Abridgment

Methodologies for Transportation Cost Analysis: A Survey

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The purpose of this paper is to present various methodologies that have been used for analyzing transportation costs as well as to discuss their merits and shortcomings with respect to the following purposes of transportation cost analysis: (a) to investigate such broad issues as economies of scale and production properties of transport firms and (b) to determine specific (or fully allocated) costs for particular transportation movements. The methodologies have generally been of three types—engineering, accounting, and economic. The principal conclusions of the paper are that (a) economic cost functions or economic cost functions in conjunction with engineering models are the desirable methodologies for investigating economies of scale and production properties of transportation firms and (b) accounting costing is a desirable methodology for determining fully allocated costs of transportation movements.

Analyzing transportation costs is often difficult because (a) the output of a transportation firm is multidimensional by its very nature and (b) transportation activities are characterized by common costs. The transportation firm provides different types of services for different users not only at different origins and destinations but also at different levels of quality. Even though the above difficulties exist, transportation costs have been analyzed for basically two purposes: (a) to investigate such broad issues as economies of scale and production properties of transportation firms (for example, separability, homogeneity, and nonjoint production) and (b) to determine specific costs (or fully allocated costs) for particular shipments and trips (in order to determine the maximum reasonableness of rates, profits, or deficits from particular movements and to investigate the existence of cross-subsidization, etc.).

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ENGINEERING COSTING

In order to analyze transportation costs by using an engineering approach, one must first specify the relevant engineering (or physical) relationships among inputs, outputs, and quality-of-service characteristics (or combinations of the above). The functions for such relationships may be derived from physical laws or estimated from sample observations. For example, Hennes and Ekse (1, Chapter 25) present such a relationship for resistance to train movement (in pounds per ton of train weight) as a function of average weight per axle in tons, speed in miles per hour, number of axles per item of equipment, etc. Examples in which engineering relationships are estimated are given by DeSalvo and Lave (2) and by Daughety and Turnquist (3).

Engineering models of the operations aspect of a firm provide information but an incomplete picture of the firm. Such models consider physical processes at the firm but not such nonoperations activities as planning and sales. On the other hand, such activities are captured to some degree by the economic models. Daughety and Turnquist (3) suggest that engineering-process models be used as constraints on cost models in order to define implicitly the technology to which the cost model is dual and thus to derive a better-specified cost model. Specifically, Daughety and Turnquist (3) use engineering-process models to estimate train speeds, which are in turn used in rail cost functions to estimate various rail cost. Further discussion of relationships between engineering and economic activities may be found in a paper by Marsden, Pingry, and Whinston (4).

One possible shortcoming in attempting to use an engineering model to develop a transportation cost function is that market prices may not exist for one or more of the physical inputs; i.e., the inputs in an engineering production function are not necessarily market inputs. Alternatively, inputs in an economic production function are market inputs for which market prices are expected to exist, as discussed by Chenery (5). Hence, if market prices do not exist for engineering inputs, difficulties arise in assigning costs to these inputs and thus in determining the costs of providing given transportation movements. In an engineering cost analysis of motor carriers by Schuster (6,7), prices for the inputs were presumably available. Furthermore, such engineering models would be precluded from investigating pecuniary economies of scale but not technological economies of scale. Pecuniary economies of scale are associated with the ability of a large firm to affect the prices for which it purchases inputs.

ACCOUNTING COSTING

Accounting costing by its very nature seeks to determine the costs of given transportation services. A cost function that relates cost to output is not developed as in the sense of engineering and economic cost functions. By using cost-accounting principles, the accountant assigns to a particular transportation movement the costs that are traceable to that movement as well as a share of common costs that the movement incurs with other movements. Thus, accounting costing may and has been used to determine specific costs (or fully allocated costs) for particular transportation shipments and trips. Applications of cost accounting in transportation cost analyses are given by Dierks (8), Cherwony (9), Whitten (10), and Young (11). A new rail costing system, referred to as the Uniform Railroad Costing System, to be used by the Interstate Commerce Commission (ICC), is basically an accounting costing procedure. This new system is designed to provide the ICC with more-specific costs on particular railroad movements.

One potential shortcoming of accounting costing is that the recorded book costs of assets may not be an accurate guide to the actual opportunity costs of these assets. Since opportunity costs are the relevant ones for decisionmaking, accounting costs may need modification to reflect actual opportunities foregone. However, since accounting data are often used in engineering and economic costing, this potential shortcoming is not unique to accounting costing.

Another potential shortcoming relates to how the accountant establishes cost accounts or categories. The fundamental purpose of accounting is to systematically order and record the financial transactions of a firm. However, the accounts may be established so that there is little correspondence between cost categories and specific transportation movements. Thus, in such circumstances, the accounts will be unable to reveal accurately either the level of cost associated with a particular transportation movement or the level of costs incurred in common with other transportation movements.

