1976



# SIMULATION ANALYSIS OF EXPORT GRAIN FLOWS THROUGH GULF PORTS

by

Jerome J. Hammond and Michael S. Salvador

American Agricultural Economics Association
1976 Summer Meetings
CONTRIBUTED PAPERS SESSION
The Pennsylvania State University
August 15-18, 1976

# SIMULATION ANALYSIS OF EXPORT GRAIN FLOWS THROUGH GULF PORTS

Jerome J. Hammond and Michael S. Salvador*

Agricultural products have become an important factor in U.S. foreign trade. Grains and soybeans have accounted for nearly three-fifths of the value of U.S. agricultural exports during the past several years. From a value of $6.7 billion in fiscal 1970, agricultural exports tripled to $21.6 billion in fiscal 1975. During the same period, the value of agricultural imports increased less than 75 percent. Thus, the $1.1 billion surplus in the balance of trade in agricultural products during 1970 swelled to a $12 billion surplus in 1975. These surpluses have helped contribute to an overall favorable balance of trade during four of the past six years and have lessened the deficit in the other two years (4, p. 2).

The U.S. transportation infrastructure apparently can accommodate, but with some difficulty, the Nation's new role as a major supplier of food and feed grains for the world. The large USSR grain purchase of 1972-73 clearly showed that the transportation system could not easily handle such sudden surges in demand. That period's record grain exports were accompanied by such bottlenecks as railcar and ocean carrier shortages and port congestion.

The objective of this paper is to apply a modeling technique in analyses of circumstances which may constrain the export of grain and

*Agricultural Economist, Economic Research Service, U.S. Department of Agriculture and Management Consultant, Ernst and Ernst, respectively. Views expressed are those of the authors' and do not necessarily represent those of the U.S. Department of Agriculture or the Economic Research Service.

soybeans through U.S. Gulf ports. The first part of the paper discusses the exports of grain and soybeans through Gulf ports. The second part describes factors affecting those export movements. Next is a brief description of the computerized simulation model used in the analysis. Finally, the results of sample applications of the model are presented.

## Grain Exports Through Gulf Ports

Grain and soybean inspections for export from all U.S. ports increased from nearly 1.2 billion bushels in 1960 to 3.2 billion bushels in 1975, reaching a peak of 3.5 billion bushels in 1973. The Gulf ports, including the Mississippi River, East Gulf, and North and South Texas ports accounted for over two billion bushels or nearly two-thirds of the U.S. grain and soybean exports during 1975 (2). 1/ More than half the wheat, two-thirds of the corn, three-fourths of the soybeans, and nearly all of the grain sorghum was exported from Gulf ports. These four commodities combined accounted for nearly 99 percent of all grain exports in 1975.

While movements of grain and soybeans through Gulf ports to specific areas change from year to year, western Europe, accounting for 617 million bushels or more than one-third of the total, was the largest customer during fiscal 1975. Japan was second with 372 million bushels or more than one-fifth of Gulf shipments. Japan also accounted for more than two-fifths of the grain sorghum. Latin America was the largest customer for wheat, accounting for 27 percent of the total. Western Europe received nearly half the corn and nearly three-fifths of the soybeans (2).

## Factors Affecting Export Movements

The growing export volume and the continuing large share flowing

1/ East Gulf: Mobile and Pascagoula; Mississippi River: New Orleans, Destrehan, Port Allen, Myrtle Grove, Ama, and Reserve; North Texas Gulf: Beaumont, Port Arthur, Houston, and Galveston; South Texas Gulf: Corpus Christi and Brownsville.

through the Gulf ports has at times severely strained the export grain system. Seasonality of grain and soybean production and large cyclical purchases by major grain using countries have further complicated matters.

The efficiency with which the export system operates is dependent on controllable variables such as export volumes, vessel design, facility location and design, and regulatory restrictions. Other variables such as inclement weather, flooding, hurricanes, fires, vessel collisions, cargo spills, and labor strikes are less controllable (or even uncontrollable).

