SIMULATING WAREHOUSE LAYOUT PATTERNS IN ORDER TO IMPROVE CUBE UTILIZATION

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The nature of the pharmaceutical industry, with its stringent controls, forces special operating procedures throughout the manufacturing cycle. One recently adopted procedure deals with our raw materials warehouse. In particular, it states that raw material, usually fine chemicals, must be identified and stored by the vendor's lot number. As a result of this change, the lot size characteristics have been drastically altered and an improved warehouse space allocation and control system is needed.

The basis of the space control system is this: Once a group of pallets, all with the same vendor's lot number, is stored in a sub-bay, nothing else is stored in that sub-bay until the last pallet of the original material is withdrawn.

The diverse nature of the lot-arrival and pallet-withdrawal patterns, as well as the fact that the study must consider over 300 major products, leads one away from purely analytical solutions. Consequently, a 460-block GPSS program was written to simulate the warehouse. The program processes a JOBTAPE that sets up the proper products to be considered, charges the warehouse to a starting level, and then imputs new lots at the proper time.

Upon receiving a new lot, the program must optimally select and assign storage locations. This task is accomplished by a series of MATRIX SAVEVALUE decision tables keyed on stack height and lot size. Each four hours of simulated time, the mode of the program shifts from input to output and the pallets are allowed to be withdrawn. All withdrawals are based on a linear depletion function whose slope is based on actual withdrawal information unique to each product. The withdrawals take zero time; and upon completion of all withdrawals, at the end of each four-hour period, certain statistical measures, such as cube utilization, vacant cube, etc., are calculated and TABULATED.

The decision variables that affect the performance of the warehouse describe the floor configuration. Of course, the program allows the floor to be laid out in many different ways in order to note the influence of the different layouts on our performance statistics. It must be pointed out that this simulation is not concerned with anything other than cube utilization; i.e., the location of products for rapid or slow retrieval is not considered.

Program Description

This is an application of a supposedly queuing-oriented simulation language, GPSS, to a nonqueue problem. For example, we use no QUEUES, STORAGES, or FACILITIES. The GPSS features of PARAMETERS, indirect addressing, and GROUPS make this a practical language for this problem.

In order to understand our problem more clearly let us look at Figures 1 and 2. These figures illustrate two extreme, yet plausible, layouts. Note that each sub-bay may be entered from only one aisle. Further note that as the bays grow larger the area of the aisles relative to the total area decreases. It is the purpose of the program to find the point at which the loss of usable cube taken up by aisles equals the savings realized by better cube utilization.

There are two basic types of TRANSACTIONS used in the program. One is called a product TRANSACTION; and the other, a new lot TRANSACTION. The product TRANSACTION is a permanent TRANSACTION that holds basic information on the product as well as the storage information for each lot of product currently in the warehouse. There are more than 300 (one for each product) of these TRANSACTIONS active in the program at all times. Each product TRANSACTION has 100 half-word PARAMETERS. The new lot TRANSACTION is a temporary information carrier. Initially, it enters the program, at the correct time, with only a product code and lot size. A SCAN command obtains information from the product TRANSACTION on the stack height and what we call a tie indicator*. The TRANSACTION next passes through the space allocation algorithm, which optimally assigns the lot to the correct storage locations. This information is then transferred to SAVEVALUE locations, where it is then picked up by the PARAMETERS of the proper product TRANSACTION. Upon this transfer of information to the SAVEVALUES, the new lot TRANSACTION is terminated (see Figures 3 and 4).

In order to convey quickly how the program operates, we resort to two simplified pictorial flow diagrams. Figure 5 illustrates the new lot entry mode, while Figure 6 shows basically how the pallet-withdrawal mode operates.

The use of PARAMETERS in the product TRANSACTION is completely dynamic. That is, new lots enter PARAMETERS with high numbers (to the right), while the current lot is always found in PARAMETERS 14,15,---. Once the current lot is depleted, the PARAMETERS associated with it are used by the next lot to be considered through a general shift of location for all lots to lower numbers (to the left). This means that lots are withdrawn on a FIFO basis. Within lots, the program operates first on small sub-bays, since these may be freed up quickly and reused by other products.

