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Abstract

The Export Grain Marketing System:
The Port Elevator Linkage

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This study measures, with use of a simulation model, expected increases in congestion cost as additional export grain moves through a representative Gulf port elevator and the associated intermodal transfer system and examines the feasibility of congestion-reducing investment in the port elevator. Analyses indicates congestion cost increase substantially as port elevator volume exceeds 125 million bushels. Further analysis indicates congestion-reducing investment by the port elevator to be economically feasible, i.e. through modification of existing plant the efficiency of the port elevator can be maintained as export volume increases.

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The Export Grain Marketing System:
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Recent estimates indicate the volume of export wheat, soybeans, and feed grains will increase from 131.0 million metric tons in 1980-81 to 170.7 million metric tons by the mid-1980's (O'Brien, 1981). Accompanying these projections are warnings that existing transportation and handling systems will experience considerable congestion as export volumes increased (Gallimore, 1981).

Perhaps the most critical link in the export grain marketing system is the port elevator. Grain is transported to the port elevator from inland production regions through the domestic transportation network. The flows connect with the international maritime system via the port elevator. As the link between these two essential systems of transport, the port elevator must orchestrate each system to achieve maximum efficiency. If the port elevator is unable to synchronzie the domestic transportation modes with the international maritime system, traffic congestion and transportation mode waiting costs increase. This can unfavorably effect marketing systems costs and producer returns (U.S. General Accounting Office).

The purpose of this paper is: (1) to analyze and measure congestion cost associated with increased export volumes and (2) determine the economic viability of changes in port elevator capacity. A model designed to simulate the intermodal transfer process at a U.S. Gulf port elevator is described.

The model is used to determine the cost of congestion associated with alternative export volumes and to evaluate changes to elevator capacity designed to improve the efficiency of the system. The model is representative of elevators operating at the North Texas port area (Houston, Galveston, Beaumont). The elevator receives rail-delivered grain from the Southern U.S. Plains (Kansas, Oklahoma, Texas) and the Midwest (Iowa, Illinois, Nebraska) (Fuller and Paggi, 1978). The North Texas port area is the leading export-wheat location in the U.S., lesser quantities of export-destined corn, sorghum, and soybeans flow through the port.

The basic economic problem in determining the viability of increased elevator capacity centers on balancing the costs of additional capacity against the delay-time costs to carriers moving through the system. Providing too much service capacity would involve excessive investment and costs. Whereas, providing inadequate service capacity would give rise to excessive waiting time for carriers. The goal is to achieve an economic balance between cost of additional port elevator capacity and the carrier costs associated with waiting for service (Hay, and Meyer and Staszheim).

The Port Intermodal Transfer System

For the Gulf port area, the export grain intermodal transfer process commences when a ship destined to receive grain from the port elevator enters the Gulf of Mexico (Figure I). When the ship enters these waters, it contacts the port elevator responsible for its loading. The ship proceeds to the port area, and upon arrival is inspected for cleanliness and seaworthiness. If the ship fails either inspection, the shortcoming must be corrected and the inspection repeated; the ship is not allowed to move to the port elevator for loading until both inspections have been passed.

Upon passing the inspection process, a ship either advances to the port elevator for loading or enters a queue. Ships are generally handled on a first-in, first-out basis. Therefore, ships are required to wait if a preceding ship is being loaded or is queued to be loaded. An exception to this service rule occurs when the port elevator has insufficient quantity of the demanded commodity in storage. In this situation, the ship is bypassed while a ship desiring a commodity which is in ample supply may advance for loading (Paggi).

Given notification of a ship's pending arrival, the elevator management determines the quantity of grain to be ordered and transported from inland locations in order to fulfill the demands of the incoming vessels. Upon notification, the inland shippers commence to order, load, and release loaded rail cars for the journey to the port elevator.

After the rail cars arrive at the port complex, they move through a series of railroad storage and classification yards prior to delivery to the port elevator. Rail cars are directed through the rail complex, based on the rail line that was responsible for delivery. Each railroad's deliveries are subjected to numerous switching activities as they transit through the network.

