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SYSTEMS APPROACH FOR OPTIMIZING NURSERY OPERATIONS

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Mechanization of any operation is done for the purpose of increasing its efficiency. Often the attitude is taken that machines are installed to replace workers. Instead we should view mechanization as a means of improving workers' efficiency and making their jobs easier. Men and machines must work together in an integrated fashion before an overall system can be improved. Machines do not necessarily improve every situation. We must look at the entire operation before we can decide whether or not a machine is needed for a particular job. To often a machine is installed at one point in production while operations before and after are not changed. As a result the machine cannot be utilized on a continuous basis. Systems analysis can help pinpoint such problems.

Systems analysis using a dynamic computer simulation model is a logical-mathematical representation of a system used for analyzing and identifying problems in a wide variety of industrial and agricultural problems. Numerous simulation models have been developed and usefully employed in various decision-making processes and identifying critical problems in systems ranging from scheduling tillage operations to harvesting and handling agricultural products. However, this valuable technique has not been employed for nursery production analysis. This paper briefly explains how this technique can be used for analyzing a simple system and then describes the analysis of two nursery operations, soil mixing and transporting containers to the field.

Let us consider a simple system consisting of a barber and customers who are seeking the services of the barber. For our example, let us consider that only one barber is available and customers arrive randomly. It is to be determined whether there is a need to add another barber to provide an efficient service so that the customers do not have to wait for a long time. The first step in analyzing this problem requires a complete model description and the collection of necessary data.

The model description is schematically shown in Figure 1. The customers arrive at somewhat arbitrary intervals, which may depend on the time of day and the day of the week. When a customer arrives, he is serviced immediately if the barber is free and no other customer is waiting; otherwise, he enters a waiting line. The customers leave the waiting line on a first in first out (FIFO) basis. The customers seek three types of service, (a) hair cut, (b) a hair cut and shave, and (c) a shave only. The time required for service will depend on the type of service he is seeking. After the service to a customer is completed, he leaves and the next customer enters for the barber's service.

