AN ORDER PICKING AND SHIPPING MODEL

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Abstract

This paper describes the use of a discrete event simulation model to aid in designing an enlarged order picking and shipping system. The model was used to compare the c.pacity effects of various conveyor configurations, to test assumptions of system design, and to arrive at an estimate of overall system capacity expansion of the revised system.

1. BACKGROUND

The shipping function of this company serves a multichannel marketing requirement, with variation from a single-item parcel post order to a full railroad car of products for a public warehouse. Therefore, the design of the order preparation procedure is quite flexible in character. The goal of engineering design is to have a relatively well controlled labor cost without sacrificing flexibility and response time.

In 1960, the assembly and preparation of a customer order was done in a conventional manner. A shipping employee, armed with an order and a cart, roamed throughout the storage area to accumulate the required items, and completed the work by filling out the appropriate shipping forms. Occasionally some packing was required, and this was done by other employees.

Since the orders handled varied widely in labor content, and the shippers chose their work, the total activity was under a minimum control and was relatively unpredictable on a daily basis. Consequently, labor productivity tended to be at a minimum acceptable level, and customer shipping service was inconsistent.

In order to improve the total shipping capability, an order picking system was designed and installed in 1961. Its main objectives were (a) work flow control, to achieve better labor productivity, and (b) flexibility of handling the variety of order types, so that customer service could be improved. A general procedural sequence of order handling was defined as (1) dispatching, (2) order picking, and (3) checking, and this arrangement continues to be employed.

The initial phase, "dispatching," implements the flexible control of customer service, and the general direction of work performed in the system. The dispatcher is the "quarterback" of the team.

Order picking is accomplished in a "modified zone" warehouse layout. A towline pulls order carts from the dispatcher to each zone, and between zones. Programmed cart-mounted flags actuate switches that divert the cart to each accumulation spur, where it waits for the order picker. As each order is completed, it is sent to the next zone, until all picking is complete.

After completion of any hand packing or other special handling, the carts are delivered to the "checker", who verifies order accuracy, and completes necessary shipping forms. In addition to assembly of regular orders via the towline method, large orders requiring full pallets are brought to check stations directly from storage area by fork truck handling.

Accumulation of work in spurs and on the towline are design features that permit the system to handle temporary surges of labor demand at "pick" and "check" stations, thus allowing orderly reassignment of personnel to accomodate the changed demand. The system thus facilitates a "work flow pattern" and flexible handling of varying product mix and monthly variations in order type.

However, as in most systems, there are gross limits to capacity. By 1967, output levels had doubled from the original design. At this point, it was observed that interference occured between workers in the same zones, and that the towline hookup by order pickers was becoming a significant source of delay. This general situation led to plans for system capacity improvement.

2. USE OF A SIMULATION MODEL

We chose simulation as the technique to use for design aid for several inter-related reasons:

(1) The variability of order size and type has already been mentioned. The system design is influenced by the need for flexibility, and it cannot be easily expressed in symbolic terms. The transaction orientated language, General Purpose Simulation System/360, proved to be useful for representing system actions and conditions.

(2) The nature of our shipping is dynamic and changeable-monthly cycling of order patterns due to commercial credit practices, seasonal variation in shipping level due to the Christmas season, and the birth and death cycling of products. This changeability tends to discourage a seeking of and "optimal" solution. The life expectancy of a "best" design is too low to make it a practical goal.

(3) This problem was a good introduction to the technique of simulation. Further design work in manufacturing systems and facilities will make use of simulation. Changeableness influences our production as it does our shipping. Since our business is consumer oriented, scheduling factors play an important role in profitable service. And, of course, simulation models are useful for study of "timing".

3. DESCRIPTION OF PHYSICAL SYSTEM

ORDER INPUT

Input to the system is composed of a wide variety of order types, including parcel post, retail, wholesale, export, inter-plant, warehouse restock, and customer service parts replacement. The system modelled handles all orders that are suitable for hand picking. Those orders and order segements requiring half-pallet or larger quantity are handled by fork truck, and are external to this system.

Orders as received by the dispatcher have been reviewed, sorted into categories, and gleaned of "short" orders, futures, and other order conditions that would preclude normal processing and completion. The dispatcher also controls order issuance in response to item depletion.

DISPATCHER

The dispatcher introduces order into the system. He picks an order at random, attaches it to a clipboard on a picking cart, sets the flags of the cart to correspond to the zones that will have picking work, and hooks up the cart to the towline.

TOWLINE

Figure 1 is a schematic representation of the essential relationships of the towline system. The towline moves the cart along until one of the flags triggers a switch to power the spur towline. If there is room in the accumulation area, the spur towline overrides the main towline and diverts the cart to a "ready" position.

