Pricing TOFC Shuttle Trains: An Equilibrium Analysis

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The determination of the most profitable pricing scheme for a freight transportation service poses difficult analytical problems. Little is generally known about the demand elasticities of a specific transportation market. The problem is especially critical in planning a new service. In this case, there will be no past experience to provide guidance and no present demand to use as a "base case" for sensitivity analysis, yet a mistake in pricing could lead to a costly failure. This paper discusses a pilot pricing study of a high-quality trailer-on-flatcar shuttle train service between three pairs of U.S. cities. The study is an illustration of how demand and cost models may be used in an equilibrium framework to determine optimal price. The demand model simulates the decisions of individual potential users of the service. Thus, it has the potential of providing a much more reliable appraisal of the likely market response to a price-service offering than more conventional methods,including most econometric models. The equilibrium analysis technique illustrated in this report is straightforward and could be profitably applied to many types of carrier marketing planning. Production use of the technique will probably have to await the development of better industry data, production demand models, and techniques for dealing with entire networks.

A trailer-on-flatcar (TOFC) shuttle train service is used in this paper to illustrate a very familiar but difficult problem for freight transportation market planners. The problem is to determine the most profitable pricing scheme for a service. Such pricing questions are always troublesome because there is little information available on demand elasticities. The problem becomes especially difficult when, as in this case, the service is only proposed. The planner thus has little previous experience to fall back on and no present demand to use as a "base case" for some type of sensitivity analysis. Without fairly accurate demand estimates, there can be no reliable revenue or cost estimates and, therefore, no profit forecasts.

This paper will demonstrate the solution of this pricing problem for TOFC shuttle trains using an equilibrium analysis. The approach uses models to estimate the demands and costs for various price alternatives. The profit-maximizing price may then be identified. A unique characteristic of this study is the use of a demand model that simulates the decisions of individual potential users of the service. As such, it has the potential of providing a much more reliable appraisal of the likely market response to a price-service offering than more conventional methods including most econometric models.

Many railroads have started TOFC shuttle train operations of one kind or another in recent years. Under this concept, TOFC operations are consolidated into a few high-volume terminals. Trailers at these terminals are loaded directly onto trains of dedicated equipment. These trains run straight through to destination terminals without further switching. Such trains offer the potential for better service and cost savings through better equipment utilization, lower switching costs, and more economical terminal operations.

The Illinois Central Gulf has been experimenting with a concept similar to the one hypothesized in this paper. The "Slingshot" provides one-day service between Chicago and St. Louis at a Plan 2½ rate of about $125/trailer. This low freight (all kinds) rate has enabled the trains to attract a substantial volume of business. (Plan 2½ is the method whereby the railroad provides the trailer, but the shipper is responsible for pickup and delivery of the shipment at the railroad yard.) Despite the fact that the train operates under a special labor agreement permitting the use of two-worker crews, there are many in the railroad industry who question the profitability of the service.

The equilibrium analysis technique illustrated here is straightforward and could be applied to many types of freight transportation market planning. The TOFC shuttle train pricing problem was selected because it is an especially appropriate illustration of the kind of problem the technique could be used to analyze. The shuttle train concept is being studied widely by both railroads and government for implementation on routes that do not have this service. Although past experience with the concept is still rather limited, a mispriced service can result in a costly failure.