Rail cars queue in sequence upon entering the various port area rail yards and are generally handled on a first-in, first-out basis. An exception to this service rule occurs when the elevator has insufficient storage to accommodate the

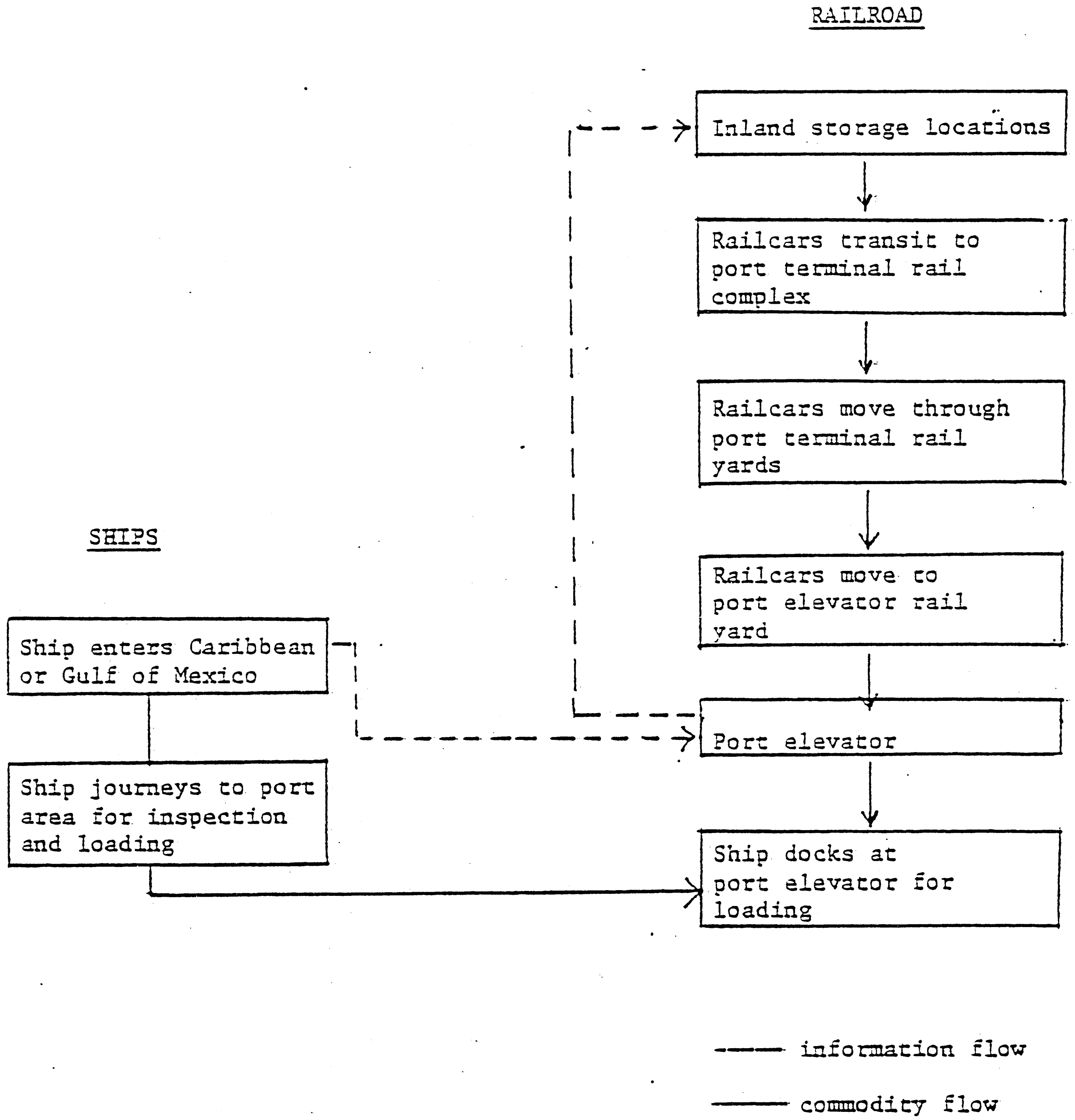


Figure 1. Components of Export Grain Intermodal Transfer Process

grain type contained in the next rail car; in this case, the car will be bypassed until sufficient storage becomes available, while cars containing the desired commodity will advance. Upon release to the elevator, the rail cars wait in the elevator's rail yard for unloading. After unloading, the empty rail cars are released to the railroad for the return trip to inland locations.

The intermodal transfer process includes stochastic features. The arrival of a ship into the transportation network is a stochastic variable in that uncertainty exists as to when the next ship will arrive in the system. The ship's transit time to the port area and the necessary time to pass both inspections are random variables as is the cargo size of the inbound vessels. In addition, the transit time on rail car movements from inland locations to the port elevator, the rate at which rail cars are unloaded, and the rate at which ships are loaded are variable.