The linear depletion or withdrawal assumption simply means that we have empirically studied each product to determine the average number of pallets withdrawn in a four-hour period. For example, if a product experiences .4 pallets withdrawn per four-hour period, it would take three periods to withdraw one pallet. When the pallet is removed, the index is changed from 3(.4) = 1.2 to .2 and we add .4 again next period. We only withdraw whole pallets. The assumption of linear withdrawals is an approximation but, in most cases, a fairly realistic one.

The last program detail to be discussed in this paper is the use of GROUPS to represent sub-bays. Figure 7 illustrates one such usage (actual). As the configuration changes, both the depth of the sub-bay associated with the GROUP and the number of entries in the GROUP may change. The space assignment algorithm determines what kind of spaces should be used (depth), then removes numbers from the proper GROUP to indicate that part of the floor has been utilized. Once this sub-bay is freed up, it is returned to the proper GROUP. If the space allocation algorithm calls for a particular kind of sub-bay and the GROUP is empty, i.e., there are no such spaces currently available, it makes a suboptimal allocation. If this, too, is infeasible, it continues to test less-optimal allocations. If these, too, are infeasible, it waits for an update and passes through the algorithm again.

Data Requirements

The inputs to the program are actual products, actual depletion rates, and actual lots added on the half-day they arrived at the warehouse. An inventory was taken of the warehouse the day the study started; so we are aware of what products were in the warehouse when we began. Originally, we planned to charge the warehouse as it was on the day of the inventory, but upon further study this turned out to be completely impractical and very expensive--it is not constant for every configuration and all changes must be made by hand. Instead, we are assuming homogeneity of product and simply charging the warehouse with new lots while not letting anything leave. We then begin normal operation and process some of the same lots under the normal simulation. We have data on more than 10,000 pallets, representing more than 1,100 lots, the data having been taken over a four-month period.