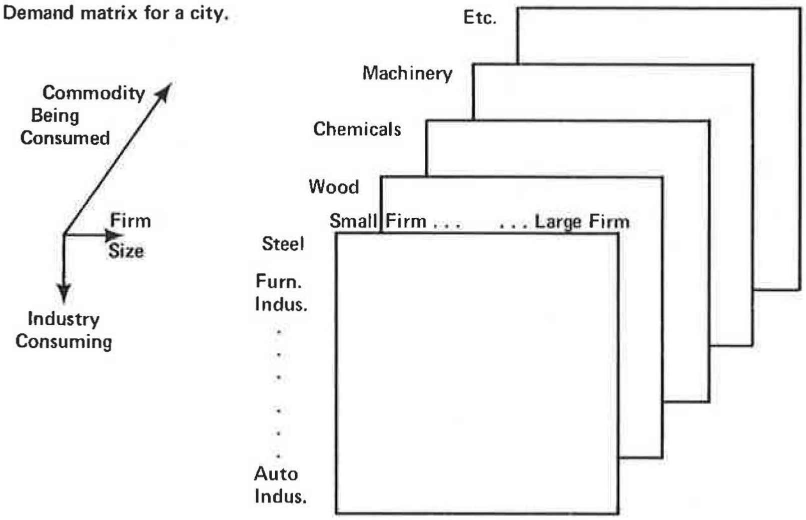
THE DEMAND MODEL

The demand model used in this study was developed at Massachusetts Institute of Technology (MIT) as part of a project to analyze the impact of various government policy options on transportation energy consumption (1). The demand for freight transportation between two cities will be the sum of the demands of many individual firms. The demand model therefore simulates the transportation decisions of a sample of firms, then explodes the sample to obtain an estimate of freight flow by mode.

Given an origin city, a commodity, and a receiving firm, the profit-maximizing transportation decision for the receiving firm may be simulated by a "logistics analyzer." This program searches for the mode and shipment size that minimize the total unit cost to the receiving firm involved in procuring the commodity. This logistics cost includes transportation charges, storage cost, capital carrying cost, spoilage cost, ordering cost, and the expected cost of any stockouts or insufficiently compensated loss and damage expense. Each of these elements of cost may be estimated as a function of the attributes of the commodity (e.g., value, density, shelf life, and storage requirements), the receiving firm (e.g., quantity of commodity used per unit time), and the mode of shipment (e.g., rate, travel time distribution, and expected loss and damage cost). The attributes of the mode are the parameters to be varied when using the model for marketing analysis. Note the assumption of transportation decision making by the receiving firm. Even when the shipping firm actually makes the transportation decision, it acts in the interest of its customer, the receiving firm. Hence, the resulting decision should be the same.

The logistics analyzer may be applied to a representative sample of receiving firms and commodities to obtain mode shares. The probability of sampling a particular firm and commodity should be proportional

Figure 1. Demand matrix for a city.



to the amount of the commodity received by the firm. It was therefore necessary to construct a demand matrix (Figure 1) showing the quantity of each input used by each firm-size class within each industry in the market area. This was accomplished by first estimating the output of each firm-size class within each industry in the market area using industry output data from the Census of Manufacturers and industry employment by firm-size class data from County Business Patterns. These outputs were then multiplied by the technical coefficients for each industry and input commodity combination from a Leontief input/output table to obtain dollar-value commodity inputs by industry and firm-size class. These technical coefficients show the dollar value of each input needed to produce a dollar of industry output. Additionally, estimates of personal consumption expenditures by commodity in the receiving area were developed; these were included in the inputs required by the retail industries. This dollar-value demand matrix was then converted to a tonnage demand matrix using data on commodity value per pound from a commodity attribute file (2).

Cells of this demand matrix are then sampled in proportion to their magnitude. The total weight of each selected commodity required by a firm-size class within an industry is divided by the number of firms in that firm-size class and industry to obtain an expected use rate for one of the firms. This information is then input to the logistics analyzer, which will search for the optimal mode and shipment-size choice. When a sufficient number of cells have been sampled, mode shares by commodity group are calculated. These mode shares are then multiplied by the flow of the commodity group between the origin and destination, as reported in the Census of Transportation Commodity Transportation Survey, to obtain an estimated tonnage by mode. It is important to understand that no modal flow data from the Census of Transportation are used, only total flows by all modes.

It is desirable to use as much commodity detail as possible. The demand matrix and the associated sampling procedure operate at the level of the five-digit Standard Transportation Commodity Code (STCC). The results are aggregated into 17 commodity-group mode shares (generally corresponding to two-digit STCCs), which are then multiplied by the total flows of these commodity groups reported in the Census of Transportation.