Port Elevators

The Gulf has 20 elevators--approximately one-fourth of those in the U.S.--located at 14 different ports. The amount of grain moving through individual port elevators is highly dependent on working storage capacity, maximum delivery or load-out rate to ships, the receiving rate from the individual modes, and maximum vessel length and draft. For individual elevators the working storage capacity, which is estimated at 90 percent of capacity, ranges from 1.7 million bushels to 7.2 million bushels (5).

Delivery rates from elevators to the ships vary even more than working storage capacity, ranging from 20,000 to 140,000 bushels per hour (5). There is also much variability in the receiving rate of port elevators from barges, trucks, rail hoppers, and boxcars. While all elevators receive grain by rail, several are not equipped to receive by truck or barge.

Economies to be gained from large vessels are limited by maximum vessel length and draft restrictions at each elevator. The length of vessel that can be accommodated by Gulf elevators ranges from 750 feet to 1,200 feet. In addition, the vessel draft capability ranges from 34 to 40 feet (5).

Merchant Fleet

U.S. grain can compete more effectively in world markets with adequate ocean shipping capacity available at reasonable costs. Following a rapid increase in exports during 1972-73, shortages of ocean vessels caused sharp price increases and brought delays in ocean shipping which resulted in some of the bottlenecks in port areas. In some cases port tieups severely affected inland grain markets.

At the end of 1975 there was idle ocean vessel capacity accompanied by low ocean freight rates. For example, the average quarterly bulk grain rates from U.S. Gulf ports to Antwerp-Rotterdam-Amsterdam fell from a high of $16.60 per short ton of grain in the fourth quarter of 1973 to an average of about $4.50 in the third quarter of 1975. Dry cargo tonnage in freighters and bulk carriers was estimated at 236 million deadweight long tons during 1975, up from 83 million in 1960. Carrying capacity of the tanker fleet, which also carries grain, has increased some fourfold since 1960. Many of these capacity increases have resulted from increases in average vessel size (1).

Transportation to Ports

Increased world demand for U.S. grains and soybeans has added greatly to inland transport demand. Equipment for movement of agricultural commodities was in short supply from the fall of 1972 and into the spring of 1974. While both domestic and export grain were eventually moved, it was done with many disruptions and increased costs to shippers and transportation firms.

The movement of grain and soybeans to the Gulf ports is highly dependent on rail and barge services. Most wheat and sorghum from Kansas,

Oklahoma, and Texas are moved to ports by rail. Barges account for much of the corn and soybeans originating from points along the upper Mississippi River System.

Covered hopper cars, which are larger and more efficient than boxcars, now carry most of the grain moved by rail. The weekly rail carloadings of grain averaged 25.8 thousand cars during 1975--down from 32.3 thousand during 1973. A part of the decline was due to heavier loads per car. In addition, some of the difference was accounted for by barge traffic which increased from a weekly average of 19 million bushels in 1973 to 23 million bushels during 1975 (3, p. 43).

## Bulk Commodities Simulation Model

The Bulk Commodities Simulation (BCS) Model was developed by Ernst and Ernst for the Office of Commercial Development of the Maritime Administration (MarAd). 2/ The overall purpose of the model was to provide a means to (1) adequately analyze the capacity and other design characteristics of the port and ship facilities involved in the export movement of bulk commodities and (2) if necessary, allocate ships in emergency situations on a cost effective basis. Initially, the model was restricted to the exporting of grain through Gulf ports and has since been expanded to allow analysis of grain exporting activities at all U.S. ports.

MarAd allowed the Economic Research Service access to the BCS model and, with their cooperation, ERS aided in the enhancement of the land-side

2/ The BCS model is documented in a three-volume set. Volume 1, entitled "Management Summary," contains an overview of the application and use of the computerized version of the model. The technical details of the model design and development are provided in Volume 2, "Technical Report." The details for actually applying the computerized version of the model are found in Volume 3, "Users Documentation."

aspects of the simulation model itself. Several modifications, including a provision for grain seasonality factors, have now become permanent features of the model.