The export-grain intermodal transfer system described above and illustrated in Figure 1, may be represented as a stochastic transportation queueing network. A queueing network consists of a series of servers which are the port elevator's rail car unloader, storage, and ship loaders. The servers are connected by a network of transportation corridors over which the vehicles move and at various junctures demand loading or unloading service. Upon completion of the service activity (loading a ship or unloading a rail car) the vehicles exit the network. At various points in the network, a limited number of servers (rail car unloaders and ship loaders) and a limited area for vehicles to wait for service exist (rail yards, ship berths). The following section briefly relates the modeling of the intermodal transfer system as a stochastic transportation queueing network.

The Intermodal Transfer Model and Procedure

A mathematical model of the intermodal transfer system and its stochastic queueing network features is not directly amenable to solution. For this reason, simulation appeared as the most practical analytical approach. By using the computerized simulation model of this system, experiments were conducted for purposes of better understanding and evaluating various system operations.

The developed simulation model describes the overall behavior of the export grain intermodal transfer system in terms of individual events of system components. The model is comprised of five smaller models. These include the ship, railroad, delivery train, port elevator, and time models. The ship model represents a ship from the point at which it notifies the port elevator of its estimated time of arrival until final departure after loading. The railroad model includes a submodel, the delivery train model, which controls movement of railcars through the port's rail terminal yards. The time model controls opening and closing of railcar unloaders and ship loading activity.

To determine the effect of increased export grain flow on congestion, volume handled by the intermodal grain transfer system is adjusted upward and generated statistics recorded. Generated waiting-time statistics in combination with rail and ship demurrage schedules are used to estimate congestion costs. To determine feasibility of congestion-reducing investment at increased volumes, the simulation model is modified to reflect increases in rail unloading, storage, and ship loading capacity. Results of these simulations are compared with simulations that include no facility modification in order to determine economic feasibility of the congestion-reducing investments.

In particular, to determine the desirability of congestion-reducing investment, the existing port elevator's expected congestion cost $E(CC_E)$ was compared with the modified port elevator's expected congestion cost $E(CC_M)$ and additional plant cost $E(PC_M)$ associated with the new investment. At any particular volume level, new investment is desirable if,

$$E(CC_M) + E(PC_M) < E(CC_E)$$

A pooled t-test was used to determine the statistical significance of differences between the two estimates.

Data

Data needs included probability distributions of mode transit times, cargo sizes and port elevator loading and unloading times as well as demurrage schedules and cost of port elevator modifications. Data to estimate the probability distributions were obtained from North Texas Gulf port elevator records and from observation of facility operations. The specific distributions were estimated using a goodness-of-fit algorithm (Phillips). The algorithm compares the observed data against ten alternative functional forms and determines the probability distribution which best fits the data. The values used in the simulation of a representative Gulf port elevator are presented in Table 1.

The model was constructed to represent four million bushels of storage capacity, one shiploader, and two rail car unloaders. This configuration was based on a composite of the facilities operating at North Texas ports.

Table 1. Probability Distributions Representing Simulation Model Activities[1]

Activity Represented by Probability Distributions	Type of Probability Distribution	Estimated Probability Distributions Mean	Estimated Probability Distributions Standard Deviation	Probability Distributions Minimum Value	Probability Distributions Maximum Value
Ships inter-arrival time into system	Expotential	51.46 hours	51.46 hours	1 hr.	507.75 hours
Ships estimated transit time to port elevator	Uniform	240 hours	13.87 hours	216 hours	264 hours
Ship cargo size	Normal	941,500 bu.	493,330 bu.	24,200 bu.	1,930,000 bu.
Railroad car transit times from:					
Upper midwest	Normal	228 hours	10 hours	198 hours	258 hours
South plains	Normal	144 hours	3 hours	134 hours	154 hours
Railroad car unloading rate[2]	Uniform	64,000 bu/hr.	1,734 bu/hr.	61,000 bu/hr.	67,000 bu/hr.
Ship loading rate[2]	Uniform	21,589 bu/hr.	739 bu/hr.	20,300 bu/hr.	22,860 bu/hr.

[1]Parameters are representative of existing intermodal transfer system. The representative facility includes four million bushels of storage capacity, one shiploader and two railroad car unloaders.

[2]The tabled handling rates reflect actual or effective rates.