If there is no room in the accumulation area, the cart remains on the main towline until it "finds" a vacant "ready" position. Accumulation zones are designed with sufficient capacity to provide a steady supply of work for the order pickers. This capacity is one of the configuration variables tested in the model.

The main towline also carries a "float" or inventory of work. A reasonable balance between sufficient "float" and some open hooks is maintained by the dispatcher. He attempts to limit his loading of the line to 50%, lest the order pickers find it inconvenient to rehook the carts to the towline when they finish their work.

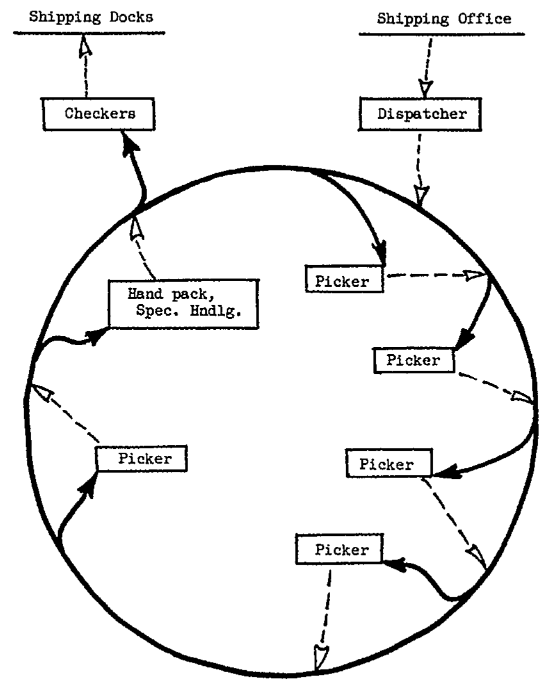

Figure 1

ORDER PICKERS

Each order picker is assigned to a zone within which he assembles his part of the order on the cart. He then lowers his flag and rehooks the cart to the main towline. The accumulation area usually keeps the order picker suppled with work. In the event that he runs out of work, the order picker will take his cart to the next zone and continue picking the order. This happens only occasionally, and again the accumulation area will soon acquire some work so that the picker can return to his "home" zone.

Figure 2 shows the simple precedence relationships that are exercised in the system. The actuating switches are set to observe this; e.g., if all picking is not complete, the cart will not enter the handpack accumulation area.

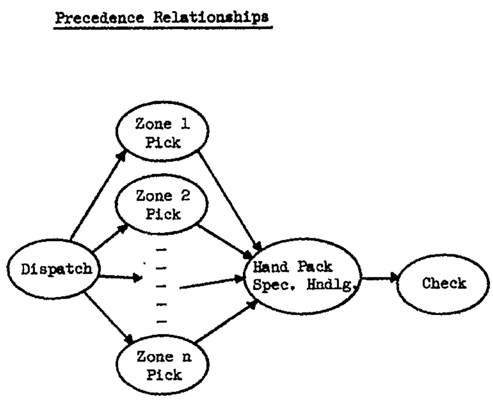

Figure 2

CHECKER

When all picking and packing is complete, the cart is diverted to the accumulation of the proper checker. The checker reviews the entire order to be sure that quantity and items are correct, he fills out the necessary bills of lading and other shipping documents, and coordinates order picked items and pallet merchandise as required. When he is done with the order, he brings the carts and pallets to the dock area.

THE ...EM

The layout of the system shows the physical arrangement of the present system. The towline is about 700 feet long, it contains 42 hooks. There are six picking zones, each with a 3-cart accumulation area. Zone seven is a hand pack zone. Zones 8 and 9 are checker stations which each have a 4-cart accumulation area.

Natural limitations of a system of this kind include:

(a) total number of order pickers employed.

(b) density of order input, and the effect of congestion.

(c) physical limit of completed order to be accumulated in dock areas.

4. VARIABLES TO BE TESTED

In determining how a system can be modified for better operating results, variables of the following are designated for measurement:

(a) transit time of each order through the system, from the time the dispatcher attaches it to a hook until it has been completely checked.

(b) the amount of delay experienced by order pickers who complete an order and have to wait for an empty hook to arrive - "hook delay".

(c) number of orders of each type successfully completed during a working day multiplied by typical dollar value will be summed up to generate a dollar volume throughout.

(d) composition of order types from which the dispatcher introduces orders into the system is varied; this tests whether the system has any discernible sensitivity to order type within the range normally experienced.