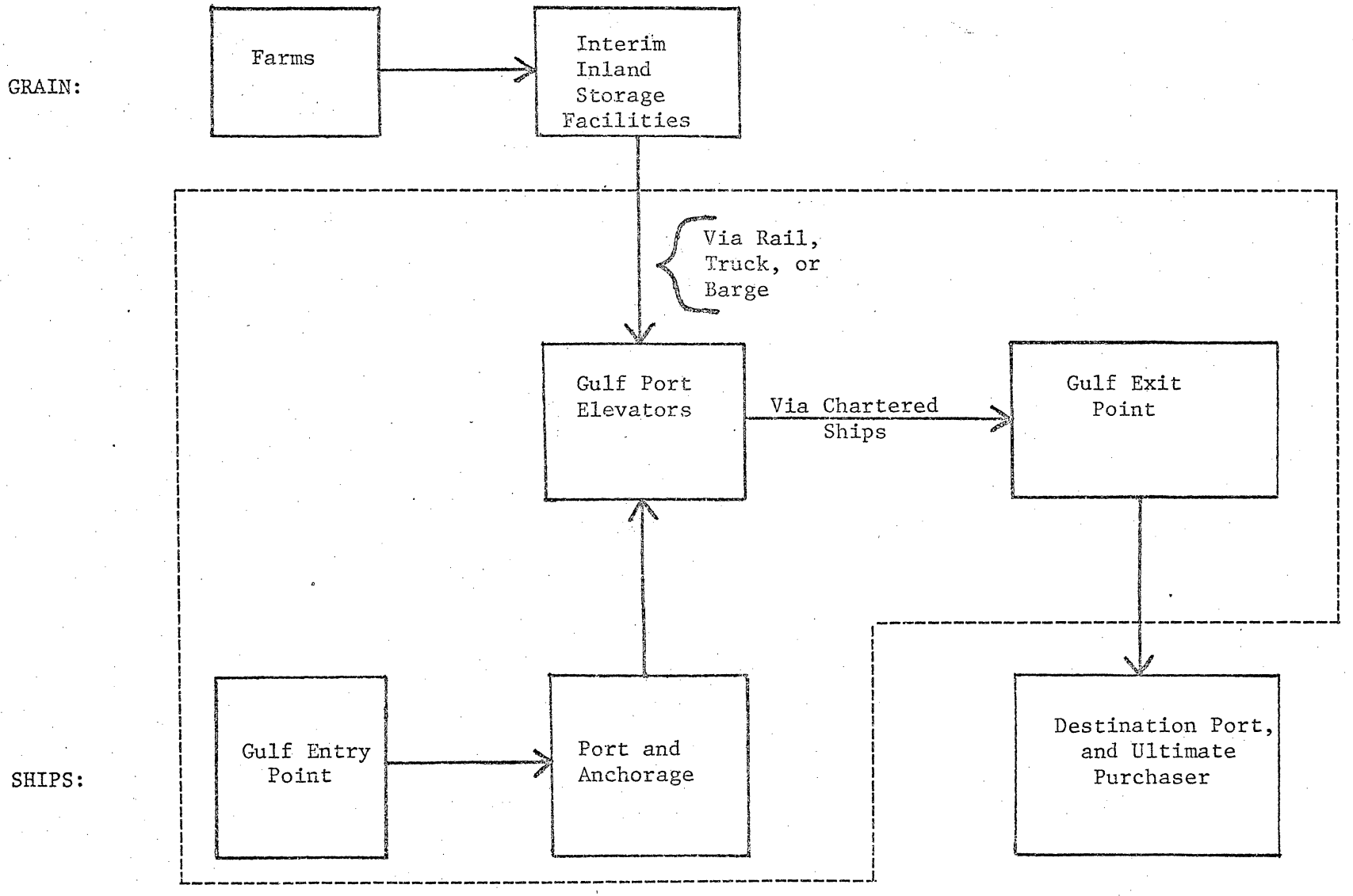
While it is not practical to provide a detailed, technical description of the model in this paper, it is essential that some information be provided in order to properly assess the results. The BCS model is a discrete event simulation model--meaning that the continuous activities of the system are represented by a chronological series of discrete events. The scope of the model as illustrated in Figure 1 includes those activities within the broken line.