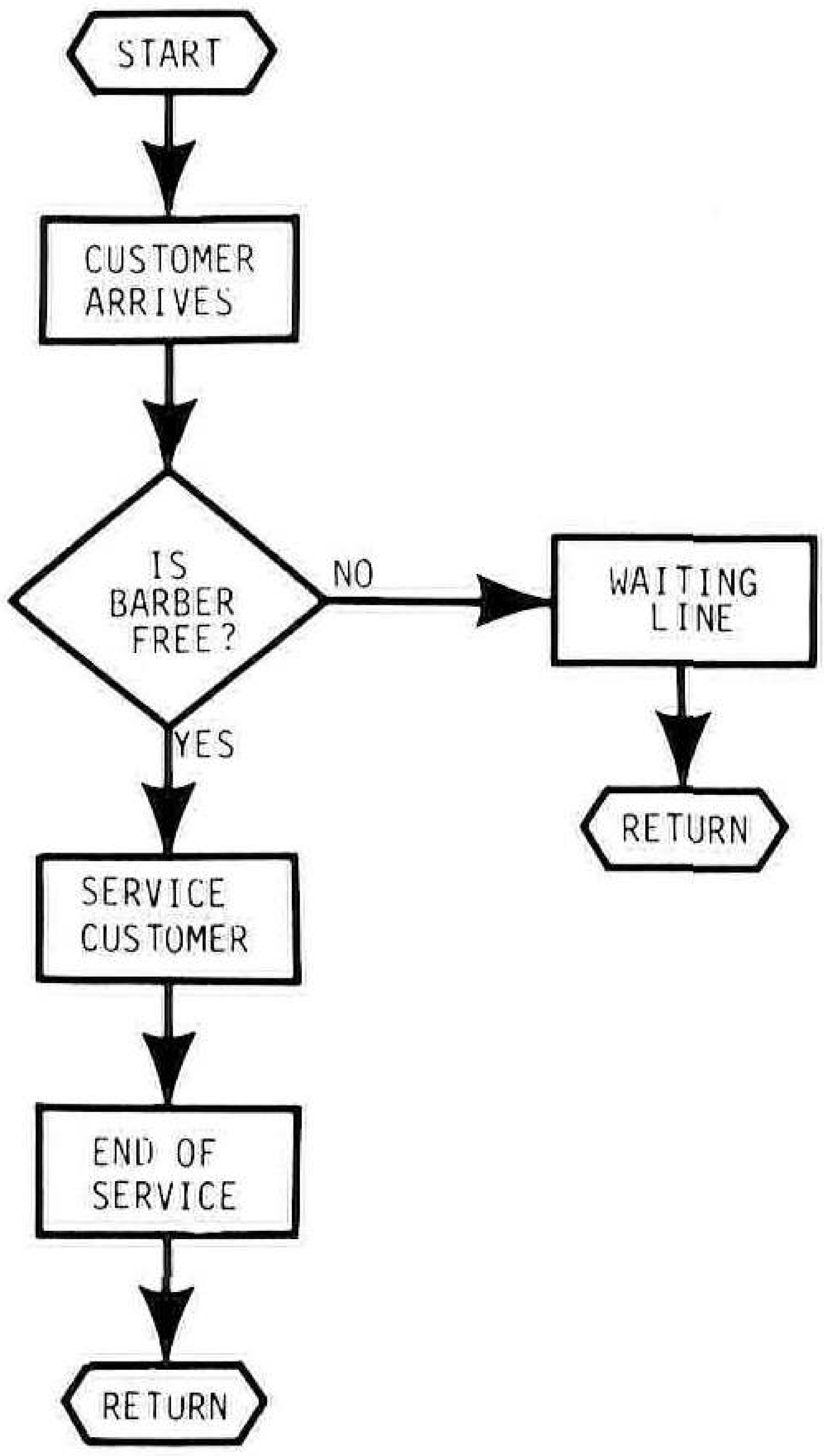

Figure 1. Model description by flow diagram of the barber shop operations.

Time data are carefully collected to develop the distributions for the arrival frequency of the customers for the time of day and the day of week, type service desired by the customers, time required to provide the service, time spent by the customers in the waiting line and the time the barber is free.

A computer model is developed in which each step of the system is carefully programmed. The time a customer arrives is determined by the use of random numbers and the frequency distribution developed from the data. The first customer is attended by the barber immediately and the time of completion of his service is scheduled depending on the type of service sought. The type of service and time of completion is also determined by the frequency distributions developed from the collected data and random numbers generated for the particular customer. The arrival of the second customer is then scheduled and he is set to receive the service if he arrives after the first customer leaves, otherwise, he is scheduled to go to the waiting line. The third customer is similarly scheduled and so on. With each customer all the statistics are recorded and after the end of the day complete information is analysed to see the amount of waiting time, percent of time the barber is busy, etc. If excessive waiting time is recorded, the computer model can be altered to have two barbers servicing customers and similar information, such as waiting time, percent of time barbers are busy, etc. can be gathered. It is possible to then analyze to see if another barber is needed on a full-time basis or required only on some days on a part-time basis. Additionally, the cost of adding another barber can be calculated to see if it would be of economic benefit.

NURSERY OPERATIONS

From the example of the barber shop operations analysis it should be evident that any system which requires discrete and continuous operations and in which occurrences take place in a somewhat arbitrary manner, computer model analysis can be effectively used to determine those changes that will improve system output. In a similar manner, nursery operations which deal with materials handling and scheduling of sequential events can be analyzed for optimizing labor, machine and economic inputs. A system of soil mixing, container filling and container handling was proposed by Verma (7) and discussed briefly as follows. Preliminary computer models of the two sub-systems, soil mixing and container transport to the field, will be explained later in the paper.

System of Soil Mixing, Container Filling and Container Handling. A system of soil mixing, container filling and container handling is shown by the schematic diagram in Figure 2. The soil is mixed by a continuous mixer (5) and fed into a container filling machine. A container stripping machine separates the containers and places them on a belt where they are filled by the filling machine. The filled containers travel on the conveyor belt. Rooted cuttings are potted in the filled containers by hand labor as they move on the belt. The flats with the rooted cuttings are stored on inclined rollers. Laborers reach over the belt to pick up rooted cuttings from the flats. After a flat is emptied, the laborer removes the empty flat and the next filled flat rolls to the end of the inclined roller. The potted containers move to the end of the belt where they are hand loaded onto a 4 foot × 7 foot pallet moving under the belt.