Estimated costs of facility modifications were obtained from the engineering department of a major grain exporter and a firm involved in elevator construction. The estimated total expenditures were $5.5, $.85, and $5.0 million for an additional shiploader, a rail car unloader, and one million bushels of additional storage, respectively. The estimated annual fixed costs of these respective investments were $583,430, $99,835, and $511,299. The addition of a shiploader was estimated to increase variable cost $131.16 per hour of operation, while an additional railroad car unloader would increase variable cost $19.84 per hour.

Information on ship and railroad demurrage schedules were obtained from Gulf port elevators. If a ship has not completed loading on the fifth day after passing inspection, a demurrage cost of $8,000 per day is incurred by the loading elevator. Railroads permit the port elevator to hold a railroad car two days without incurring demurrage; on days 3 through 6, a daily charge of $20 per car is incurred, while on days 7 through 9, a daily charge of $30 per car is incurred. Railroad cars held in excess of 9 days incur a daily charge of $60 per car.

Results

To estimate the effect of increasing export volume on port area congestion, the simulation model was used to generate a series of waiting-time statistics for annual export volumes of 125, 130, 160, and 180 million bushels. The results of the analysis indicated that per bushel congestion costs rise substantially as volumes handled by the elevator increase. At volumes of 125 million bushels and 130 million bushels the per bushel congestion cost is estimated at $.022 and $.031, re-

Table 2. Summary of Feasible Congestion-Reducing Investment by Port Elevator

Annual Port Elevator Volume	Feasible Congestion-Reducing Investment[1]	Expected Congestion and additional plant cost with Investment	Expected Congestion cost without Investment	Estimated Savings of Investment[2]
(1,000,000) bu.		($/bu.)	($/bu.)	($/bu.)
130	1 shiploader	.0239	.0311	.0081
160	1 shiploader and 1 million bushels storage	.0269	.0818	.0549
180	1 shiploader and 1 million bushels storage	.0277	.1182	.0905

[1]Represent feasible additions to a port elevator which includes four million bushels of storage, one shiploader and two railroad car unloaders. All other modifications and combination of modifications were not feasible.

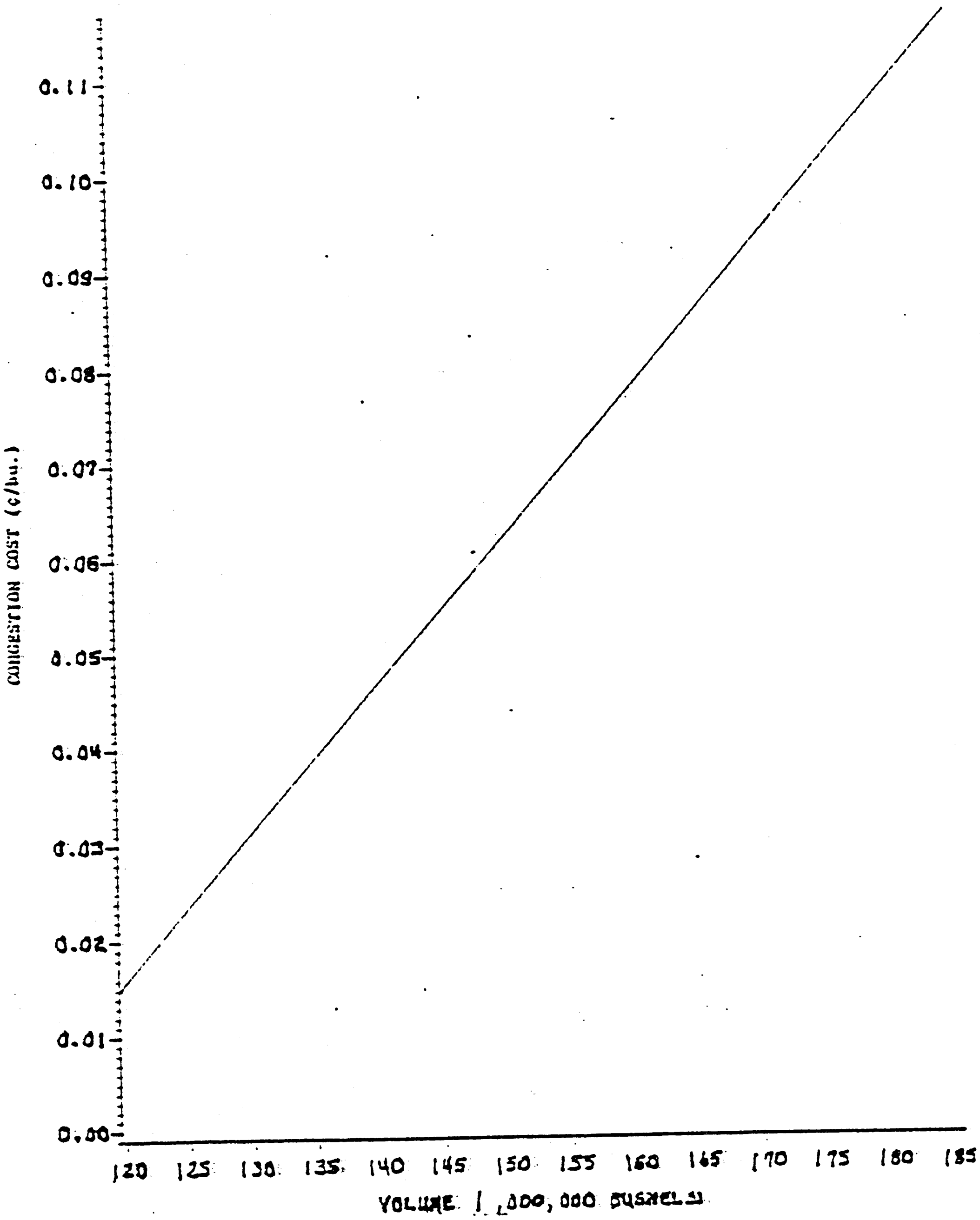
[2]The null hypothesis, that expected congestion cost without investment was greater than expected congestion and additional plant cost with investment, was rejected with $\alpha = .05$.