5. CONFIGURATIONS COMPARED

A general expansion of order picking and shipping capacity has become necessary, as mentioned in the introduction. Because of the past effectiveness of this system, no major revision is planned; rather, a straight forward expansion will be developed.

As can be seen from examination of Figure 3, the present system is limited by the building shape. It lacks ease of further expansion. The picking zones are of unequal shape and size, and the dock areas limit the accumulation of merchandise for pickup by common carriers.

The larger system, Figure 4, since it will be in a new building, will have a more favorable arrangement. Picking zones of ideal shape and equal size can be arranged. Shipping accumulation areas can be designed for higher levels of activity.

However, the present overhead towline, properly modified, will be used in the new building. This minimizes the amount of new investment needed, and perpetuates a form of hardware capable of easy modification in the future. The purpose of the modelling reported in this paper is to define the presently needed modifications for the larger towline system.

The configurations compared by this series of models include:

(a) Present 42 hook towline with six zones
vs
Larger 50 hook towline with eight pick zones

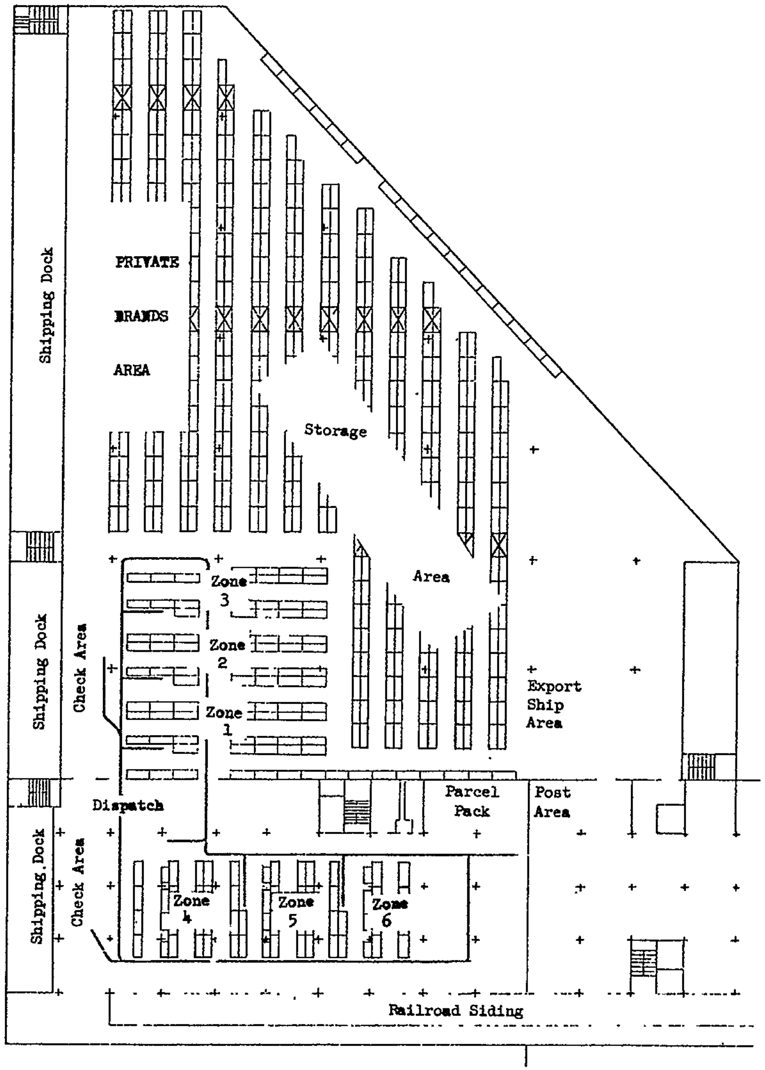

Figure 3 - Present System

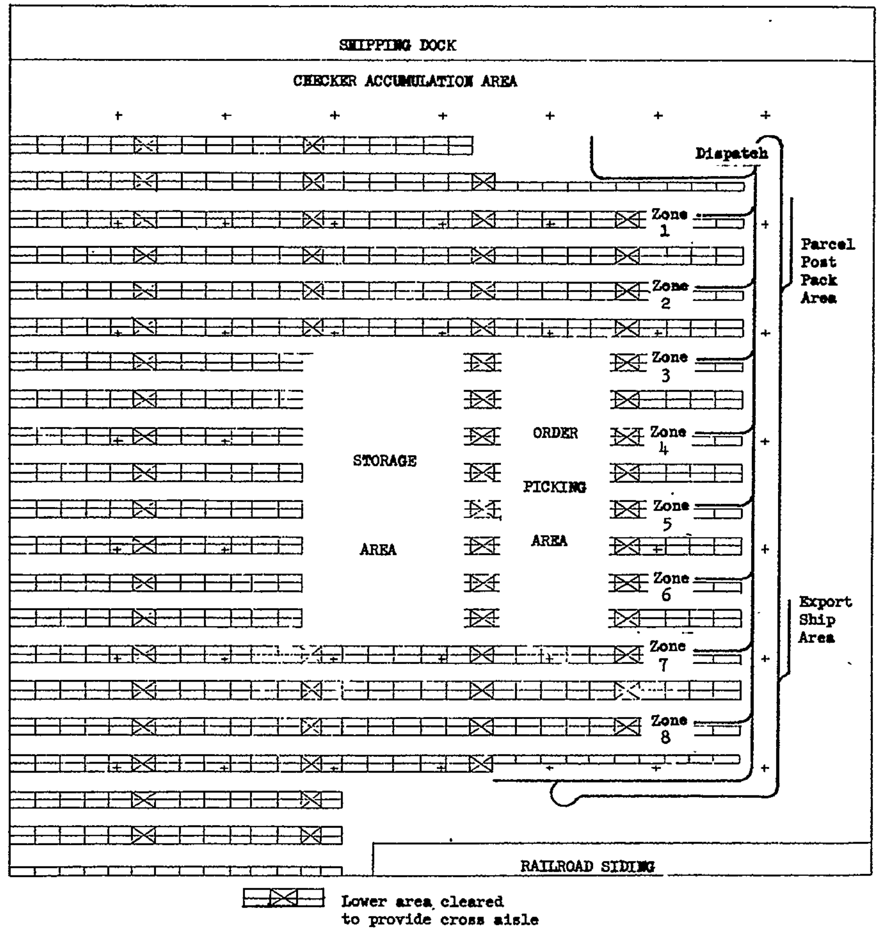

Figure 4 - New System

(b) Larger 50 hook towline system, accumulation capacity:

3 vs 4

(c) Larger eight zone towline system, 50 hook vs 35 hook towline length.

6. MODEL APPROACH

The following exerpts from the general flowchart and the program coding indicate the degree of literal imitation of behavior and system activity as used in the model.

Order input is generated at several density levels in each system. Order type and service times are the input variables.