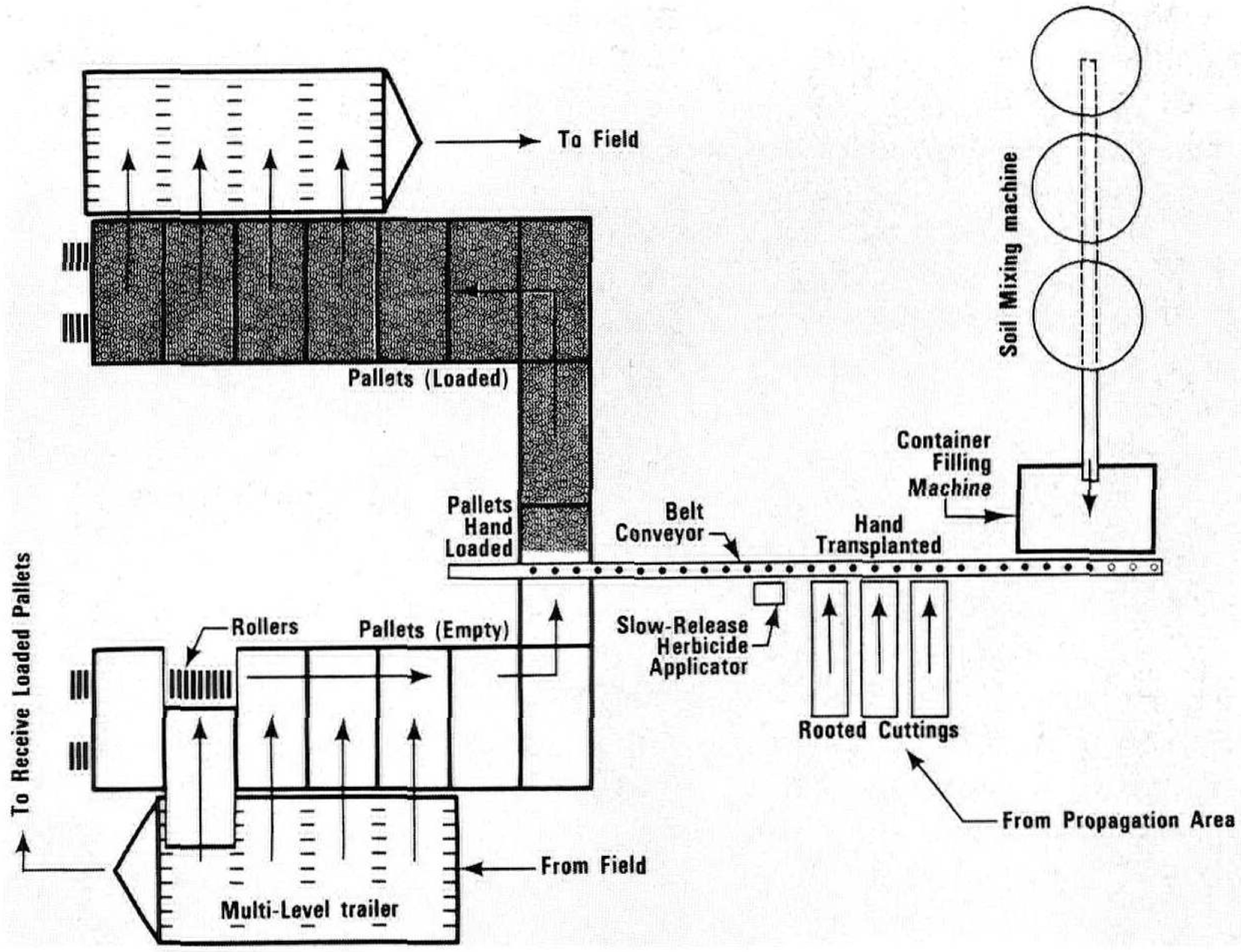

Figure 2. Overall system for soil mixing, and container filling, handling and transport.

A palletized trailer and pallets were designed for transporting containers to the field. The trailer bed is made out of 7 foot long sections of roller conveyor placed across the trailer. The rollers are placed at distances so that they support the pallets on both edges. This provides an easy way to roll the pallets in or out of the trailer bed. An arrangement was made so that the pallet can be positioned in an overhang position or taken out completely. For other details refer to Verma (7).

At the potting area a U-shaped roller conveyor layout provides an arrangement for the empty pallets to move under the belt for receiving the potted containers. The sequence of operation envisioned is that a trailer from the field will come to the U-shaped roller conveyor, unload the empty pallets brought from the field onto the conveyor and go to the other end for the loaded pallets. The loaded pallets are slid onto the trailer and the trailer will be ready to return to the field where the containers are placed on the growing area.

The overview of the proposed system as described above is an alternative method of accomplishing a task common to all container nurseries. A multitude of mixing, container filling and transporting methods are presently employed by nurserymen. However, none of them are fully analyzed to provide a streamlined method for utilizing the labor and machines used in performing this task. For this specific system, two subsystems are analyzed in greater detail, which will be combined into the analysis of the complete system and compared with the present day system at a future time.

Sub-System I: Soil Mixing. The soil mixing operation utilized in this system is a machine developed by Verma (5). The basic components of the machine are hoppers, a conveyor belt and a rotary mixer. The materials are metered from the hoppers onto the conveyor belt forming ribbons of materials layered on each other. The rotary mixer intercepts the layered ribbons of materials, mixes them thoroughly and deposits the mixture on the belt. The mixed material is then conveyed to the container filling machine.

Let us assume that three materials are to be mixed in the following proportions: Material 1, 50%; Material 2, 25%; and Material 3, 25% by volume. One hopper is designated for each material. These materials are stored in separate pile some distance away from the hoppers and a front end loader is used to bring the materials from the piles to load the hoppers when they are nearly empty. One part-time laborer is required to drive the loader for filling hoppers. When the loader is free it is parked at pile 1 and the laborer is assigned to perform another operation in the system. Objectives in the design of the mixing operation are (a) to have laborer free approximately 80% of the time to do other operations, (b) to have a mixing rate equal to the rate needed by the container filling machine and (c) to have all hoppers at least 10% full so that mixing is not stopped.

It can be readily envisioned that several factors affect the soil mixing system: (a) Size of hoppers, (b) Mixing rate, (c) Size of loader bucket, (d) Speed of loader, (e) Distances between the respective piles and hoppers and (f) Time when the filling of hoppers is initiated. The soil mixing rate was set to fill approximately 30 "one-gallon" containers per minute. Hopper 1 was designed to have twice the capacity of hoppers 2 and 3 because the volume of material 1 in the soil mix was twice that of materials 2 and 3. Similarly, the capacity and speed of the loader were assigned with a range within which they may vary. Other variables were also assigned values (Table 1). Where it was appropriate, a range was assigned so that a value within the range may be randomly selected during the computer simulation. The system layout is schematically shown in Figure 3.