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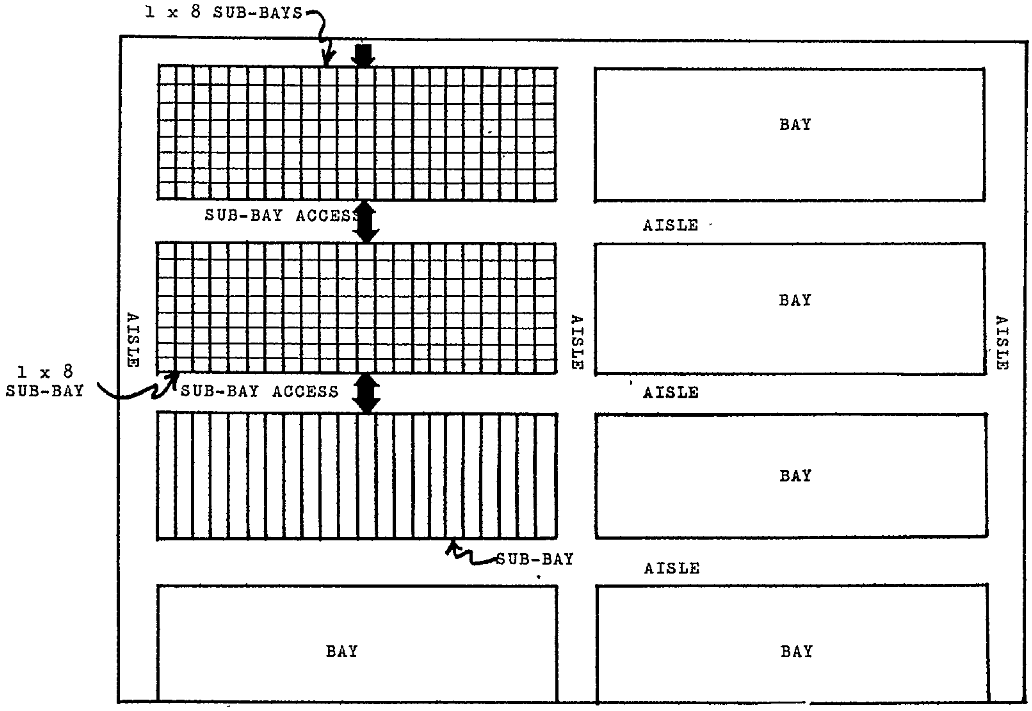
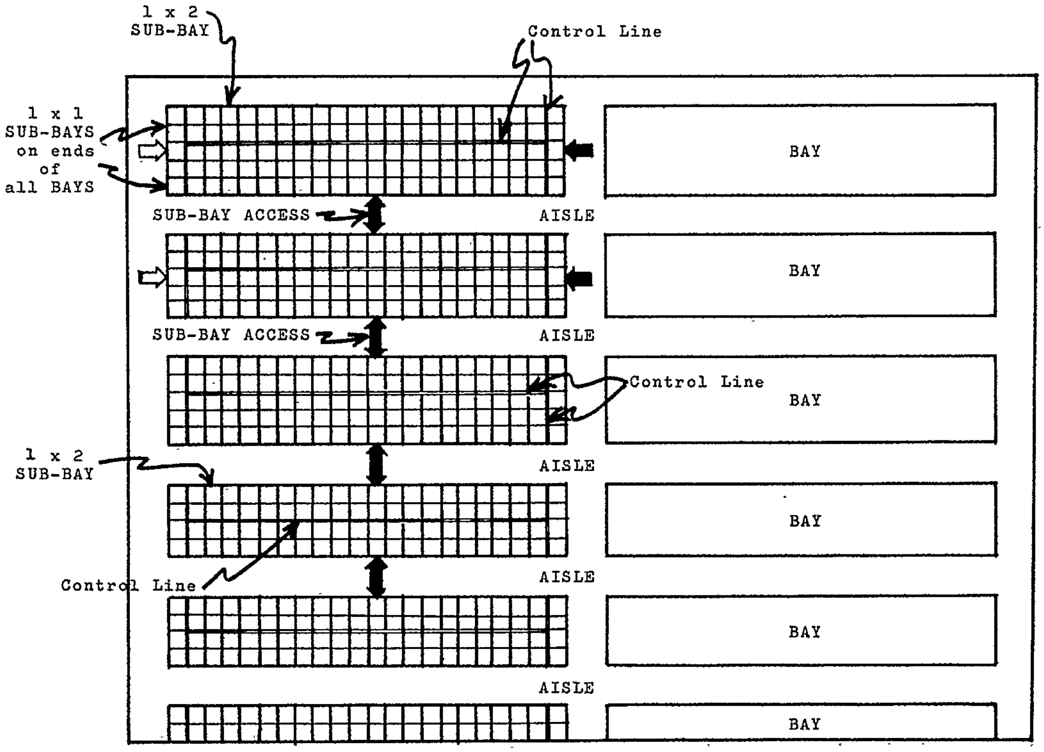
* Some products, because of their nature, do not have a stack height over 1 or 2. However, when two contiguous sub-bays are assigned one or more pallets, depending on the depth of the sub-bay, a pallet may be placed half and half to split the gap. This, of course, increases the cube utilization of the two sub-bays.



WAREHOUSE LAYOUT WITH LARGE SUB-BAYS - NO CONTROL LINES

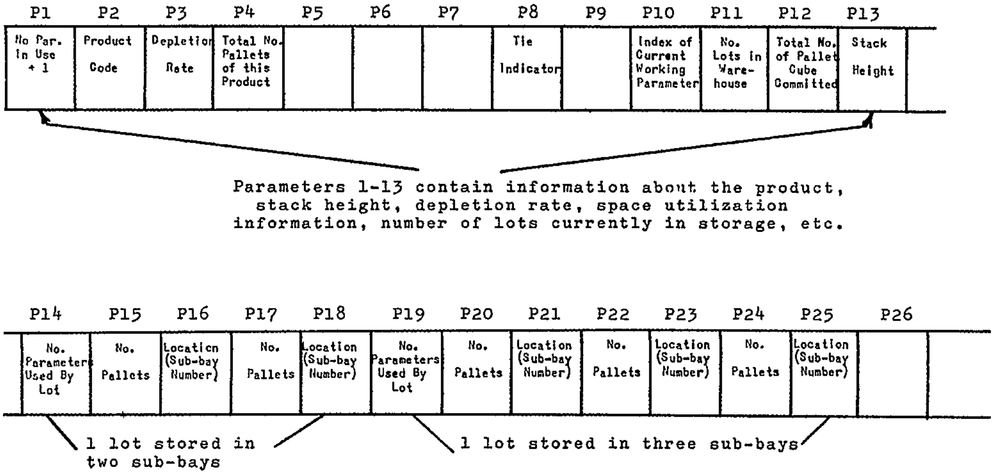
FIGURE 1.