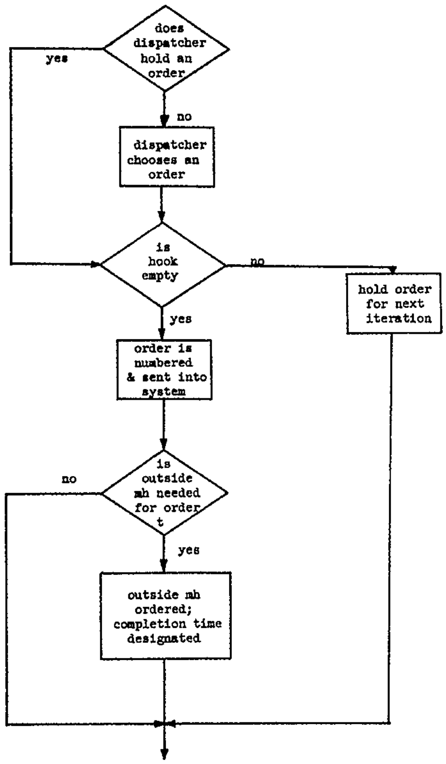

Figure 5 DISPATCHER ROUTINE

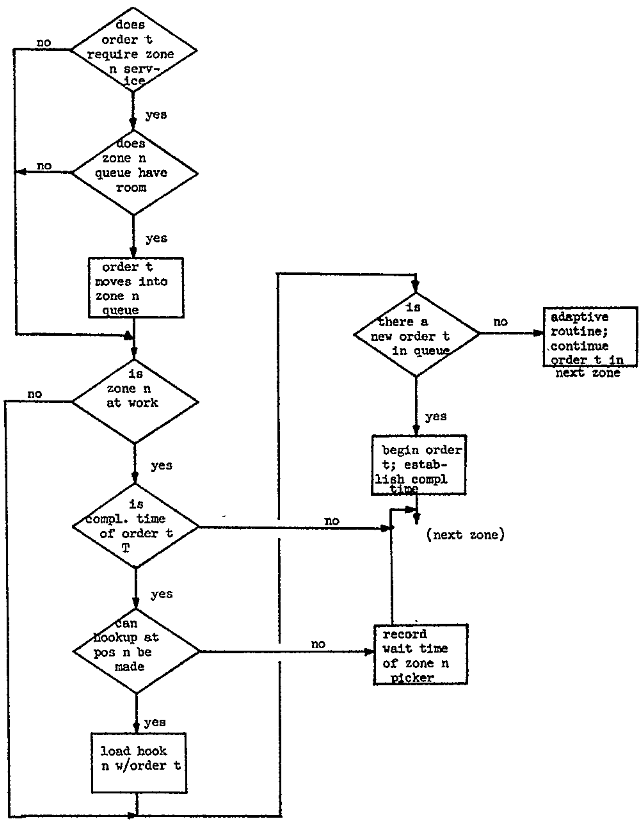

Figure 6 ORDER PICKER ROUTINE

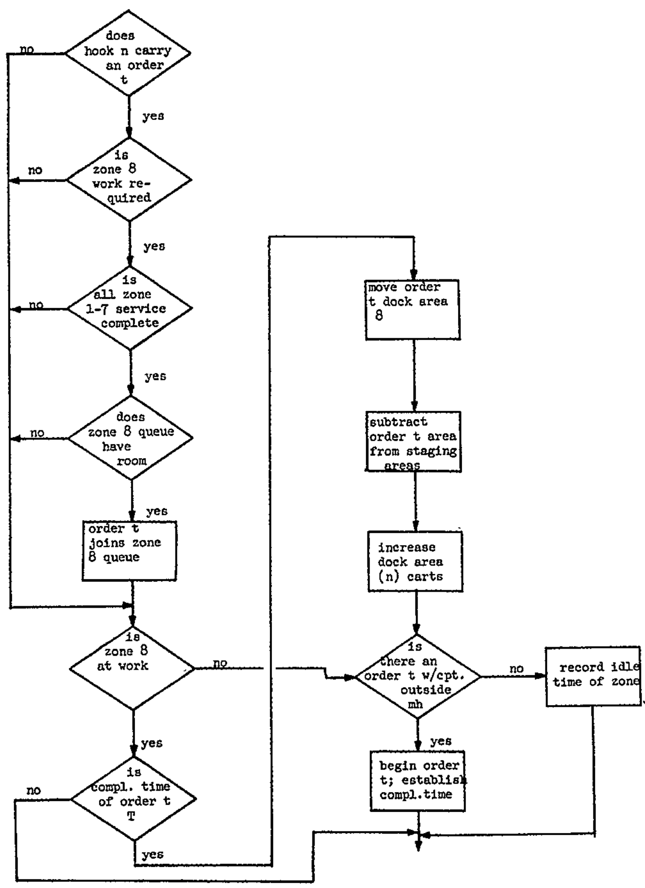

Figure 7 CHECKER ROUTINE

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                       DISPATCHER ROUTINE

        GENERATE   7,5
        TEST L     X39,K25,TERMINATE

                   ( an order is written, based
                      on empirical data)

DSP     GATE LR    V1,PSD
        LOGICS     V1
        SAVEVALUE  39+,K1
        ADVANCE    2,0
        TRANSFER   ,ONE
PSD     SAVEVALUE  20+,K1
        ADVANCE    1,0
        TRANSFER   ,DSP
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Figure 5B

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                       ORDER PICKER ROUTINE

ONE     TEST G     P1,KO,AAT
        GATE SNF   1,BAT
        ENTER      1
        SAVEVALUE  39-,K1
        LOGICS     V2
        SEIZE      ONE
        LEAVE      1
        ADVANCE    P1,0
        ASSIGN     1,KO
        ASSIGN     11-,K1
        TEST G     S1,K1,EAT
DAT     GATE LR    V3,CAT
        LOGICS     V3
        RELEASE    ONE
        SAVEVALUE  39+,K1
        ADVANCE    1,0
        TRANSFER   ,TWO
BAT     SAVEVALUE  1+,K1
AAT     ADVANCE    2,0
        TRANSFER   ,TWO
CAT     ADVANCE    1,0
        SAVEVALUE  11+,K1
        TRANSFER   ,DAT
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Figure 6B

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                       CHECKER ROUTINE