In addition to the possibility that cost accounts may be established arbitrarily, the rules for determining how common costs are to be shared among particular transportation movements are generally established arbitrarily. Accounting rationale may be given for the establishment of such rules but not an economic rationale. This point is discussed by Braeutigam (12). A final shortcoming of accounting costing is that without the formal specification of a function that relates cost to output, this costing approach is not conducive to investigating such broad issues as economies of scale and production properties of transportation firms. It has also been argued that accounting costing is a deviation from the economic theory of cost, since marginal costs of transportation services cannot be obtained.

ECONOMIC COSTING

When economic costing is proposed for analyzing transportation costs, it is generally assumed that the parameters of a cost function that relates cost to output are to be estimated. In order to use economic cost functions to analyze transportation costs, one must first specify the form of such functions. In the transportation cost literature, three general functional forms have been considered:

1. Linear functions, which assume that a straight-line relationship exists between costs and output;
2. Nonlinear functions, which assume that a curved relationship exists between cost and output; and
3. Polynomial functions, which include linear terms as well as higher-order nonlinear terms.

The linear specification is restrictive in that marginal costs are assumed to be the same at all levels of output. Alternatively, the nonlinear specification allows marginal cost to vary with output. The nonlinear specification has been limited primarily to those nonlinear forms that have exponential parameters and it thus restricts cost elasticity with respect to output to be constant. This nonlinear specification and the linear specification also impose the restriction of homotheticity; i.e., regardless of the size of a transportation firm, the proportional mix of inputs will remain the same. In contrast, polynomial functional forms may be specified so that the restrictive assumptions of homotheticity and constant marginal cost are not imposed. Examples of such functional forms are given by Spady and Friedlaender (13,14).

In addition to function specification, measurement of transportation output for the cost function also has to be considered. One of the earlier attempts to identify the proper unit of measurement for transportation output was made in a paper by Wilson (15), who argued that the sales unit (or the ton mile) was the appropriate output measurement for freight transportation. Waters (16) states that a ton mile that involves opposite directions is not the same product nor is the movement of a ton mile of perishable commodities necessarily the same output as the movement of a ton mile of bulk materials. Further, the quality of service for ton miles may differ according to speed, flexibility, and other characteristics of service.

In a paper by Spady and Friedlaender (14), a particular type of polynomial cost function is presented that attempts to account for quality differences in transportation services. The functional form is a hedonic trans-log function. The function is hedonic in that cost is a function of an effective output (or hedonic function), which in turn is a function of a generic measure of physical output and its qualities. For example, Spady and Friedlaender (14) express effective output as a function of ton miles and some of their various characteristics as average shipment size, average length of haul, average load, etc. Other applications of the use of trans-log functions in analyzing transportation costs are given by Daughety and Turnquist (3); by Oum (17); by Brown, Caves, and Christensen (18); by Caves, Christensen, and Swanson (19); and by Spady and Friedlaender (13).

With transportation firms providing a wide range of outputs at different levels of quality, it is virtually impossible to introduce specific variables in the cost function for each type of output. Hence, Spady and Friedlaender (13, p. 28) conclude that aggregation of factors and outputs is necessary. However, aggregation itself presents problems in terms of not only which cost accounts to aggregate but also what functional form of aggregate functions to use. Spady and Friedlaender (13) conclude that there is really no alternative but to assume homothetic aggregation functions. Further discussion of aggregation functions may be found in papers by Samuelson and Swamy (20), by Fisher (21), and by Spady and Friedlaender (13, pp. 28-30).

If one rejects homothetic aggregation, there is not generally any aggregation function that exists that has desirable properties with respect to measurement scale, etc. Thus, in the absence of homothetic aggregation, one must use totally disaggregate data (which is generally infeasible in view of the large number of different inputs and outputs associated with transportation firms). Alternatively, if one ignores the restrictions imposed by homothetic aggregation and simply adds together ton miles or freight cars, it is likely that extreme biases will result in the estimated cost or production functions.

With aggregation being necessary in order to estimate transportation cost functions, merits as well as shortcomings arise in using such functions to analyze transportation costs. In using aggregated data, economic cost functions (especially trans-log functions) may be used to investigate economies of scale for transportation firms, to predict aggregate costs as a basis for comparative evaluation of different firms or operations, and to test for separability, homogeneity, and nonjoint production in transportation. Further discussion of these topics may be found in a report by Spady and Friedlaender (13).

Shortcomings from aggregated cost functions are primarily concerned with the inability of such functions to predict disaggregated costs and therefore to determine costs of particular transportation movements (or fully allocated costs). Furthermore, these functions would not be an appropriate means of allocating common costs among transportation movements that incur these costs in common, since the functions were estimated by using aggregate rather than disaggregate data.