Input data for the model are generally divided into three parts: (1) System attribute data; (2) statistical data; and (3) event data. The system attribute data represent the port facilities, inland transportation system, commodity types, and maritime resources to be included in the simulation. For purposes of the analysis described herein, these data were initialized to represent 20 elevators at 10 ports in the Gulf of Mexico with one entry/exit point for an average ship type. 3/ The commodities considered were wheat, corn, soybeans, and sorghum; and they were assumed to arrive at the elevators by rail covered hopper cars, rail boxcars, trucks, or barges. Specific attribute data for the system include maximum ship length and draft that can be accommodated, working storage capacity, receiving rates for inland modes of transportation, delivery rate to ships, etc., in the case of elevators.

Unlike the attribute data, which generally define the system being analyzed, the statistical data generally define the supply and demand

3/ The model assumes that New Orleans, Destrehan, Ama, Myrtle Grove, and Reserve are all at the same location.

Figure 1.--Major Steps in the Exporting of Grain Through U.S. Gulf Ports



assumptions associated with the simulated operation of the system. Specifically, statistical data can be used to generate random ship and grain arrivals or randomize the value of certain attribute data.

The event data are the specification of user-controlled events which are to occur during a simulation at a specific time. These events include port shutdown, ship reallocation, and general attribute and statistical data changes.

## Results of Analysis

The specific analysis reported here includes estimation of the effects of changes in export grain flows through Gulf ports for: (1) a 20-percent increase in grain exports with normal elevator operating hours; (2) a 50-percent increase in grain exports with normal elevator operating hours; and (3) a 50-percent increase in grain exports with elevators operating at 16 hours. Space does not allow the presentation of results for more sophisticated analysis such as port and modal closures which have also been performed.

For purposes of this paper, only excerpts from the system-wide summary output reports provided by the model have been presented in Table 1. Note, however, that the BCS model does provide additional information including detailed reports for individual elevators.

### Base Case

The first step in the simulation analysis was construction of a base case for the Gulf. The base case establishes a norm against which the relative effects of changes can be measured.

Several assumptions and data were required in constructing this base case. Because export data were available for 1975, it became the base

year. The amount and commodity type arriving at the Gulf was allocated to the elevators in the proportion occurring during 1975. Additionally, the grain was distributed to the different modes according to the receiving capacity of the modes. To permit shiploading to begin on the first day of the simulation period, it was assumed that the elevators were half full. Finally, to adequately represent average grain and ship queues, ship arrivals and elevator delivery and receiving hours were adjusted to the levels required for the model to deliver to the ships virtually all the grain that arrived at elevators during the period. 4/

More than two billion bushels of grain moved through the Gulf ports in 1975. As a result of the base case simulation of this period, an average of only a quarter of a million bushels of grain was queued at the elevators at any given time. The elevators were initialized with 48 million bushels in storage and only 5 million bushels were added to that figure during the year. The grain was loaded on 2,366 ships with only eight empty ships having to be detained temporarily at anchorage (Table 1).

Event 1

Event 1 represents a 20-percent increase in grain and ship arrivals over the base case with the elevators operating the same number of hours as in the base case. With these assumptions some congestion occurred. The average amount of grain queued at the elevators increased from 252,000 bushels (base case) to 1.8 million bushels--a sevenfold increase. In addition, more than 400 ships were temporarily detained at anchorage,

4/ Eight hours became the normal daily receiving operating hours for 19 elevators with the remaining one at 10 hours. However, for the elevators to deliver their grain receipts to the ships it was necessary for 12 elevators to operate 8 hours a day with the remaining 8 operating 16 hours.

Table 1.--Summary analysis of simulating Gulf export grain flows under alternative events