To simulate accurately the mixing operation, a flow diagram, Figure 4, was constructed describing the sequence of op-

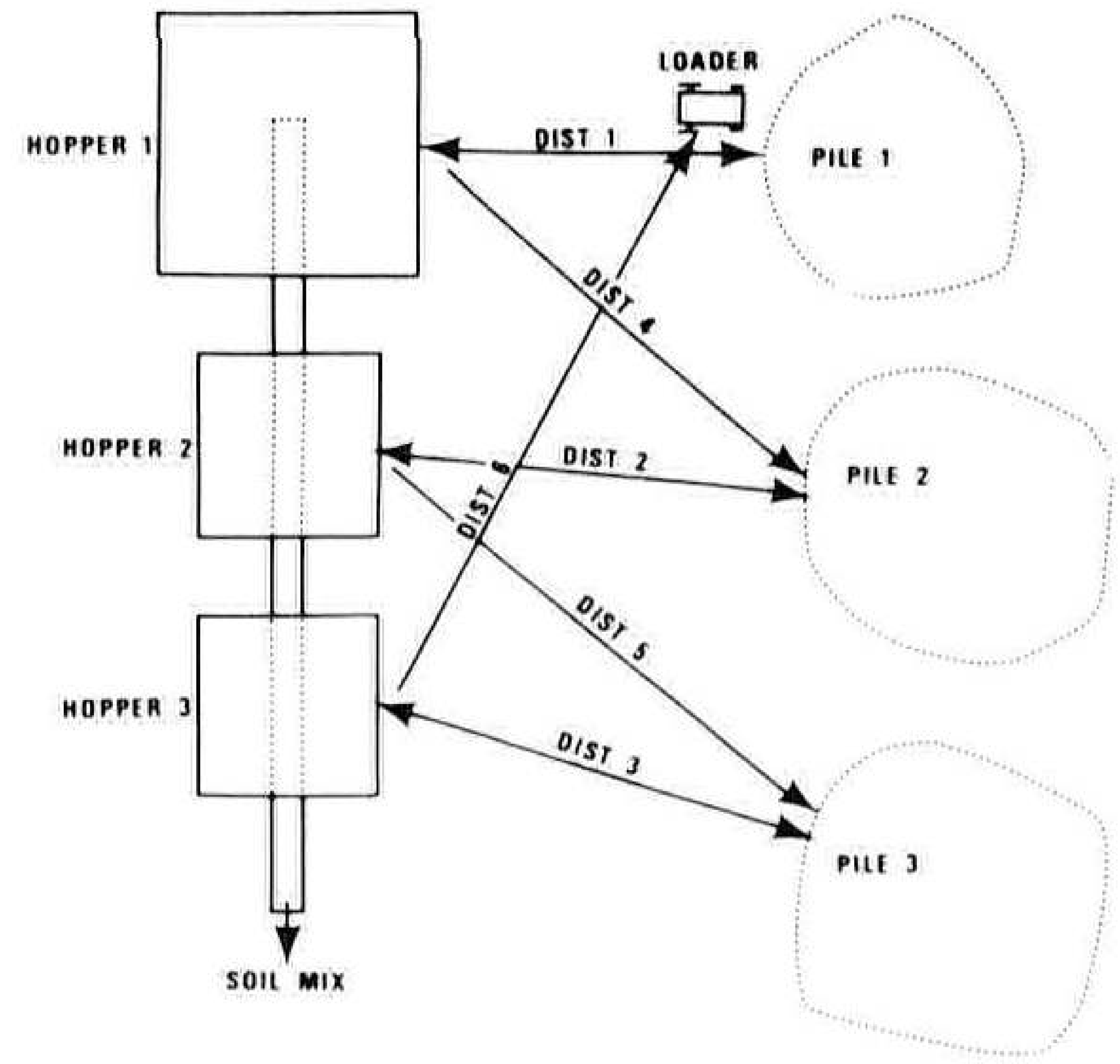

Figure 3. System layout for the soil mixing operations.

Table 1. List of variables and their values for the soil mixing system.

Variable	Description	Values
DIST (1)	Distance between hopper 1 and pile 1 (meters)	50
DIST (2)	Distance between hopper 2 and pile 2 (meter)	60
DIST (3)	Distance between hopper 3 and pile 3 (meters)	50
DIST (4)	Distance between hopper 1 and pile 2 (meters)	75
DIST (5)	Distance between hopper 2 and pile 3 (meters)	60
DIST (6)	Distance between hopper 3 and pile 1 (meters)	72
SPDL	Speed of loader (meters/minute)	144 to 225
CAPL	Capacity of the loader bucket (Cubic meters)	0.34 to 0.45
RATMX	Rate of soil mixing (cubic meters/minute)	0.075
SOIL 1	Percent of material 1 in the soil mix by volume	50%
SOIL 2	Percent of material 2 in the soil mix by volume	25%
SOIL 3	Percent of material 3 in the soil mix by volume	25%
HCAP (1)	Capacity of hopper 1 (cubic meters)	4.5
HCAP (2)	Capacity of hopper 2 (cubic meters)	2.25
HCAP (3)	Capacity of hopper 3 (cubic meters)	2.25
BCAP	Percent of the capacity of hopper 1 at which the loading begins	25%
HOP	Percent of the capacity of any of the three hoppers at which mixing stops	10%

erations. All hoppers were initially assigned to have enough material to start soil mixing. The loader is initially parked in pile 1. At each time increment a check was made to see if the hopper 1 has emptied to BCAP (25% hopper 1 capacity). If BCAP did not occur it was asked if it was the end of the day. If the day had ended, the simulation was completed for the day, otherwise the time was incremented and once again the question was asked if BCAP has occured. When BCAP occurred, it

