOCKOUT

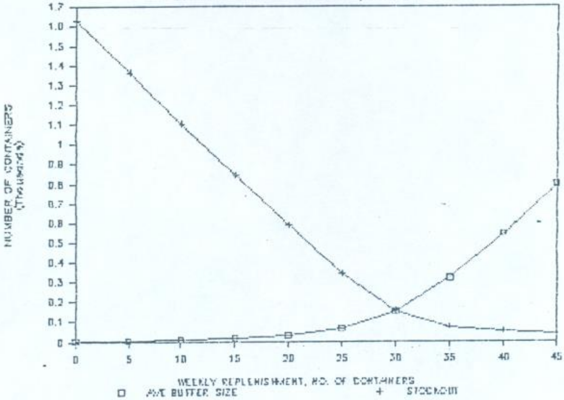


FIGURE 15

CONSTANT REPLENISHMENT — COST ITEMS

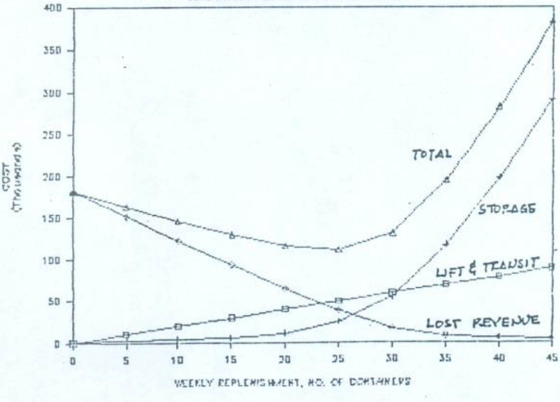


FIGURE 16

SOURCE PORT – BUFFER/STOCKOUT

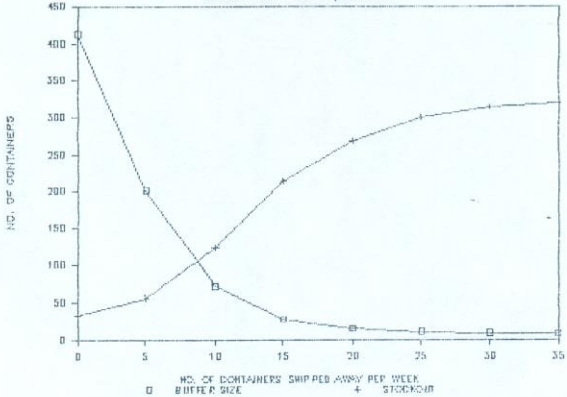
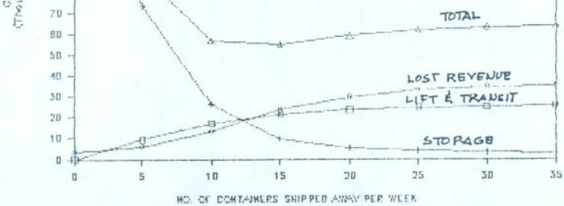