The Philadelphia-Cleveland, Chicago-Houston, and San Francisco-Los Angeles pairs analyzed in the MIT energy policy study are used as the setting for this study. An "area," as used here, refers to the Census of Transportation "production area" or "market area," which includes all the Standard Metropolitan Statistical Areas (SMSAs) in the origin or destination metropolis. The rates, travel time distributions, and loss-and-damage estimates of the rail carload, full truckload, less than truckload (LTL), and barge modes are taken directly from the MIT study. These were explored in some detail in that study based on data from waybill samples, contacts with carrier officials, and Interstate Commerce Commission reports.

THE COST MODEL

The TOFC shuttle train service evaluated is envisioned as differing from most conventional TOFC services in that it uses dedicated equipment operating in run-through trains without intermediate loading stops or switching and uses efficient, high-volume trailer loading facilities. The service is assumed to use existing roadbeds maintained well enough to allow for a reliable average origin-to-destination speed of 64 km/h (40 mph). The net result from the viewpoint of consumers should be highly reliable service at timings competitive with those of highway service. In other respects, the service is not drastically different from conventional TOFC service. Use of conventional TOFC equipment is assumed, as well as operation under present work rules, although the alternative of two-person operation will be considered. A flat Plan 2½ rate is assumed, with the rate perceived by the customer including an additional charge for pickup and delivery. The trains would offer overnight service between Philadelphia and Cleveland and between San Francisco and Los Angeles; second-morning delivery would be available between Chicago and Houston.

The cost model used in this study associates unit costs with various elements of TOFC shuttle train operation. For example, a fixed cost of crew wages and benefits per crew day was assumed, as was a fixed locomotive maintenance cost per kilometer, a fixed trailer ownership cost per year, and so on. Fairly accurate estimates of the cost of virtually any type of TOFC shuttle train service could be constructed using these "building blocks". The cost model is basically an adaptation of the cost model presented in a Reebie Associates study (3). Various unit costs and other

aspects of the model were adjusted after comparison with one railroad's proprietary data and consultation with several industry experts.

Costing of new railroad services has always been a difficult undertaking due to joint costs and the invariability of many of these joint costs with respect to volume. It may be profitable for a railroad to operate some services that do not cover their "share" of the invariable portion of the joint costs, although all new services should cover any additional costs associated with them. Unfortunately, it is not clear in some areas, such as track maintenance, to what extent costs vary with the traffic handled. Two cost estimates are therefore developed for each service—a "minimum" cost, which includes only costs directly associated with the purchase and operation of the trains and loading facilities, and a "maximum" cost, which includes a share of track maintenance and administrative overhead. This system leaves analysts free to develop their own judgments as to the true cost of the service, although it is undoubtedly closer to the maximum than to the minimum.

A fixed train length is assumed, with the train operating on the average at 60 percent of capacity. This low average ratio of trailers loaded on the train to total places available for trailers was felt to be necessary to ensure service reliability. This low average load factor would ensure that a trailer very seldom would have to be held until the next day because a train was full.

Costs are estimated using both conventional four-person crews and two-person crews such as those used on the "Slingshot." The cost of owning and operating a caboose on each train is included in the four-person crew cost estimates.

Trailers and locomotives are assumed to be purchased under equipment trusts, amortized at 10 percent over 7 years and 12 years, respectively. Trailers are assumed to have a five-day cycle time for the Philadelphia-Cleveland and San Francisco-Los Angeles runs and six days for the Chicago-Houston run. This allows one day for the trip (two days for Chicago-Houston), one day for customer loading, one day for customer unloading, and two days of slack time. This use is considerably better than that achieved by most existing TOFC services; however, it is not as good as that achieved by many truck lines. In order to allow sufficient power to maintain a moderately high average speed, a 1.6-kW/t (2-hp/trailing ton) ratio is assumed in calculating locomotive requirements. Many railroads have a policy of operating more locomotives than actually necessary to pull the train as insurance against frequent breakdowns. As will be shown, the feasibility of a TOFC shuttle train service may hinge on the ability to operate short trains reliably with a single locomotive. Rail cars are assumed to be leased from Trailer Train Corporation at standard rates.