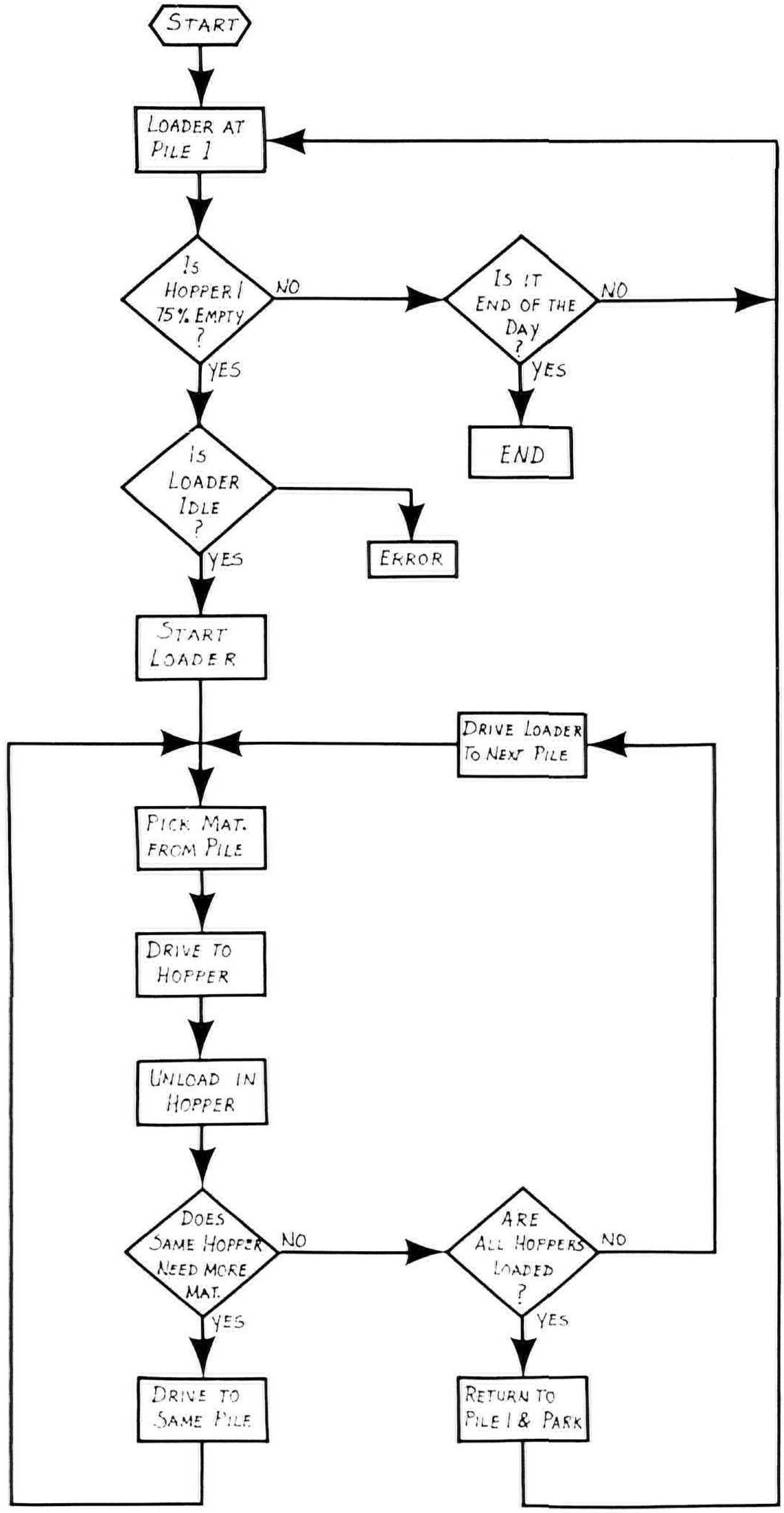

Figure 4. Model description by flow diagram of the soil mixing system.

was determined if the loader was busy. If the loader was found to be busy, an error message was printed. This was done because it would show that the hoppers are metering out the materials faster than the loader can load. Therefore, the designed system is inadequate. However, if the loader is not busy, the time to start the loader is calculated. Then time for picking material in the loader bucket, travel time to hopper 1 and time for unloading the bucket into the hopper is calculated. The amount of material dropped in the hopper is added to the amount already in the hopper. At this point, it is determined if another load can be accommodated in the hopper without overfilling it. If another load is needed, the travel time back to the same pile, time for loading bucket, travel time from the pile to hopper and dump time is calculated and the hopper status is updated. Suppose the hopper is now full, the loader is directed to go to the next pile and start loading the next hopper until it is full. Similar procedures are repeated until the last hopper is full at which time the loader is directed to return to pile 1 and park. The loader waits in pile 1 until BCAP occurs again when another loading sequence is started.