FIGURE 17

SOURCE PORT – COST ITEMS



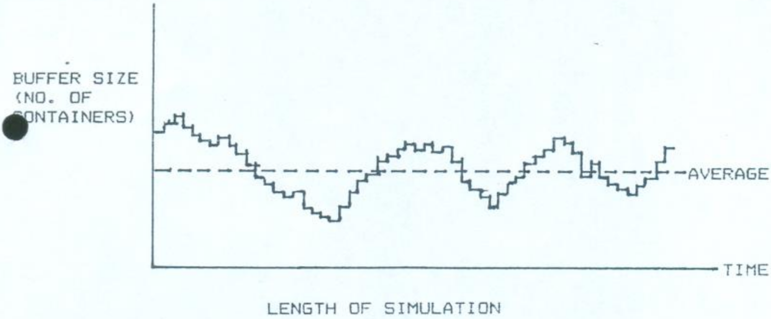


Figure 7

AVERAGE BUFFER SIZE

FIGURE 8

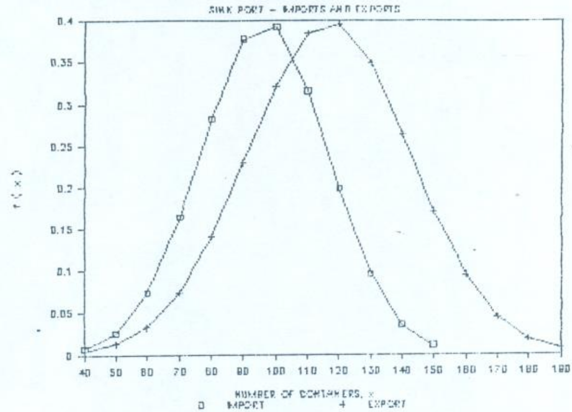


FIGURE 9

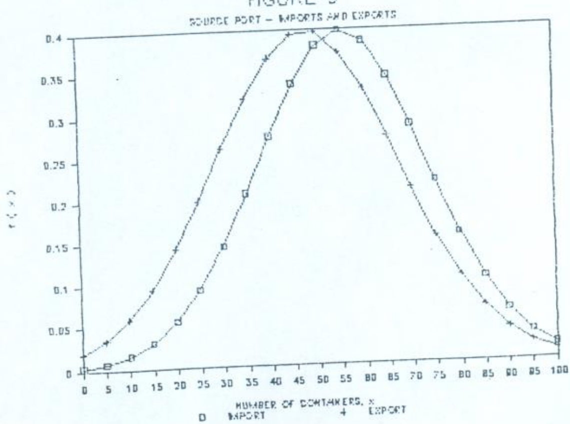


FIGURE 10

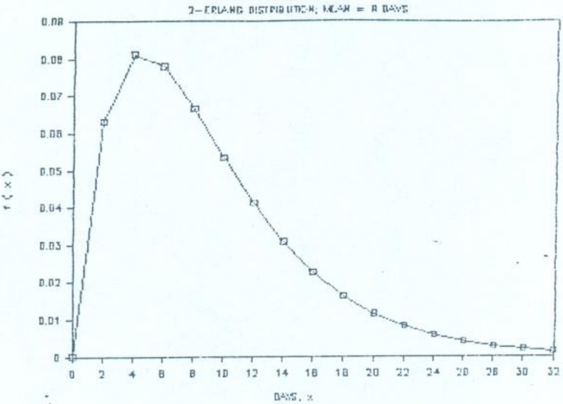


FIGURE 11

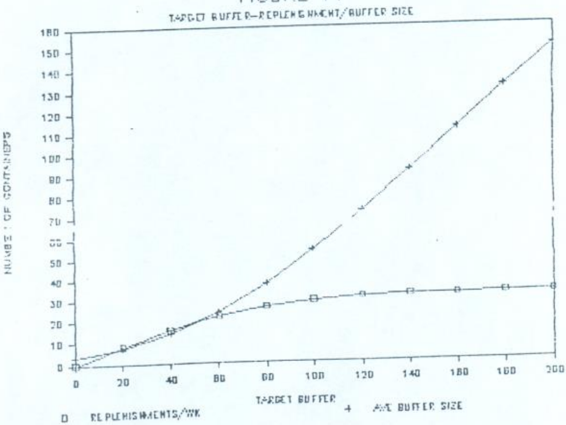


FIGURE 12

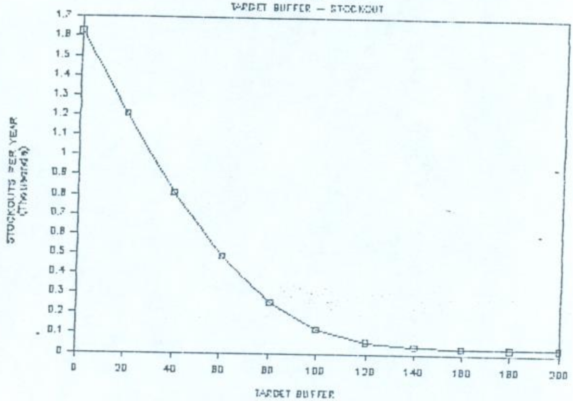


FIGURE 13