



1979

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Bridges, Thomas C.; Loewer, Otto J. Jr.; Walker, John N.; and Overhults, Douglas G., "A Computer Model for Evaluating Corn Harvesting, Handling, Drying and Storage Systems" (1979). *Biosystems and Agricultural Engineering Faculty Publications*. 129. https://uknowledge.uky.edu/bae_facpub/129

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Notes/Citation Information

Published in *Transactions of the ASAE*, v. 22, issue 3, p. 618-621, 629.

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Digital Object Identifier (DOI)

<https://doi.org/10.13031/2013.35072>

A Computer Model for Evaluating Corn Harvesting, Handling, Drying and Storage Systems

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AGRICULTURAL systems have been the subject of many types of computer models and simulations. Holtman et al. (1970) presented a corn harvesting simulator and Morey et al. (1971) used simulation techniques to analyze net profit of a corn harvesting and handling system during a particular weather year. A study by Carpenter and Brooker (1970) also utilized simulation and presented minimum cost systems for harvesting, drying and storing shelled corn. These simulations in general require many inputs and are not directed to the operation of the individual producer.

The selection of corn harvesting, handling and storage facilities requires many management decisions by the producer. Some of these include the type of hauling vehicle, the type of handling equipment, selection of a drying technique and the economic feasibility of grain storage. Consideration must also be given to the amount of capital the producer is willing or able to spend, the physical parameters associated with the farmstead and the available labor resources. All feasible arrangements should be examined, and comprehensive information that permits the selection of the optimum or least cost system meeting the above-mentioned requirements is needed. Such analyses, if performed by an individual, would be difficult and time consuming.

To incorporate the foregoing considerations and provide detailed decision information for a producer's individual operation, the design computer simulation CHASE (Chase Handling And Storage Evaluator) was developed.

The objective of this report is to provide a description of the capabilities of CHASE and how it is used by design and research engineers.

PROGRAM CAPABILITIES

CHASE performs the following functions:

- 1 Examination and design of harvesting, handling, drying and storage systems which meet the requirements imposed by the farm operator.
- 2 Ranks the costs of the feasible systems considered.
- 3 Presents the equipment and labor required by each feasible system.

Article has been reviewed and approved for publication by the Electric Power and Processing Division of ASAE.

This paper is published with the approval of the Director of the Kentucky Agricultural Experiment Station and designated as Paper No. 75-2-19.

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SYSTEM DESCRIPTION

The initial step in developing CHASE was to define the criteria and the assumptions to be used in the program, and the limits each would encompass. The beginning point of the system commences when corn is ready for harvest, which is designated by the producer as the initial moisture content of his harvest. From this point, 60 different shelled corn systems are compared. Each system is a feasible combination of delivery vehicles, handling equipment, drying technique and storage, and terminates at a point designated as "ready for market". This term specifies when the grain is ready to be sold and may vary with the individual system. CHASE does not investigate marketing costs or returns to the producer.

DESCRIPTION OF THE FLOW NETWORK

The flow network of CHASE is divided into five sections: harvesting, hauling, handling, drying and storage (Fig. 1). The harvesting section assumes the grain is being harvested by a combine. After harvest, six possible methods of hauling grain from the field to the facility are considered. These include three wagon types and three truck types which are categorized according to their unloading method. The wagon categories include gravity flow unloaded wagons, auger unloaded wagons and manually unloaded farm wagons. Truck categories are a manually unloaded farm truck, a farm truck that is gravity unloaded by use of an overhead hoist and a gravity unloaded dump truck.

The handling section of Fig. 1 assumes that the hauling vehicle will unload into a pit or a transport auger hopper, thus establishing a connecting link between hauling and handling methods. The pit, whether it is of the gravity or auger type, is associated with a bucket elevator while the auger hopper is attached to a transport auger.

There are five possible combinations of drying and storage within each type of handling. The combinations that include storage are layer drying, batch-in-bin drying and a comparison of automatic batch and continuous flow drying. The no-storage (or minimum storage) combinations are batch-in-bin drying and a comparison of automatic batch and continuous flow drying. The latter two combinations require the producer to dry and sell immediately. However, the no-storage combinations do have sufficient storage space to hold one day's drying.

The flow network contains a total of 60 combinations of hauling, handling, drying and storage. Each combination is a feasible system and is acceptable as an on-the-farm method of grain handling.