During the entire simulation, accurate statistics were recorded and maintained. Table 2 lists the values of various variables obtained for a 600 minutes soil mixing run. It was found that the loader and laborer were free approximately 81% of the time to perform other operations and hoppers 1, 2, and 3 had 2.67, 1.39 and 1.4 cu m of material on an average, respectively. The hoppers were always more than 10% full, therefore, the mixing was never stopped for lack of material in the hoppers. A total of 56, 27, and 27 loads of materials 1, 2 and 3 were dropped in hoppers 1, 2, and 3, respectively. The system was, therefore, designed to meet all objectives. Had we failed in meeting our objectives, we could redesign the system until satisfactory results were obtained.

Additionally, a plot was made of the amount of material in each hopper, permitting a visual inspection of the conditions that existed during the entire 600 minute run.

Sub-System II: Container Transport to Field. The container transport system is designed to utilize pallets and a trailer which uses pallets to form the bed. The trailer and pallet designs were briefly discussed earlier.

An empty trailer arrives at the loading dock where it receives four pallets loaded with the potted containers. The trailer then leaves for the field where the containers are set on the growing area. The trailer and the driver wait until the four pallets are empty. The trailer then returns to the unloading dock where the empty pallets are unloaded onto the roller conveyor

Table 2. Results of the computer simulation for the soil mix system.

Variable	Description	Value	Standard Deviation
QSTAR	Number of times loader started	6	
FREE	Mean percent of time loader and laborer were free	80.9	9.5
QSEQ	Number of loading sequences	6	
FILLA	Number of times hopper 1 was loaded	56	
FILLB	Number of times hopper 2 was loaded	27	
FILLC	Number of times hopper 3 was loaded	27	
TWORK	Time it took to drop load (minutes)	0.81	0.19
SSA	Mean amount of material in hopper 1 (cu.m)	2.67	0.94
SSB	Mean amount of material in hopper 2 (cu.m)	1.39	0.51
SSC	Mean amount of material in hopper 3 (cu.m)	1.40	0.51

and then it is scheduled to go to the loading dock. If either the loading dock is busy with another trailer or there are less than four loaded pallets, the trailer is assigned to a waiting line. When the dock becomes free and there are four loaded pallets, the trailer is pulled out of the waiting line and goes to the loading dock.

Before the trailer leaves for the field, it is determined whether there are enough rooted cuttings for potting. If the number of rooted cuttings goes below a predetermined number, the trailer is scheduled to detour from the field to the propagation area where it picks up four pallet loads of rooted cuttings. The trailer then travels to the rooted cuttings storage area (marked rooted cuttings in Figure 2), unloads the four loaded pallets, picks up four empty pallets and goes to the unloading dock. The process is then repeated.

The system objectives are to determine the minimum number of trailers that can move the potted containers to the field and bring rooted cuttings from the propagation area to the potting area so that (a) there are always enough rooted cuttings and the potting is not stopped, (b) the loaded pallets are moved out to the field at such a rate that there are never more than 8 pallets waiting at the loading dock, and (c) the trailer time at the waiting line is a minimum.

The container transport system was designed as shown in Figure 5. Various distance and time data required to perform tasks were chosen for the system and are listed in the Table 3. A range of values were assigned to those variables which are expected to occur. During the simulation a value within the

Table 3. List of variables and their values for the container transporting system.

Variable	Description	Value
DISTLF	Distance between the loading dock and field (m)	1080
DISTFG	Distance between the field and propagation area (m)	720
DISTGP	Distance between the propagation area and the area where root cuttings are stored at the potting area (m)	1080
DISTFU	Distance between the field and unloading dock	1350
TRIPPU	Time required to travel from the rooted cutting area to the loading dock (min.)	0.4 to 0.6
NOPPT	Number of pallets per trailer	4
NOPPP	Number of plants per pallet	100
NOLPP	Number of rooted cuttings per pallet	800
RATPOT	Number of containers potted/min.	26.7
SPOT	Travel speed of trailer (m/min)	144 to 225
TRIPUQ	Trip time from the unloading dock to waiting line (min)	0.3 to 0.7
TRIPUL	Trip time from the unloading dock to loading dock (min)	0.4 to 0.6
TRIPQL	Trip time from the waiting line to loading dock (min)	0.4 to 0.6
TWORK	Time required to unload pots in the field (min)	10 to 14
TWORK	Time required to load pallets with rooted liners in the propagation area (min)	2 to 4
TWORK	Time required to unload pallets with rooted liners and load empty pallets (min)	1.5 to 2.5
TWORK	Time required to unload empty pallets on the unloading dock (min)	1.5 to 2.5