EQUILIBRIUM RESULTS

The basic method used for the equilibrium analysis is fairly straightforward. For each different rate, the tonnage demand for the TOFC shuttle train service in each direction for each city pair is calculated. These tonnage demands are converted to trailer-per-day demands using a 14.5-t/trailer (16-ton/trailer) average payload. Because trailers are assumed to travel both directions by TOFC shuttle train, the maximum demand of the two directions determines the length of the train that must be operated. Given the train configuration, costs can then be calculated for each of the rates. At the same time, revenues for each assumed rate are calculated from the demand estimates. Revenues and costs can then be plotted against rate on the same axis. Profit or loss at each rate level may then be determined by inspection.

It should be noted at the outset that for each of the three city pairs considered, the TOFC shuttle train service is unprofitable on the basis of maximum cost at all rate levels when using a crew of four workers. The short trains used in a TOFC shuttle train service make the crew cost per trailer high. Thus, the difference between a crew of two and a crew of four becomes extremely important. Only the results obtained by using a crew of two will therefore be discussed in the following sections.

Philadelphia-Cleveland City Pair

The service provided by both truck and carload rail modes between Philadelphia and Cleveland is believed to be of only fair quality. Full truckload traffic may be subject to delays waiting for drivers. Rail traffic must be classified at the Pittsburgh yards. A TOFC shuttle train was therefore hypothesized to offer a decided reliability advantage over both truck and rail and a travel time advantage over rail. The lowest rate considered for the TOFC shuttle train is $235/trailer, a rate comparable to present rates on the "Slingshot." This rate undercuts most truckload rates and many carload rail rates.

Figure 2 compares TOFC shuttle train costs and revenues. The solid line indicates total annual revenues at the various rate levels; the upper dotted line represents "maximum" cost of serving this demand, and the lower dotted line represents the "minimum" cost of serving this demand. An interesting feature of this figure is that the revenue line drops slowly, indicating an elasticity of demand slightly less than one. Revenues hold up reasonably well even at high rate levels, due to the willingness of consumers to pay a premium for the higher level of service provided by the TOFC shuttle train.

Although the service appears to do fairly well on a minimum cost basis, the comparison of revenues with maximum costs is not nearly so favorable. The service is profitable only at high rates. A $480/trailer rate would seem to be most appropriate, resulting in a profit of about $260 000/year.

Los Angeles-San Francisco City Pair

Although the rail distance between Los Angeles and San Francisco is roughly the same as between Philadelphia and Cleveland, the nature of the market for transportation between the two areas differs dramatically. The California cities are well served by both truck and rail; both modes offer direct service between the two areas. Truck has an advantage over rail in that the highway route between the two cities is almost 160 km (100 miles) shorter than the rail route. Truck rates also tend to be lower due to the highly competitive, loosely regulated trucking industry serving this intrastate route. Both of these factors tend to make the market for a TOFC shuttle train service less promising than between Philadelphia and Cleveland. On the other hand, the total freight transportation market is much greater between Los Angeles and San Francisco than between Philadelphia and Cleveland—roughly four times greater according to the Census of Transportation.

A comparison of the TOFC shuttle train revenues and costs at various rate levels is presented in Figure 3. The high elasticity of demand with respect to price is reflected in the sharply dropping revenues curve. As with the Philadelphia-Cleveland city pair, the service does reasonably well on a "minimum" cost

Figure 2. Comparison of annual revenues versus costs for a TOFC shuttle train service between Philadelphia and Cleveland.