| Item | Base Case | Event 1 | Event 2 | Event 3 |
|---|---|---|---|---|
| Commodity/Elevator Summary (000 bus.) | | | | |
| Total amount arriving at elevators | 2,009,448 | 2,402,192 | 2,991,085 | 2,991,085 |
| Daily average arriving at elevators | 5,520 | 6,599 | 8,217 | 8,217 |
| Average amount queued at elevators | 252 | 1,774 | 27,350 | 16,059 |
| Final amount queued at elevators | 0 | 1,335 | 44,636 | 25,827 |
| Total amount received by elevators | 2,009,448 | 2,400,857 | 2,943,449 | 2,965,258 |
| Daily average amount received by elevators | 5,520 | 6,596 | 8,086 | 8,146 |
| Total amount delivered to ships | 2,004,002 | 2,392,775 | 2,925,538 | 2,962,806 |
| Daily average amount delivered to ships | 5,505 | 6,574 | 8,037 | 8,140 |
| Final amount stored in elevators | 53,587 | 56,223 | 66,052 | 50,593 |
| Average amount stored in elevators | 61,281 | 59,552 | 63,248 | 57,661 |
| Ship Summary | | | | |
| Total number of ships entering ports | 2,382 | 2,852 | 3,556 | 3,556 |
| Total ships detained at anchorages | 8 | 417 | 1,626 | 759 |
| Average number of ships at anchorage | 0 | 2 | 39 | 23 |
| Final number of ships at anchorage | 0 | 7 | 84 | 43 |
| Average wait-time at anchorage (hrs.) | 0 | 5 | 93 | 53 |
| Total number of ships loaded | 2,366 | 2,825 | 3,454 | 3,498 |

with an average waiting time for all ships of five hours (Table 1).

Event 2

The information presented for the second event is based on a 50-percent increase in grain exports and ship arrivals. The delivery and receiving operating hours are the same as in the base case.

It can be seen that the average amount of grain queued at elevators increased to more than 27 million bushels, or nearly a third of present elevator working storage capacity. In essence, this congestion would tie up a large amount of inland transportation capacity. For example, the queued grain would approximate 45 unit trains of 100 hopper cars each if it all arrived by rail.

On the shipping side, the model indicates that there would be a total of 1,626 ships detained at anchorage during the year. This may appear to be large, but note that the average waiting time for all vessels was only 93 hours. The costs of ship delays in port in such a situation are significant, however.

Event 3

The third event also assumes an increase of 50 percent in grain and ship arrivals. However, the receiving and delivery hours have been increased to 16 hours for all of the elevators. This adjustment in operating hours is reflected in the output for event 3. When compared to event 2, the average amount of grain queued at the elevators decreased by nearly two-fifths. This was attributed to the fact that approximately 20 million more bushels of grain moved through the elevators. The total number of ships detained at anchorage decreased by over 50 percent because more ships were loaded. Also, the average wait-time for all ships decreased to 53 hours.

## Summary and Conclusions

Grain and soybean exports have become an important factor in U.S. foreign trade. Gulf ports account for nearly two-thirds of these exports. The U.S. transportation and grain handling system has at times not been able to easily handle surges in exports as evidenced by past railcar and ocean carrier shortages and port congestion. There is some evidence that flexibility is diminishing rather than expanding.

Results of analyses indicate that there is adequate capacity for increased exports of grain and soybeans through Gulf ports. Congestion does occur, and as would be expected, increases with increases in grain flows. Nevertheless, congestion diminishes substantially with increases in elevator operating hours. Thus, there is a tradeoff between new investment, added operating costs, and congestion costs. The exact effects of increased costs due to extra shifts were not determined and thus not considered in the analysis.

The BCS model and the computer programs developed to implement it are not restricted to analysis of U.S. Gulf ports. The model inputs and structure are comprehensive enough to permit the specification of virtually any similar system of port operations which may include additional ports, port loading facilities, vessels, and commodities. In addition, the present Gulf model can be easily modified to reflect the two new elevators planned for completion this year at Houston and New Orleans.

## References

(1) Reinsel, Edward I.
"Ocean Shipping Highlights in Grain Trade." U.S. Dept. of Agriculture, Foreign Agricultural Trade of the U.S., Wash., D.C., Jan. 1976.

(2) U.S. Department of Agriculture, Agricultural Marketing Service Grain Market News, Wash., D.C., various issues.

(3) _____, Economic Research Service
Agricultural Outlook, No. 9, Transportation Data, Wash., D.C., April 1976.

(4) _____
U.S. Foreign Agricultural Trade Statistics Report, Fiscal Year 1975, Wash., D.C., Dec. 1975.

(5) U.S. Department of Commerce, Maritime Administration
The Maritime Bulk Commodities Simulation Model, three volumes, prepared for the Office of Commercial Development by Ernst and Ernst, Wash., D.C., March 1975.