WAREHOUSE LAYOUT WITH SEVERAL SUB-BAY SIZES

FIGURE 2.

PRODUCT TRANSACTION
100 Parameters



P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13
No Par. In Use + 1	Product Code	Depletion Rate	Total No. Pallets of this Product				Tie Indicator		Index of Current Working Parameter	No. Lots in Ware-house	Total No. of Pallet Cube Committed	Stack Height

Parameters 1-13 contain information about the product, stack height, depletion rate, space utilization information, number of lots currently in storage, etc.

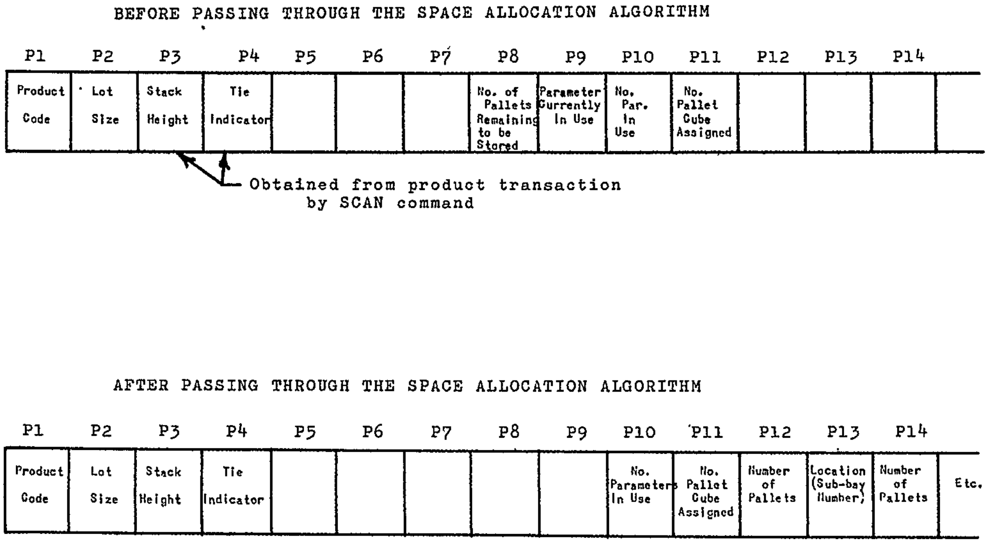
P14	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26
No. Parameters Used By Lot	No. Pallets	Location (Sub-bay Number)	No. Pallets	Location (Sub-bay Number)	No. Parameters Used By Lot	No. Pallets	Location (Sub-bay Number)	No. Pallets	Location (Sub-bay Number)	No. Pallets	Location (Sub-bay Number)	

1 lot stored in two sub-bays

1 lot stored in three sub-bays

FIGURE 3.

NEW LOT TRANSACTION
40 Parameters



BEFORE PASSING THROUGH THE SPACE ALLOCATION ALGORITHM

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
Product Code	Lot Size	Stack Height	Tie Indicator				No. of Pallets Remaining to be Stored	Parameter Currently In Use	No. Par. In Use	No. Pallet Cube Assigned			