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REFERENCES

1. R.G. Hennes and M. Ekse. Fundamentals of Transportation Engineering. McGraw-Hill, London, 1969.
2. J.S. DeSalvo and L.B. Lave. A Statistical Engineering Approach to Estimation of Railway Cost Functions. Rand Corp., New York, NY, 1968.
3. A.F. Daughety and M.A. Turnquist. Development of Hybrid Cost Functions from Engineering and Statistical Techniques: The Case of Rail--First Year Final Report. Transportation Center, Northwestern Univ., Evanston, IL, 1979.
4. J. Marsden, D. Pingry, and A. Whinston. Engineering Foundations of Production Functions. Journal of Economic Theory, 1974, pp. 124-140.
5. H.B. Chenery. Engineering Production Functions. Quarterly Journal of Economics, Vol. 63, No. 4, Nov. 1949, pp. 507-531.
6. A.D. Schuster. An Economic Analysis of Motor Carrier Less-Than-Truckload Transportation Services. Ohio State Univ., Columbus, Ph.D. dissertation, 1977.
7. A.D. Schuster. Statistical Cost Analysis: An Engineering Approach. Logistics and Transportation Review, Vol. 14, No. 2, 1978, pp. 151-164.
8. P.A. Dierks. Applying Cost Accounting to Transit System Financing. Management Accounting, Vol. 60, No. 6, Dec. 1978, pp. 20-23.
9. W. Cherwony. Cost Centers: A New Approach to Transit Performance. Transit Journal, Vol. 3, No. 4, Fall 1977, pp. 70-80.
10. H.O. Whitten. Functional Cost Accounting for Railroads. ICC Practitioners Journal, Vol. 43, March 1976.
11. R. Young. A New Regulatory Accounting System for Railroads. ICC Practitioners Journal, Vol. 43, May 1976.
12. R.R. Braeutigam. An Analysis of Fully Distributed Cost Pricing in Regulated Industries. Bell Journal of Economics, Vol. 11, No. 1, Spring 1980, pp. 182-196.
13. R.H. Spady and A.F. Friedlaender. Econometric Estimation of Cost Functions in the Transportation Industries. Center for Transportation Studies, Massachusetts Institute of Technology, Cambridge, Sept. 1976.
14. R.H. Spady and A.F. Friedlaender. Hedonic Cost Functions for the Regulated Trucking Industry. Bell Journal of Economics, Vol. 9, No. 1, Spring 1978, pp. 159-179.
15. G.W. Wilson. On the Output Unit in Transportation. Land Economics, Vol. 35, No. 3, Aug. 1959.
16. W.G. Waters II. Statistical Costing in Transportation. Transportation Journal, Vol. 15, Spring 1976, pp. 49-62.
17. T.H. Oum. A Cross-Sectional Study of Freight Transport Demand and Rail-Truck Competition in Canada. Bell Journal of Economics, Vol. 10, No. 2, Autumn 1979, pp. 463-482.
18. R.S. Brown, D.W. Caves, and L.R. Christensen. Modeling the Structure of Cost and Production for Multiproduct Firms. Southern Economic Journal, Vol. 40, No. 1, July 1979, pp. 256-273.
19. D.W. Caves, L.R. Christensen, and J. Swanson. Productivity in U.S. Railroads, 1951-1974. Bell Journal of Economics, Vol. 11, No. 1, Spring 1980, pp. 65-83.
20. P.A. Samuelson and S. Swamy. Invariant Economic Index Numbers and Canonical Duality: Survey and Synthesis. American Economic Review, Vol. 64, 1974, pp. 566-593.
21. F.M. Fisher. Approximate Aggregation and the Leontief Conditions. Econometrica, Vol. 37, July 1969, pp. 457-469.

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Abridgment

New Ranking Procedure and Set of Decision Rules for Method of Internal Rate of Return

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A new ranking procedure and revised set of decision rules have been developed for the method of the internal rate of return. Their application will lead to a clear-cut and proper decision about acceptability and about the best alternative, at least as long as the minimum attractive rate of return is at least as large as the borrowing rate for capital that must be acquired outside the firm or agency.

I will not argue here about which economic analysis method (e.g., internal rate of return, net present value, or benefit/cost ratio) is preferable but instead will outline a new ranking procedure and a new set of decision rules for the method of internal rate of return in order to ensure that the decisions that result from its use are always correct and unambiguous. Of some importance, this discussion will be limited to cases in which the minimum attractive rate of return (MARR) will be at least as large as the borrowing rate (BORR) for capital that must be acquired outside the firm or agency. [For a discussion of the case in which MARR < BORR see the Discussions and Closures included with the paper by Wohl (1).]

SITUATIONS THAT CAN LEAD TO AMBIGUOUS OR INCORRECT DECISIONS

One situation that sometimes leads to incorrect or ambiguous decisions is that in which there is more than one internal rate of return for a given alternative. Specifically, whenever the net annual cash flows during the n-year analysis period (i.e.,