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Development of Hybrid Cost Functions From Engineering and Statistical Techniques: The Case of Rail-Phase II Final Report

University Research Program

Executive Summary

Final Report
Under Contract
DOT-OS-70061

DOT/OST/P-30/85/008
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16. Abstract

Cost analysis is important in every transportation industry, to the firms or agencies which provide service, to regulatory bodies, and to public policy makers. In the past, railroad cost analyses have been of two types: 1) statistical analyses of aggregate cross-section data from a variety of firms, or 2) very detailed operations-oriented studies. The premise of the work reported here is that a "hybrid" approach, using both economic theory and statistical methods on the one hand, and engineering analysis of operations on the other, can produce superior results.

This report covers Phase II of the project, which focused on analysis of a major class I railroad. A short-run variable cost function was estimated econometrically, and used as a basis for deriving the associated long-run function. We also developed a simple, but relatively accurate, network model to estimate operating costs. This model may be used to estimate origin-destination specific marginal operating costs. Econometric analysis of the output from the model leads to a theoretically justifiable equation for predicting marginal operating costs, and their sensitivity to changes in flows and input prices.

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scale economies

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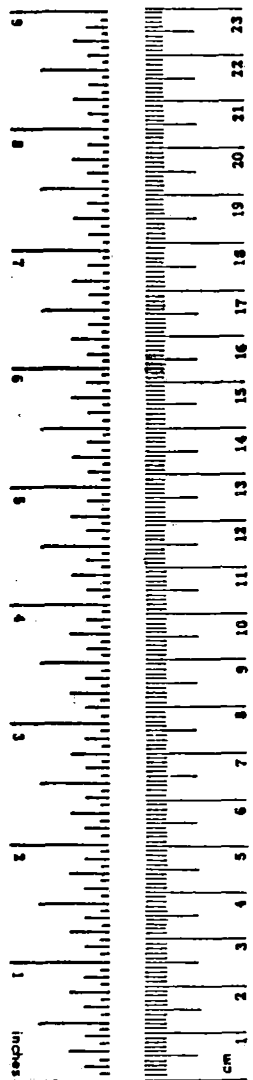
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

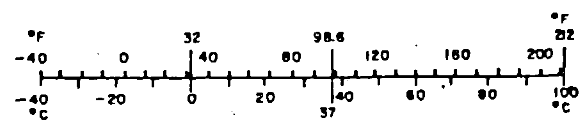
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



DEVELOPMENT OF HYBRID COST FUNCTIONS FROM ENGINEERING AND STATISTICAL TECHNIQUES: THE CASE OF RAIL

Final Report to the
U.S. Department of Transportation
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October, 1984

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Principal Investigator: Andrew F. Daughety
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Cornell University
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EXECUTIVE SUMMARY

Introduction

An understanding of the nature of costs of production is important in every regulated industry, both for individual firms and their regulators. At the most basic level a firm will require cost data for corporate planning. For example, a firm may wish to know what size plant to build, whether to upgrade the quality of plant or whether, at an existing tariff, the revenues for a service cover the incremental cost of providing the service.

Regulators and other policy makers also have many reasons to seek improved information about costs. When examined correctly, cost data can be used to determine whether there are in fact economies of scale in production, and whether regulation is a necessary tool of social control in a given industry. Regulators often ask whether a service is being subsidized by other service of a multiproduct firm, is subsidizing other services, and whether the provision of service by one mode will eliminate another mode over a given route.

Problem Studied

Previous railroad cost studies typically have examined a cross section of Class I railroads, using ICC data, and most have assumed a single product, usually total ton-miles. Several aspects of these studies have served to limit the inferences that can be drawn. They rely on data from the ICC accounts rather than on raw data from the firm. With few exceptions, they have specified a relatively simple functional form for costs, and assert that the form is appropriate without a test of that assertion. Few adjust for quality of service, and more importantly, many do not account for the multiproduct nature of virtually every rail firm. Finally, they do not attempt to adjust for the fact that some railroads operate with a more complicated network than others.