DATA INPUTS

One source of data inputs for the model is the informa-

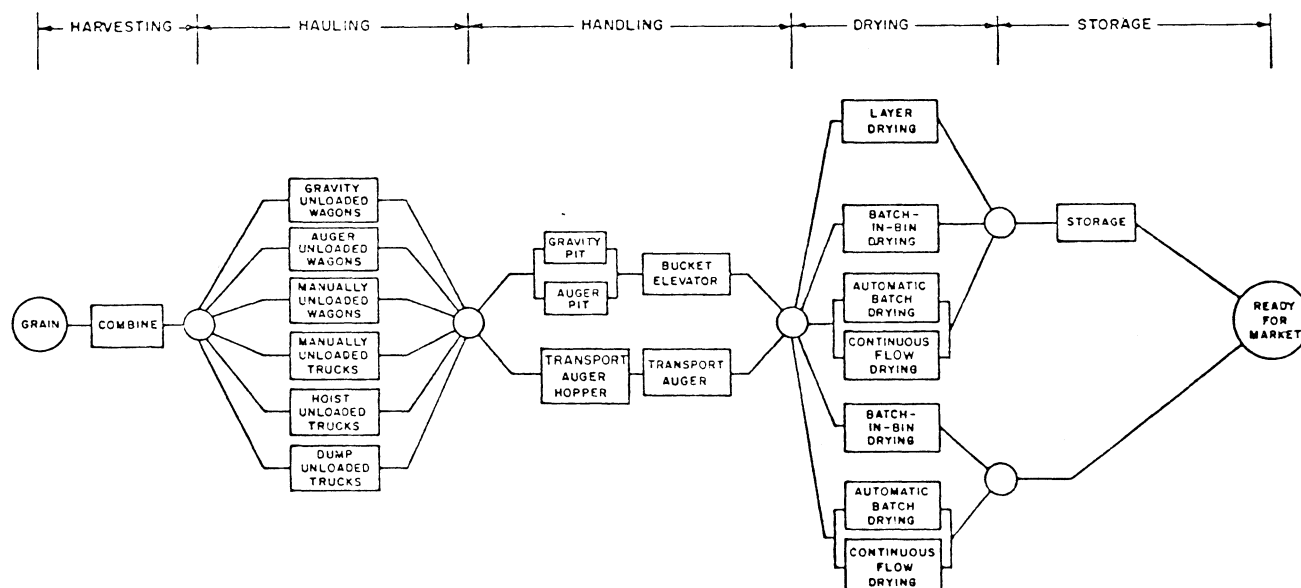


FIG. 1 The flow network of systems compared by CHASE.

tion supplied by a farmer and is designated as producer inputs. These parameters are used to analyze a particular farmstead and vary with the individual situation. The producer inputs are restricted to the types of information that the producer could readily supply. Parameters pertaining to the producer's farming operation are acres of corn, expected yield per acre in dry bushels (15.5 percent wet basis), row width in inches, the number of days that the harvester will operate, the length of the harvest day in hours and the length of drying day in hours for portable drying. Other producer inputs are the distance from the field to the facility in miles, the moisture content at the start of harvest (percent wet basis) and the desired moisture contents (percent wet basis) for storage and for selling at the elevator. Producer inputs pertaining to local energy and labor costs include electricity rates (dollars per kilowatt-hour), gasoline and liquid propane fuel costs (dollars per gallon), and a labor wage rate (dollars per hour).

A second source of data input information is specified as analyst input. The analyst is designated as the person who provides analyses for the producer. Analyst's inputs include equipment costs, equipment types and design data necessary for the program's operation. These data are stored in the program and will not change for the individual analysis. However, they may be updated periodically, which is the responsibility of the analyst.

COST CALCULATIONS

Throughout the program, references are made to investment costs, fixed or annual costs and operating costs. These costs are the basis the program uses to select the optimum system and rank the remaining feasible solutions.

Investment costs are defined as the prices paid by the producer for any equipment. These costs are based on list prices and were obtained from representative manufacturers (loewer et al., 1976b) and do include construction costs.

The fixed cost of an item is represented by the sum of the yearly depreciation for the item, the interest on the investment and a charge for taxes, insurance and

housing. A value was obtained that expresses the fixed cost as a percentage of the item's list price. The program stores these percentages (Table 1) for all equipment and applies them whenever a fixed cost is desired. All equipment percentages are based on a straight-line method of depreciation, a 10 percent interest rate and a 2 percent charge for taxes, insurance and housing.