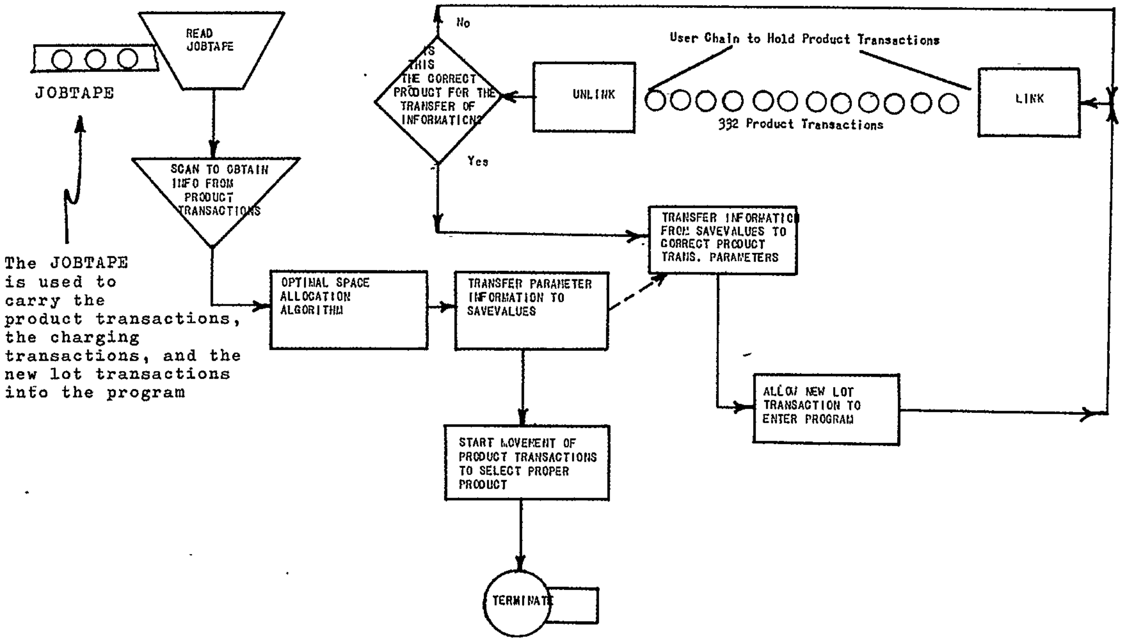
Obtained from product transaction by SCAN command

AFTER PASSING THROUGH THE SPACE ALLOCATION ALGORITHM

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	
Product Code	Lot Size	Stack Height	Tie Indicator						No. Parameters In Use	No. Pallet Cube Assigned	Number of Pallets	Location (Sub-bay Number)	Number of Pallets	Etc.

FIGURE 4.

NEW LOT ADDITION MODE



The JOBTAPE is used to carry the product transactions, the charging transactions, and the new lot transactions into the program

FIGURE 5.

PALLET WITHDRAWAL MODE

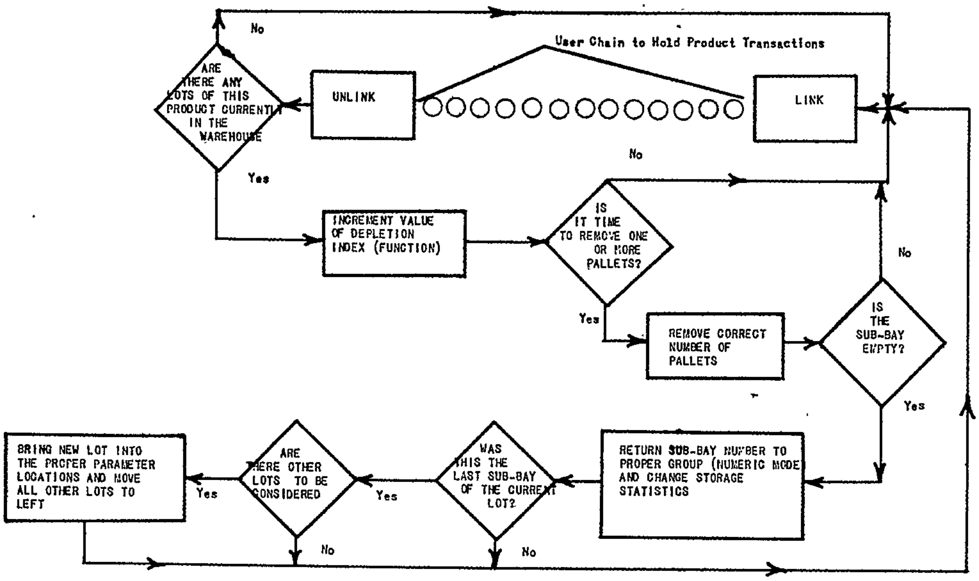


FIGURE 6.

GROUP USAGE

GROUP 2. (8 Deep)	335,337,339, . . . 439,441	A total of 58 sub-bays
GROUP 3. (2 Deep)	2,4,6,8,10, . . . 322,324,326	A total of 163 sub-bays
GROUP 4. (7 Deep)	346,348,350, . . . 440, 442	A total of 58 sub-bays
GROUP 5. (2 Deep)	1,3,5,7, . . . 323,325	A total of 58 sub-bays
GROUP 6 (1 Deep)	448,449,450, . . . 719,720	A total of 278 sub-bays

Each number represents a physical location on the warehouse floor.

FIGURE 7.