CKR     TEST E     P11,KO,ONE
        TEST E     P9,KO,PKR
        GATE SNF   10,CKT
        ENTER      10
        SAVEVALUE  V20
        LOGICS     V20
        ENTER      CKR
        LEAVE      10
        ADVANCE    P10,0
        LEAVE      CKR
        TABULATE   P12
        TRANSFER   .%,TLR
        SAVEVALUE  38+,K1
TLR     TERMINATE
```

Figure 7B

7. COMMENTS ON VALIDATION

Within the limits of the 64K core capacity of our 360/IBM 30 computor, this model has been programmed to be reasonably faithful to the actual behavior of the members of the order pick system. In effect, the value of this model depends on its "face validity", and the fact that it is being used in a process of "paired comparison". What simplification has been employed in the model affects both the old and the new system. It is thus likely that the "inaccuracies", to the degree that they exist, cancel out in the paired comparisons.

Dispatcher behavior is reasonably imitated in assuming random choice of orders. There is no reason for or likelihood that he introduces orders in a pattern arrangement. The limit of "50% hook load" is probably more of an approximation of real life. While the dispatcher attempts to maintain an even work pressure on the system, it is quite likely that the system load may fluctuate. Recognizing this, the dispatcher could compensate with a burst of loading activity.

Order picker performance is assumed to be a constant rate. Amount of work is a generated variable within an empirically-observed distribution. The model assumes adaptive behavior to the extent that the order picker, lacking further work in his zone, will continue with the order at hand in the next zone. This compensates for minor outages of work and is a reasonable imitation of expected real life activity. However, the model cannot accommodate or imitate reassignment either within or beyond the system. In the model, therefore, some idleness may be recorded that is unlikely in real life.

Checker behavior is well approximated in the model. Stable work loads and substantial waiting lines maintain a backlog for checkers, similar to that observed in real life.

8. RESULTANT VARIABLES DATA

NEW SYSTEMS VS OLD SYSTEM