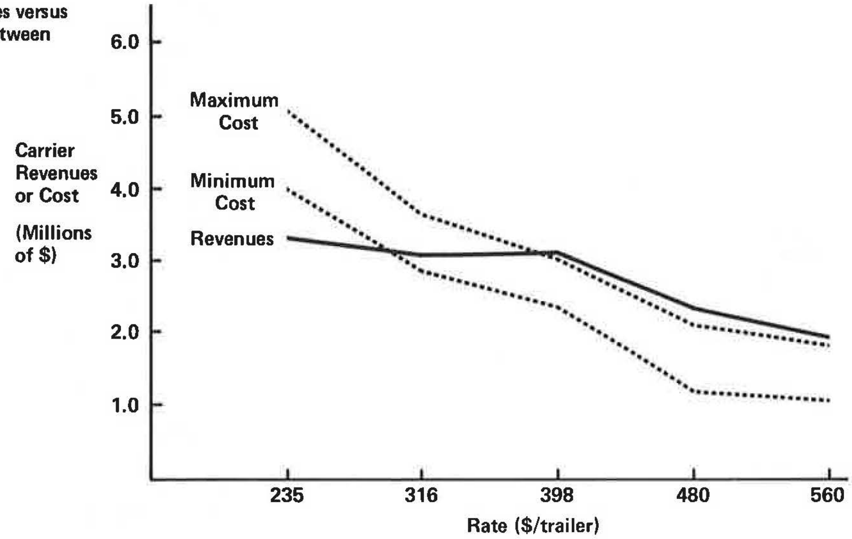


Figure 3. Comparison of annual revenues versus costs for a TOFC shuttle train service between Los Angeles and San Francisco.

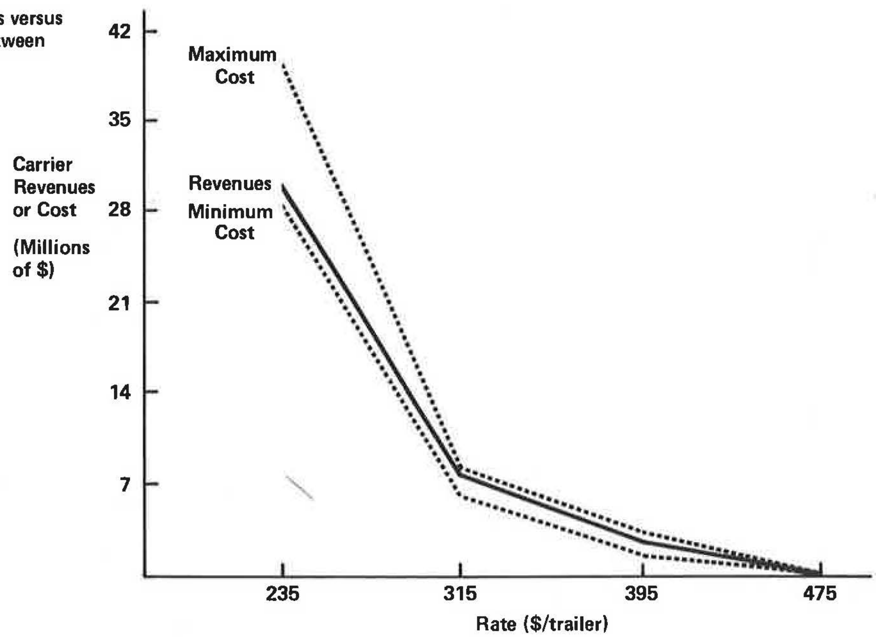
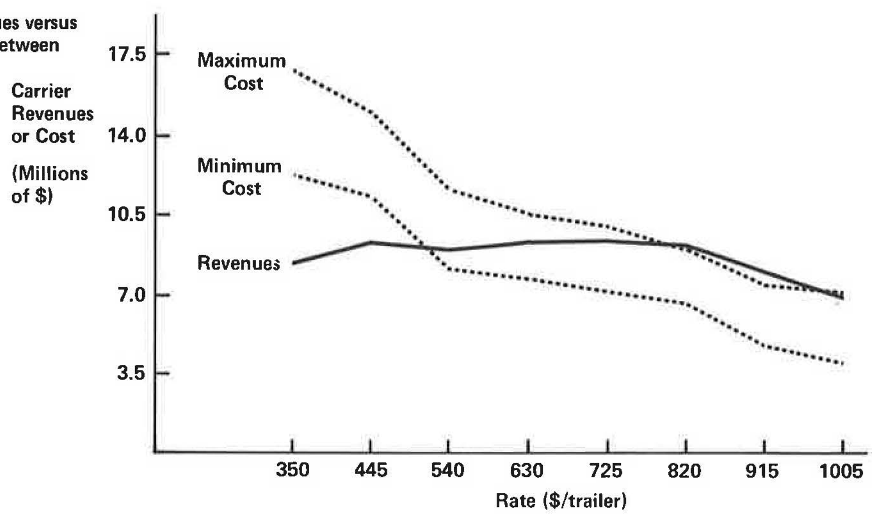