Annual costs include the fixed cost and the operating cost of a particular item of equipment plus that of construction, if any. The operating cost is generally divided into an energy charge and a maintenance or repair charge. Equipment comparisons in the program are based on least annual costs, and it is noted that labor costs are not considered with each individual selection. However, a labor charge is assigned each total system and is included in the final ranking.

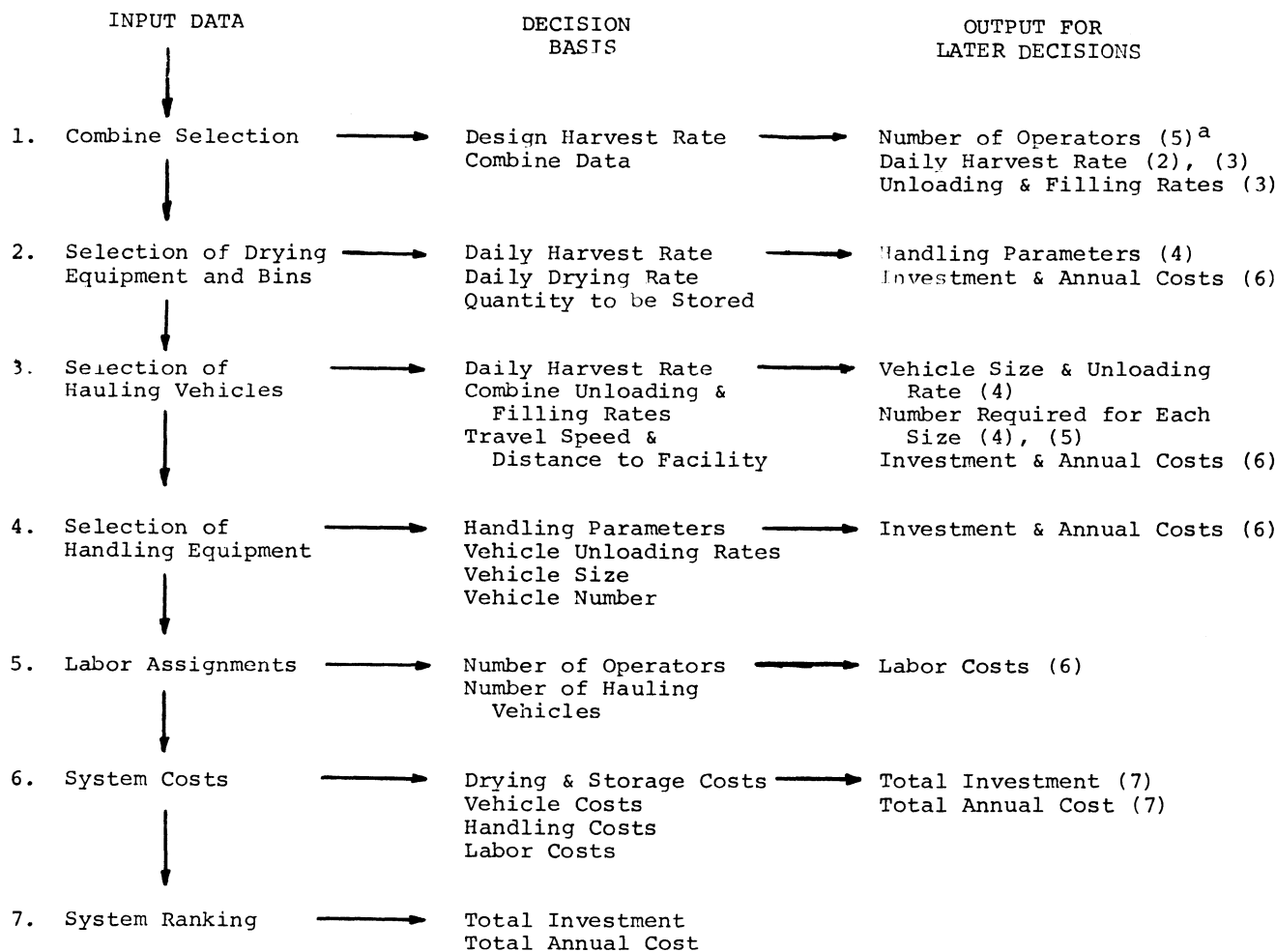
PROGRAM DESCRIPTION

The program begins examination of all feasible hauling, handling, drying and storage systems with the selection of a combine. CHASE deviates from the flow network in Fig. 1 by then considering all drying and storage combinations. The program continues the analysis of