spectively. At volume levels of 160 million and 180 million bushels the estimated congestion cost increases to $.081 and $.118 per bushel, respectively. Approximately 45 percent of the per bushel congestion is attributable to ship demurrage and 55 percent is due to railroad car demurrage charges. A linear equation developed by regressing congestion cost against corresponding export volumes indicated this relationship (Figure 2). Congestion costs increase by $.00155 per million bushels at volumes above 125 million bushels with the existing elevator facilities.

The analysis of investments designed to reduce congestion indicate that the feasibility of such investments depend on the volume handled by the port elevator. At a volume of 125 million bushels, the costs associated with facility modification exceed the reduction in congestion costs. When the volume increases to 130 million bushels, the addition of a second shiploader becomes feasible, reducing congestion cost from $.0311 to $.0239 per bushel. If annual port elevator volumes were increase to 160 and 180 million bushels, an additional million bushels of storage in combination with the second shiploader would be desirable (Table 2). As indicated in Table 2, the facility modifications yield reductions in congestion costs of $.008, $.055, and $.091 per bushel with export volumes of 130, 160, and 180 million bushels, respectively.

Summary and Conclusions

This study measures, with use of a simulation model, expected increases in congestion cost as additional export grain moves through a representative North



$$¢/bu. = -.17066 + .00155V \qquad R^2 = .87$$
$$(-7.58) \qquad (10.72) \qquad N = 20$$

V = annual port elevator volume (1,000,000 bu.)

( ) = t statistics (significant at the α = .05 level)

Figure 2. Estimated Per Bushel Congestion Cost at Alternative Volumes by a Representative Gulf Port Elevator.

Texas Gulf port elevator and the associated intermodal transfer system. In addition, the study examines the feasibility of congestion-reducing investment in the port elevator. Because Gulf ports are responsible for about two-thirds of U.S. grain exports, most of these facilities operate at high volumes. The representative facility receives rail-delivered grain from Midwest, and South Plains regions. In this study, congestion cost includes the port elevator's rail and ship demurrage costs; no effort is made to estimate the external costs generated by additional port elevator congestion.

The analysis indicates congestion cost increase substantially as port elevator volume exceeds 125 million bushels. Per bushel congestion cost is estimated to be approximately $.02 bushel at an annual volume of 125 million bushels but to increase to about $.11 per bushel at an annual volume of 180 million bushels. Analysis indicate that congestion-reducing investment in the port elevator to be economically feasible, i.e., through modification of existing plant the efficiency of the port elevator could be maintained as export volume increases.

With the current market organization, it is difficult to know whether increased congestion costs associated with higher export volumes can be passed to other participants in the marketing system. If these added costs are not fully borne by the exporting facility, the incentive to invest in congestion-reducing investment will diminish. Producers may then bear some of the additional costs associated with the anticipated increase in exports.

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