Our own research on railroad transport costs represents a very different approach to the problem. In an earlier report (Daughety and Turnquist, 1979) we developed a notion of "hybrid" analysis that reflected some crucial differences from the previous work.

1) Our analysis focused at the level of an individual firm, and used cost and production data obtained directly from the firm rather than from the ICC. This has a number of important advantages, including the avoidance of arbitrary cost allocations of the sort often found in the ICC accounts. We employed a time series analysis for a single firm rather than a cross-sectional analysis for a particular year.

2) The multi-product nature of the firm was incorporated into the analysis. Models were estimated with disaggregated volume (by commodity type) as well as with aggregate data. Output was characterized both by the volume of freight hauled and by the average speed of a shipment through the system. We explicitly recognized that speed of service is an important determinant of rail costs, and included this in our estimates.

3) We used information about the underlying technological production process, developed through engineering process functions, to improve both the specification of technology and the efficiency of our estimates.

In several respects the last point was particularly novel. Historically, most econometric estimates of cost functions have ignored valuable information on service-related variables which may be generated by engineering process functions. We have labeled our method a "hybrid" approach because it included such information.

This report builds on the first phase of the project in a number of important ways.

1) We have again focused our attention at the level of individual firm. This time, we have worked with data from a major class I railroad with a complex network; the Phase I effort purposely examined a small railroad with a simple network. Thus, we have developed techniques that address a wide range of existing firms. An important byproduct is that we can use the two case studies to examine the cross-section analyses discussed above.

2) Again we address the multi-product nature of the firm by including a quality variable (average speed of service) in the econometric model of the firm's costs. The econometric results include estimated short-run and long-run functions, thus allowing a direct comparison with results from the cross-section analyses discussed above.

3) We have expanded significantly the project's analysis of railroad operations. In our Phase I report engineering process functions were used to improve the econometric analysis. In this report we show how economic theory can be used to extend the operations/engineering analysis. Taken together, the two reports clearly show the advantages and potential of joint economic/engineering analysis of firm activities.

Results Achieved in Phase II

A short-run variable cost function was estimated using monthly data on 1) operating costs; 2) carloads moved; 3) average speed of service; 4) the prices of fuel, equipment, and labor; 5) a measure of track capital called "effective track." The long-run cost function was derived from the short-run function. Analysis of the estimation results indicated the following:

1) The firm faces significant economies of density; i.e. given the fixed configuration, at fixed speed-of-service increases in aggregate carloads moved will result in reductions in average costs per carload. Coupled with the Phase I results, this indicates that both large and small railroads can have significant density economies.

2) The major short-run factors of production (fuel, labor and equipment) are inelastic substitutes for one-another. Thus, each factor is a substitute for the others, but only to a small degree.

Comparison with the cross-section cost models indicates two sources of error in this literature:

1) Often such models do not control for systematic differences among firms, leading to biases in estimated coefficients. Moreover, cross-section analyses that do not control for firm differences cannot separate economies due to changes in firm size and configuration from economies due to more intensive configuration use (i.e. economies of density).

2) In general, cross-section studies have not used properly constructed quality-of-service measures. We find that eliminating the speed-of-service quality variable is not only a specification error in the model; such elimination tends to bias downward the estimate of returns-to-scale.

We also developed a simple, but accurate, model of rail operations that estimates system operating costs to within 15% of actual values. The model provides a rail firm with a convenient tool for operations cost analysis because it is easy to set up and inexpensive to solve. Moreover, we showed how to use the model to generate an origin-destination specific marginal operating cost prediction equation. This was another example of our hybrid analysis. Economic theory was used to formulate the estimation problem, and engineering analysis was used to provide the details on specific origin-destination movements. Together, the two methods produced a valid marginal cost function.

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