TABLE 1. FIXED COST PERCENTAGE AND DEPRECIATION SCHEDULE FOR EQUIPMENT USED IN CHASE

Item	Depreciation schedule, yrs	Percent*
Bin	20	11.1
Auger	7	19.5
Concrete	20	11.1
Electric motor	10	15.6
Aeration fan	10	15.6
Pit	20	11.1
Bucket elevator	20	11.1
Layer drying fan and heater	10	15.6
Batch-in-bin dryer	10	15.6
Combine	10	15.6
Corn head	10	15.6
Truck	10	15.6
Wagon	15	12.6
Tractor	15	12.6
Portable dryer	10	15.6
Miscellaneous	10	15.6

*Percent includes depreciation, interest, taxes, housing, and insurance.



^aNumber refers to subsequent input data step.

FIG. 2 Decision sequence used by CHASE.

each system by examining the hauling vehicles and handling methods and completes the study with an economic ranking of all systems. This decision sequence is shown in Fig. 2.

Before selecting a combine, the program calculates an average daily harvest rate. This is determined by dividing the total harvest by the number of days the producer will operate the harvester. The least cost combine (or combines) which meets this harvest rate is selected and certain characteristics of the combine are stored for future use. These include the grain tank size, the average daily harvest rate and the hourly harvest rate. The average daily harvest rate of the combine becomes the design rate for all delivery, storage and drying combinations evaluated by CHASE.

After selecting a combine, the program begins analysis of all drying and storage combinations. The storage layout involves an X, Y, Z coordinate system advanced by Loewer et al. (1976a). CHASE also uses many of the techniques and design routines that are found in the computer program BNDZN (Loewer et al., 1976a). CHASE will always select a minimum number of equally sized bins to store the entire harvest while limiting the bins to a maximum height of nine rings. The no-storage combinations provide a minimum storage capacity equal to 1 day's harvest.

After completing the storage design of a particular in-bin drying and storage combination, the program

designs the drying equipment based on the average daily harvest rate, the initial moisture content of the grain, the desired dry moisture content of the grain and ambient conditions of 15.1 °C and 65 percent relative humidity.

In the case of layer drying, CHASE limits the drying fan to a maximum of 14.9 kW (20 hp) and allows only one fan per bin. Drying fans exceeding this size are not readily available and the absence of three phase power makes the power companies reluctant to allow the use of large single phase motors in Kentucky.

If the calculated fan size is greater than 14.9 kW, the program redesigns the bins with a larger diameter and rechecks the power requirements. The procedure is repeated until a fan size of 14.9 kW or less is required or the diameter reaches the maximum allowed by the program. If the horsepower is unacceptable at this point, the program adds another bin and repeats the process. A feasible layer drying system is obtained when the fan size is acceptable and the producer has enough storage for the total harvest.

For batch-in-bin drying CHASE selects the drying bin diameter such that the height of the average daily harvest is always 4 ft or less. This prevents excessive fan horsepower and overdrying of the grain near the bottom of the batch. Once the diameter is established CHASE selects the eave height at four rings to allow each access for a man working inside.

In selection of a portable drying method, CHASE makes a comparison between an automatic batch and a continuous flow dryer. The desired drying rate is the average daily harvest rate divided by the length of the drying day (supplied by the producer). Both dryer types must meet the producer's requirements and a witholding bin is designed for each dryer. CHASE then selects the dryer type and associated equipment with the least annual cost. The output differs from in-bin systems in that the fan horsepower is quoted from sales literature and the heat size is calculated from manufacturer's data.

After selecting the drying equipment, CHASE establishes handling parameters for each drying and storage combination. These include the method handling capability, the bucket elevator discharge height and the transport auger length. Method handling capability is defined as the minimum handling capacity dictated by a particular drying and storage combination. For layer drying the method handling capability is equal to the delivery rate of the harvest from the field. Batch-in-bin drying dictates a minimum rate required to move the daily harvest in 2 h. Portable drying requires that the grain be moved at a rate equal to that of the unloading auger of the dryer or surge bin.