In the first comparison, the old system and the new 50 hook system are matched by generation interval (or density of input), and Figure 8, 9, 10 show the new system to be approximately 30% faster in transit time, having about one-third the hookup delay, and being more responsive in total throughput than the previous one. Throughput of course, is the basic characteristic to be compared, and in this the new system promises to have about 50% more capacity than the old one.

COMPOSITION OF ORDERS

Composition A in Figure 11 shows the average mix of orders handled at the present system. The dis-

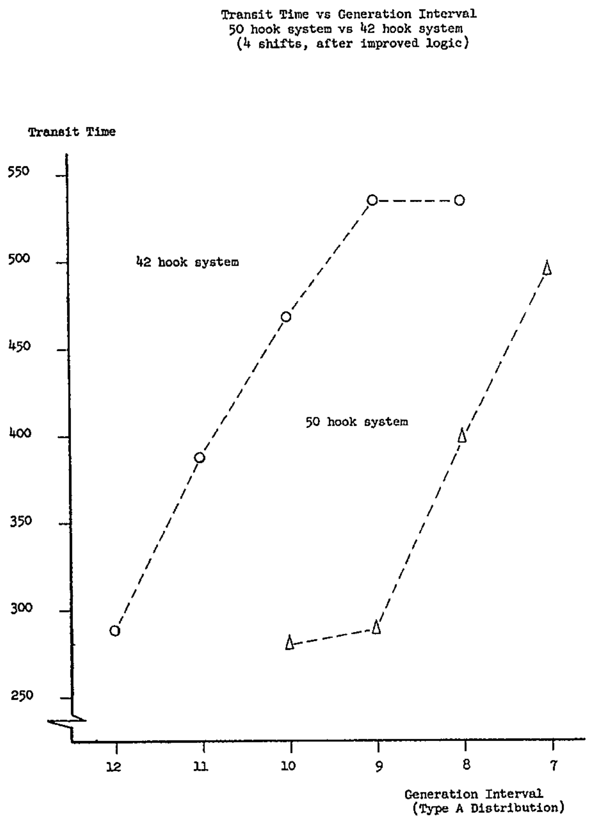


Figure 8

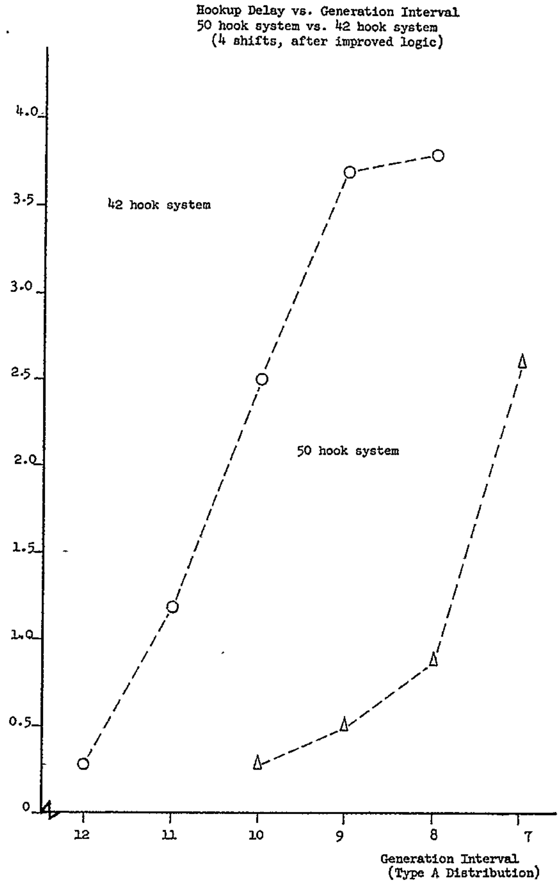


Figure 9

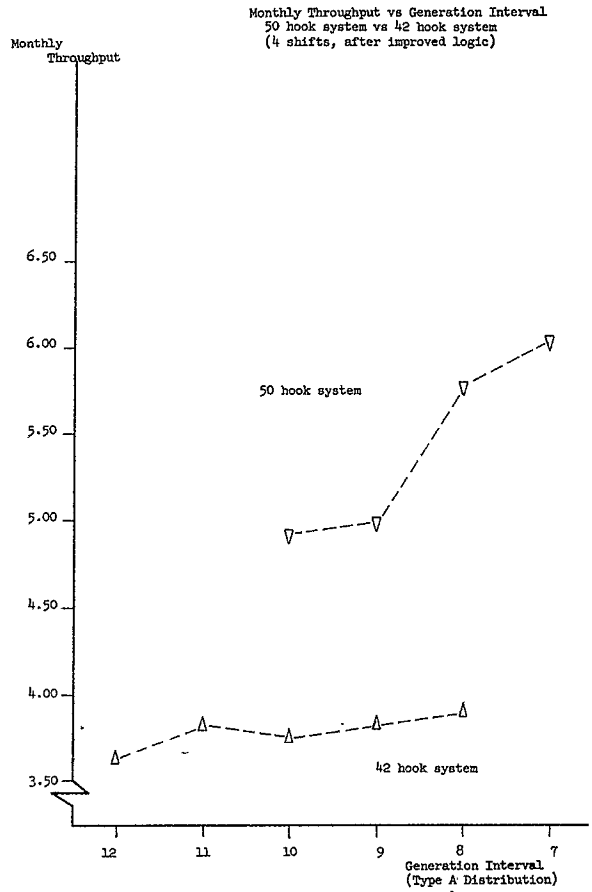


Figure 10

tribution was varied in B,C,D, and E in order to test whether there was a discernible effect of variation in order composition on overall throughput of the system.

Figure 12 shows the transit time, hookup delay, and throughput reflected from the simulation results. The range of throughput is about nine percent, and this could suggest the system behaves in a stable manner within the range of the order compositions tested.

VARIATION IN ORDER COMPOSITION

ORDER TYPE NO.	ORDER COMPOSITIONS (PERCENT)				
	A*	B	C	D	E
(1)	60	57	70	59	58
(2)	7	6	5	7	7
(3)	15	20	11	15	14
(4)	3	3	2	4	3
(5)	9	8	7	9	12
(6)	6	6	5	6	6
	100	100	100	100	100

* standard

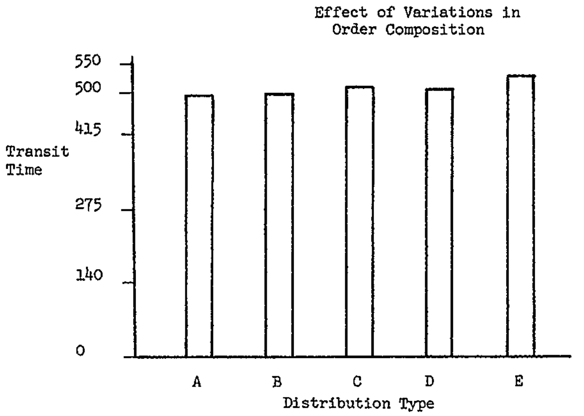
Figure 11

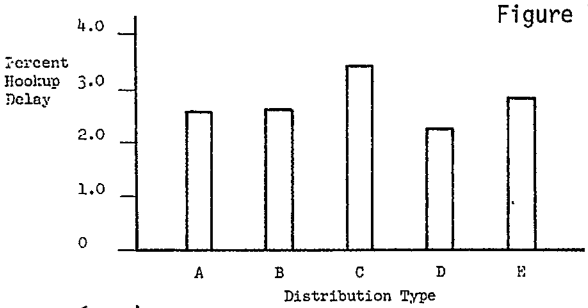
CONFIGURATIONS

(a) The new system layout has two natural towline lengths; either the towline can be limited to a loop on the west side of the distribution center, or it can have a north leg in addition. Other layout characteristics are the same: what was compared was 35 versus 50 hook towline capacity.

It might be expected that the longer towline provides the greater degree of on-line storage, and possibly less interference with the order pickers. Figure 13 shows that this is the case; percent hookup delay is definitely lower with the 50 hook towline. Figure 14 shows somewhat greater throughput, however, the degree is not striking. Transit time in Figure 15 indicates slower velocity through the system with the longer towline. This may be the result of a larger "pipeline", the ability of a longer towline to hold more storage.