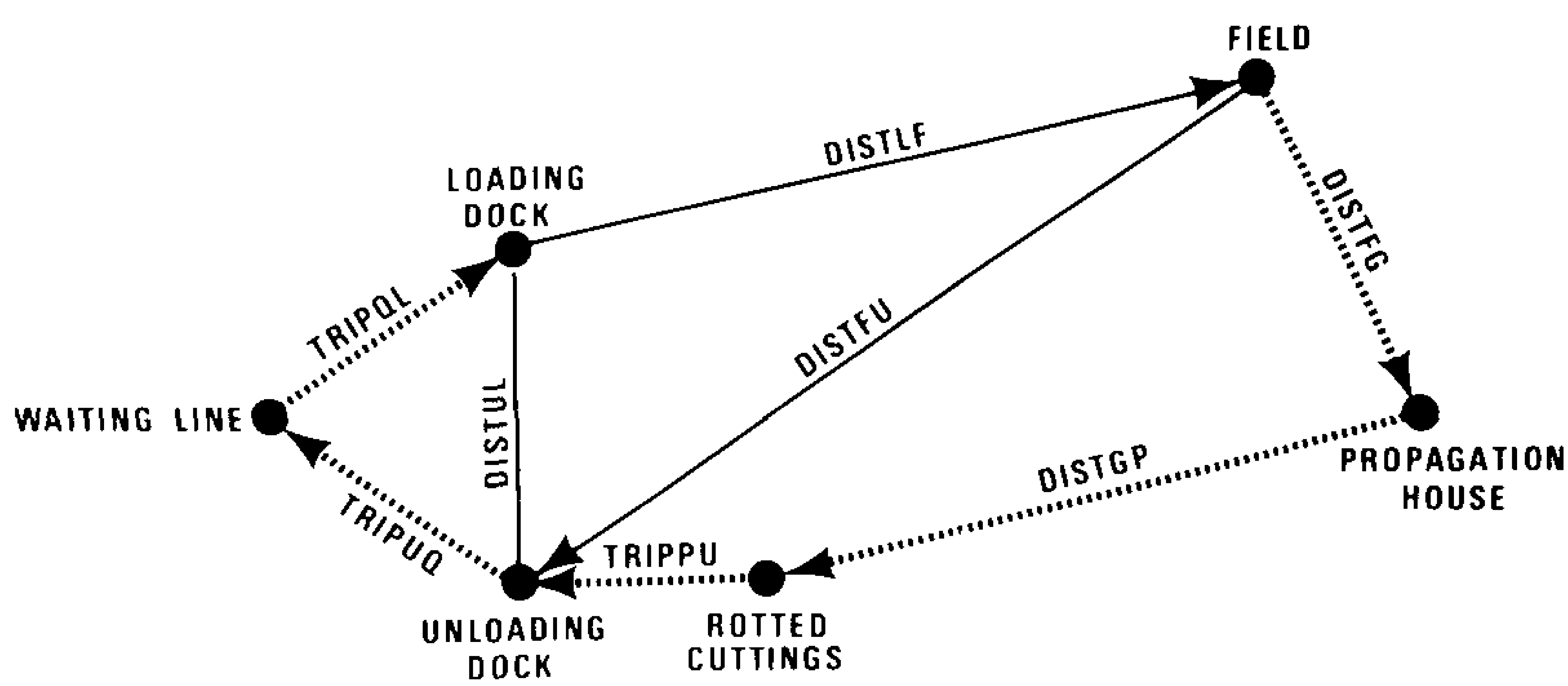

Figure 5. System layout for the container transporting operations.