Upon completion of the drying and storage design, the program selects the delivery vehicles and designs the handling equipment. Determination of the number of hauling vehicles is based on the assumption that the vehicles must deliver the average daily harvest rate to the facility such that the harvester never has to wait for a returning vehicle.

The number of vehicles is a function of time required to load the vehicle by the harvester, the total time for field and road travel, any waste time that may be lost positioning wagons and opening gates, etc., the unloading time of the vehicle at the facility, the number of harvester unloadings to fill the vehicle and the time required to fill and unload the harvester's grain tank (Hunt, 1973).

After determining the minimum number of vehicles of a specific type, the actual unloading rate of the vehicle (never exceeding the maximum unloading rate for that type) is calculated and used to design the pit. Both gravity flow and auger type pits are designed for each size vehicle, and the type with the least cost is selected as the pit for that vehicle. CHASE then selects the least cost combination of dump pit size and vehicle capacity within a specific vehicle type.

This procedure is repeated for the transport auger. CHASE has established a method handling capability for each drying and storage combination, and the transport auger is designed to handle this minimum handling capacity or the unloading rate of the vehicle, whichever is larger. CHASE then designs a transport auger for each size vehicle within a specific type and selects the least cost combination.

The bucket elevator is also designed using the minimum handling capacity and discharge height associated with each drying and storage combination. It is not vehicle dependent because the pit is the connecting link between the elevator and the transport vehicle.

CHASE assigns the vehicle costs in the following manner. The investment cost of any particular system includes the total cost of all tractors and wagons or trucks as the case may be. Only a portion of the fixed

cost of tractors and trucks is included in the annual cost of a system. This portion is determined to be twice the number of harvest days divided by the total days per year, based on the assumption that 1 out of every 2 days during the harvest period is a "good" harvest day.

As each system is designed, both investment costs and annual costs are calculated and totaled. After the design of all systems is completed the program ranks all systems by investment cost and by annual cost.

Validation of CHASE was accomplished in three ways. First system costs produced by the model were checked against equipment prices provided by many different companies involving all aspects of machinery used within the model. Next certain systems selected by CHASE (a static deterministic model) were compared in a dynamic simulation (Benock et al., 1977), and checked to see if they functioned correctly. Finally the model was field validated in that facilities have been constructed using the design dimensions given by CHASE with these facilities being found functionally correct.

The previous sections have briefly described the program and the design analysis used by CHASE. The program does not directly follow the sequence of events shown by Fig. 1. A brief description of the decision sequence and the decision making parameters used by CHASE is presented in Fig. 2. A sample program output and explanation of it is presented by Bridges et al. (1976a) and a complete program listing is available in the U.K. Agricultural Engineering Technical Series No. 9 (1976b).

PROGRAM USE

The economic ranking of all systems allows the producer many options and alternatives. The producer who desires a new facility can visualize the yearly expense incurred by each of 60 feasible systems and can compare alternative methods of grain handling. If this producer has a limited amount of capital, he may prefer to examine only those systems within this limit. Another application of CHASE would be to vary certain inputs, allowing the producer to see the change in system costs and the effects of his decisions.

CHASE also provides management information for the producer with fixed items of equipment. The system information listed in the rankings allows the producer to check each system that contains his existing equipment. From this list of systems that utilize his existing equipment, he may evaluate the options remaining to him in terms of investment and annual cost.

CHASE has been used as a research tool to optimize facility design based on capacity and harvest rate (Bridges et al., 1976c). Similar research studies are presently being conducted investigating other design parameters.

CHASE is currently being used by extension personnel at the University of Kentucky to analyze Kentucky farm operations (Loewer et al., 1977). To date, farms from 16 other states have also been analyzed on a fee-charge basis. CHASE is used with other programs dealing with design and economics of grain storage and drying (loewer et al., 1975, 1976a), which provides producers with an extensive management and planning tool on which to base their decisions. Program decks and documentation have been provided to other states and are available from the authors which complete documentation for \$15.

(Continued on page 629)

Computer for Evaluating Corn Harvesting

(Continued from page 621)

SUMMARY

CHASE can supply the producer with complete and accurate data to aid him in his decision making. It allows the producer to concentrate on the system concept rather than the selection of a single piece of equipment, and gives him the ability to compare many alternatives before any capital investment is required. It has also been used as a research tool to provide design information.

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