(b) Accumulation zone capacity in the old system was three. It was suspected that a capacity of four would be an advantage in smoothing out the work. Although this is a minor design detail, the comparison of simulation runs (Fig. 16) did suggest that present hookup delay would be favorable influenced by larger accumulation zone capacity. Throughput is also improved slightly, while transit time remains almost the same.





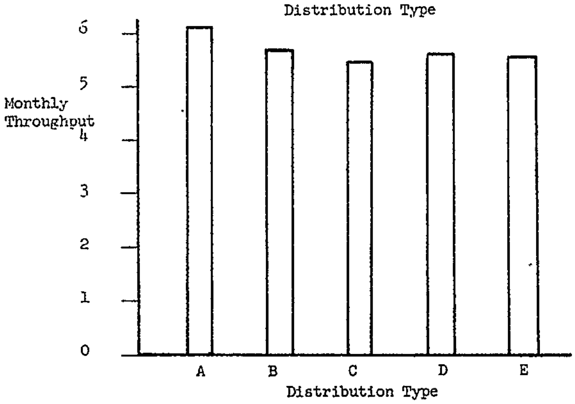


Figure 12

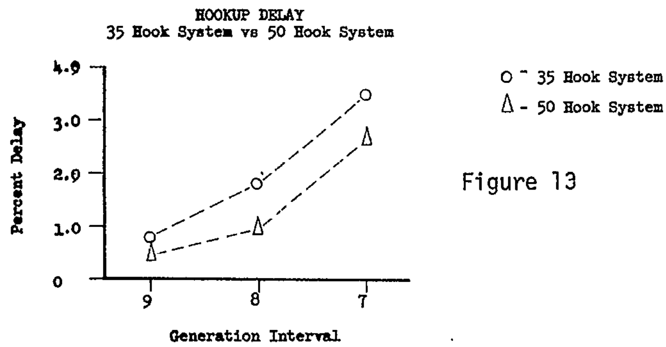


Figure 13

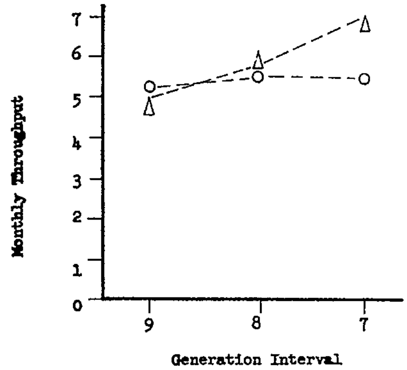


Figure 14

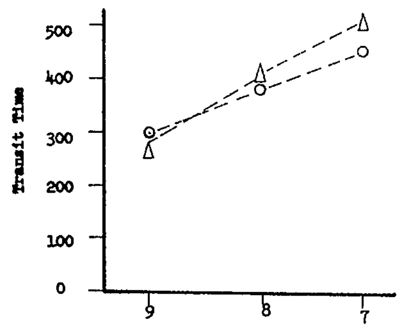


Figure 15

9. CONCLUSION

Simulation runs of the old system model tended to yield a constant throughput while the generation interval was varied. In general, the old system appeared unresponsive, and this effect of limited output was experienced in the fall of 1967. During the past season a heavy overtime schedule was followed in order to accomplish the shipping output.

By comparison, the new system shows good response to variation of the generation interval, indicating that the system has a significantly greater capacity. At comparative "generation interval" the gain in capacity appears to be about fifty percent. However, it would be necessary to extend the range of input until the system showed signs of congestion before a true comparison could be made. For the purpose of this model, the

Accumulation Zone Capacity

	Transit Time	Monthly Throughput	Percent Delay
3	445	5.5	2.8
4	445	5.8	2.3

Figure 16

throughput gain of fifty percent is sufficiently informative.

About six man-months of Industrial Engineering time were used for this model, together with 55 hours of running time on an IBM S/360 MOD 30 64K Computer. Core size was somewhat limiting, and the output portion (staging areas for common carrier loading) was analyzed separately.

The indicated Configuration choices were incorporated into the new towline and distribution center at West Bend, Wisconsin. Occupancy began in July, and full operation was anticipated by October. This approximates the peak shipping level, and will be a test of the system's capacity. The recent growth of our business makes further system evaluation and modification a certainty, both at West Bend and other plant locations.

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