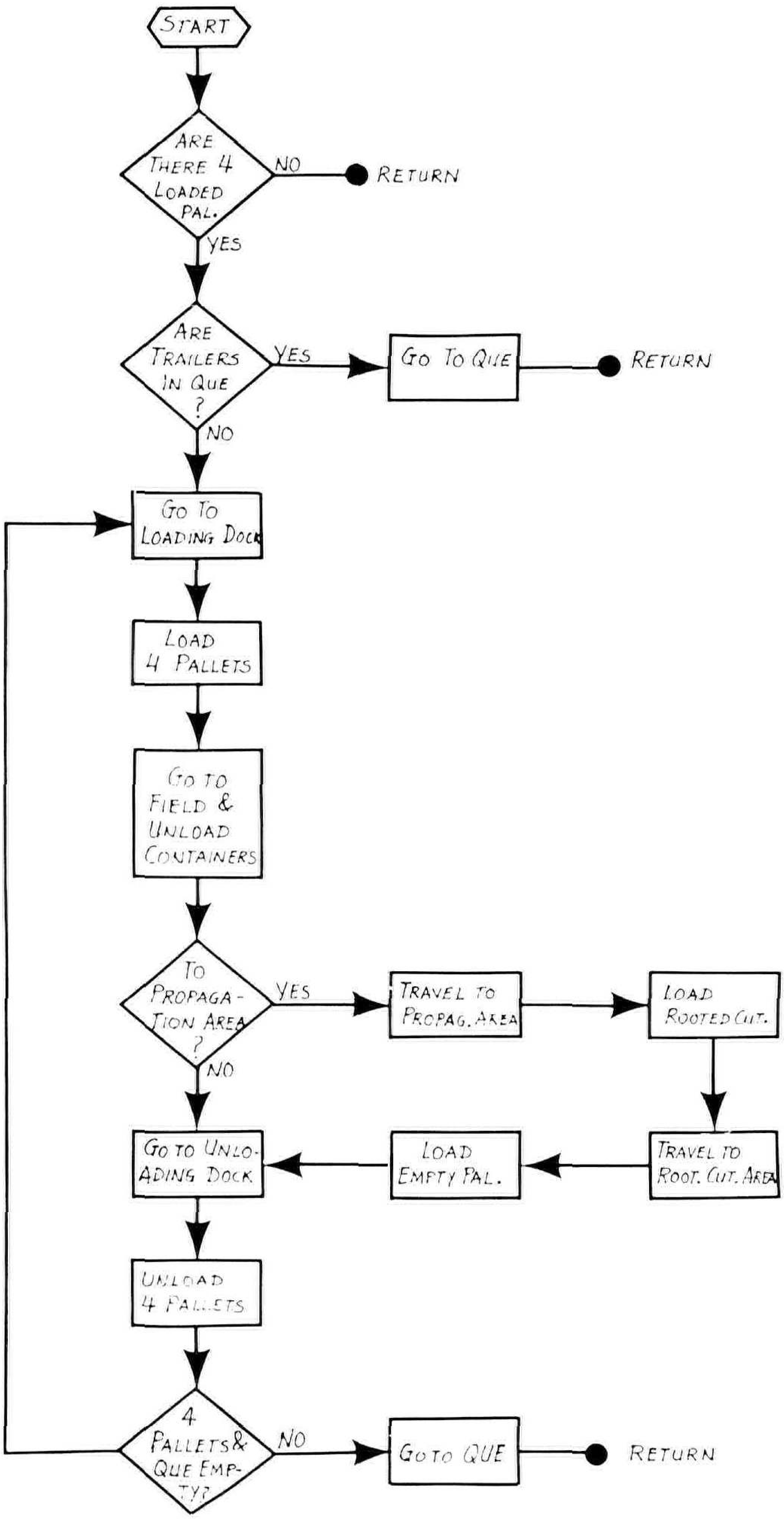

Figure 6. Model description by flow diagram of the container transporting system.

range was randomly selected.

To accurately simulate the container transporting system, a flow diagram was contructed describing the sequences of operation (Figure 6). Each step was carefully simulated in the computer model with the assigned range of values for each variable. Three runs were made using one trailer, two trailers and three trailers moving the containers in the system.

During the entire simulation, accurate statistics were recorded. It was found that when three trailers were used they were in the waiting line for an average of 15.15 minutes with maximum and minimum waiting times of 41.5 and 3.5 minutes. When the number of trailers was reduced to two in the system, the average waiting time was reduced to 0.125 with minimum and maximum of 0.0 and 1.0 minutes. In both cases, the number of loaded pallets on the dock did not exceed 8 pallets during the entire simulation. However, when one trailer was used, no time was spent in waiting, but the number of pallets at the loading dock exceeded the 8 pallet limit. In fact, at the end of the 600 minute simulation nearly 84 loaded pallets had accumulated on the dock. In all three cases the trailer was detoured to the propagation area at a mean interval of 137.1 minutes with maximum and minimum being 201.5 and 94.9 minutes.

From these results it was obvious that one trailer could not transport containers and bring rooted cuttings to keep pace with the rest of the system. Three trailers were an excessive commitment for moving containers and too much time was being wasted in the waiting line. Two trailers were able to keep pace with the rest of the system and there were no significant losses of time.

CONCLUSIONS

The simple example of the barber shop and the two simulations of the nursery operations show how systems simulation can assist significantly in designing nursery operations. To often machines have been introduced in a system without upgrading the other segments. Invariably, this has resulted in faulting the machine performance, whereas, the blame should have been placed on the support component. System analysis will minimize chances of such occurences and will provide a means of upgrading the utilization of labor, machine and other resources. Future analysis will incorporate all components into an overall system which will be efficient at all levels.

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PIECE WORK RATES AND APPLICATIONS IN PLANT PROPAGATION, PRODUCTION, SHIPPING, AND CONSTRUCTION

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We became interested in piece work applications several years ago when we realized our production rates were not as good as some other nurseries around the country. There were, in fact, tremendous differences in efficiencies from one nursery to another. Several nurseries were using piece work rates in preparing and sticking cuttings, filling pots and transplanting liners to larger containers. Our first attempt at piece work was in our propagation department and involved filling 2¼ inch pots and preparing and sticking cuttings. We met with a great deal of resistance from our employees, which could be expected with any change, especially one involving their income. It didn't take long before the better workers realized they could make 1½ times their normal pay if they worked efficiently.

We soon started applying piece work to many other nursery operations. There are advantages and disadvantages; however, the advantages are far greater. Probably the greatest advantage is that we have an established fixed cost for each operation. Other advantages to this system are the following: the jobs require fewer employees, employees make more money, we are able to attract better workers, and most employees prefer piece work. We no longer need be concerned about getting a job