Figure 4. Comparison of annual revenues versus costs for a TOFC shuttle train service between Chicago and Houston.



basis. On a "maximum" cost basis, however, the service is unprofitable at all rate levels.

Chicago-Houston City Pair

The long distance between Chicago and Houston distinguishes this city pair from the other two. Although both rail and truck service tends to be fairly good, a reliable TOFC shuttle train service is believed to offer some improvement in service over both. Despite its long distance, the traffic between this pair of cities is fairly heavy—roughly the same as between Philadelphia and Cleveland. One might speculate that the economies of rail line-haul operation would make a TOFC shuttle train a profitable undertaking between this pair of cities.

Figure 4 presents the comparison of revenues and costs at various rate levels for the Chicago-Houston TOFC shuttle train service. The almost horizontal revenue curve indicates an elasticity of demand near one, although revenues do drop off at higher rates. Like the previous two city pairs, the service does well on a "minimum" cost basis. Profitability is achieved on a "maximum" cost basis only at fairly high rate levels. At a rate of $915/trailer, the service yields a profit of $430 000/year.

Comment

Perhaps the most striking thing about these results is the differences in estimated demands between city pairs and the different responses of these demands to variations in rates. Clearly, the nature of freight transportation markets varies greatly. It is important to have demand forecasting methodologies for production use that take into consideration the characteristics of individual freight transportation markets.

CONCLUSIONS

This study has illustrated the application of equilibrium analysis to a TOFC shuttle train. This same type of analysis could be applied to the pricing of most any freight transportation service, or to other characteristics of the service as well. In fact, the authors have used essentially the same models presented here to compare shuttle trains using several alternative types of container-on-flatcar technology (4).

The results suggested here are somewhat counter-intuitive but reasonable considering the service that was assumed. The results suggest that profitability for this TOFC shuttle train will be achieved, if profitability is possible at all, by operating a low-volume, high-rate service. At profitable rates, the Philadelphia-Cleveland and Chicago-Houston services would carry only 13 and 21 trailers a day, respectively. This differs from the more conventional concept of a TOFC shuttle train service, such as the "Slingshot," which emphasizes low rates and high volume. It would be interesting to repeat this analysis assuming a lower cost, but slower, less reliable service. It is possible that such a service might prove more profitable than the premium service hypothesized here.

These models have allowed us to understand the consequences of the multitude of individual firm decisions that will determine the market for a service. As such, they represent a considerable advance over other methods, such as aggregate econometric models, which require gross assumptions about the relationship of transportation demand to the economy of a region. Better industry data, production-type demand models, and the development of techniques to deal with the entire transportation network are imperative before large-scale implementation can begin.

ACKNOWLEDGMENT

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Economics of Improved TOFC/COFC Systems

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The success of future rail intermodal traffic hinges on satisfying demand, meeting new market needs, and realizing railroad profit objectives. To look at these opportunities, the Federal Railroad Administration has sponsored several major ongoing intermodal studies to