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LOSS-COST FUNCTIONS FOR EVALUATING FORECASTS OF DEMAND FOR TRANSPORTATION ROLLING STOCK

by

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1.0 Introduction

"Almost every transaction which occurs in the life of the nation involves transportation as one element of cost. Thus, the material well-being of the nation is improved when goods are manufactured and services are rendered under conditions where the real cost of transportation is kept to the minimum necessary to provide fully adequate services," Royal Commission on Transportation, Vol. 11, 1961.

Transportation has always occupied centre stage of Canadian political life and economics. Canada was tied together at Confederation by the offer of railways, and later the Trans-Canada highway with its system of ferries, and national airways. The various provinces were attracted into Confederation through a monopoly rail system to a larger national market for their goods. The early dream of bringing about an equalization of economic opportunities and national unity through the railway system was never fully realized from the perspective of individual provinces. However, rail transportation continues to play a very significant role in the country's economic development and government strategies for management of the economy.

The Transportation Department of Canada spent 1.2 billion dollars on what it calls surface transport during the 1984-5 fiscal year. Of this amount 73.7 per cent was spent on rail transportation services in contrast to 6.5 per cent on highway and road safety. Estimates of expenditures for 1985-6 on these two types of transportation are 73.6 and 7.6 per cent respectively, Estimates 1985-6, Transportation Canada. The percentage share of the transportation sector GDP at 1970 was just under 6 per cent. This is reflected in a growth in the absolute share of the transportation sector in GDP by 78.6 per cent over the 1971 base year value. By contrast the index for GDP itself only increased by 50 per cent over the same period, Canadian Statistical Review, January 1986. One of the major features of the growth in the trasportation sector is the rapid increase in the importance of trucking at the expense of rail transportation in "feeder" and mainline-haul traffic. The Royal Commission on Transportation 1962 reports that rail freight traffic fell from 73.8 per cent of Canada's total freight ton-miles in 1942 to 53.8 per cent in 1957, while highway traffic rose from 3.2 per cent and highway 10.5 per cent.

Because of the importance of railways and trucking in the Canadian Transportation system and the reorientation of policies to their development along commercial and market lines, it is important to determine which methods are most suitable to forecasting the demand for transportation facilities and rolling stock in the trucking and rail industries. It is also appropriate to explore methods for measuring the accuracy of these forecasting methods and the oportunity costs resulting from having to make decisions regarding capacity requirements based on these forecasts (or under uncertainty) as opposed to decisions based on perfect information. Clearly the economic objective of moving goods and persons and rendering services under conditions that ensure that the real cost over the entire transportation network is minimized depends on the ability to select the best methods to forecast demand for transport facilities. The objective should be to explore approaches and to establish procedures and methods for evaluating them.

2.0 Forecasting the Demand for Transportation Facilities

Most transportation companies provide services in a network system. Some types of transport systems are open and some are closed. Estimating or forecasting the demand for transportation facilities in such network systems is quite different from forecasting the demand for a particular commodity in a single market located within a well defined geographic area. The demand for transportation services derives from the need to move goods, services and persons between points (nodes) in the network. We may divide these facilities into (1) facilities that carry the goods and persons between various points in the network (rolling stock) and (2) fixed facilities in the form of railway yards, runways, airplane hangars, garages, terminals, office buildings and computed and other electronic communication systems, etc., etc. Theoretically, if rolling stock never break down, that is, if trucks, planes, trains and rail cars are in continuous use then there will be little or no use for garages, hangars, railway yards. In fact this is impossible so that the system must contain these facilities at main throughput points in the network. This requirement is a negligible constraint in the trucking industry; but in the case of railways it is a very important factor in any economic analysis of that carrier. That is, any major expected increase or shifts in the movement of goods, services, and persons would not only have a significant impact on demand for rolling stock but also on that for fixed facilities. However, in the immediate or medium term changes in traffic are reflected mainly in the demand for rolling stock and are usually measured in ton miles hauled and passenger miles. This is true for both rail and road transport carriers.

Our preliminary analysis of methods used in forecasting the demand for transportation facilities and equipment reveals practices which range from judgmental methods based on the knowledge of experts to quite sophisticated techniques combined with varying degrees of expert intervention. In all cases there was an absence of a rigorous methodology for evaluating the accuracy of the forecasts. The common response to this situation is that "the present system works". There is the need for a methodology which takes us beyond the purely descriptive and subjective evaluation of accuracy characterized by such statements.

3.0 Statement of Problem

Armstrong (1978), Makridakis and Wheelwright (1982) and Mahmoud (1984) summarized in their work a number of measures for determining the accuracy of forecasting methods. Examples of some of these measures are: Percentage Error (PE), Mean Percentage Error (MPE), Mean Absolute Percentage Error (MAPE), Adjusted Mean Absolute Percentage (AMAPE), Mean Squared Error (MSE), R-Squared, Coefficient of Variation, Theil's U-Statistic and Gardenfors' "I" Value (1980), the D-W Statistic. Many of these techniques manifest several shortcomings when used as a single indicator of accuracy. Various combinations of these measures such as MSE, combined with D-W Statistic and the Theil U-Statistic provide in many cases an analytic framework for determining the relative accuracy of various forecast models. However none of these methods measured the value of the trade off between the cost of using a forecasting method and the accuracy of that method. The need for such a measure of accuracy has been pointed out by Mahmoud, 1982.

In an organizational system where the capital invested in facilites is very large, and where the financing of excess capacity is very costly relative to the cost of a forecast system, the penalties of using the wrong forecasts system or not using a particular system could be very significant in monetary and socio-political terms. For example, in Canada the early assumptions that railways would continue to be the principal mode of transporting goods and persons over the long-run led to heavy investment in excess capacity. The emergence of fierce competition from trucks in the fifties through to the early seventies caused persistent large positive differences between actual demand and planned capacity in the rail transportation industry. The fact that investment in fixed capacity was so large relative to rolling stock did not make it possible to adapt the system easily to the rapidly changing market conditions. To offset the economic distortions and inequities resulting from the burden of the debt associated with this excess capacity government established a system of direct and indirect subsidies to the industry. These forecast errors have cost the tax payer hundreds of millions of dollars which represent a sort of measure of opportunity cost. Given the size of these expenditures and the need to reduce the national deficit greater attention must be given to choosing more accurate forecasting methods. We suggest therefore that loss-cost functions be used to evaluate the cost benefits of using or not using a given facilities-demand forecast system for rail and truck transportation. This is particularly true of the Rail Transportation industry.

Anticipating the volume and direction of various types of traffic well in advance is very essential to efficiency in the system. Our loss-cost functions will explicitly take into consideration errors in forecasting demand for transportation facilities and rolling stock. Loss-cost functions will be developed under varying assumptions with respect to the relationship between available capacity owned by the carriers, the forecast of demand for rolling stock and actual demand. The merit of these functions rests in the fact that the methods translate the forecasting error into dollars when the forecast results are compared with a perfect forecast. They allow the managers to select the most suitable forecasting method(s) for their organizations in terms of a common measure that can be easily understood.

4.0 Methodology

For the purpose of discussion we limit ourselves to the development of opportunity cost (loss-cost) for trucking services. The assumptions on which the opportunity cost or the loss cost functions are based are as follows:

1. From the past data the trucking company forecasts the demand for its services for the next planning period using some forecasting methods available to it.

2. Based on the forecasts the company plans to meet the demand for the services, if possible, from its own fleet.

3. The company is able to subcontract if the forecast for the demand for the services exceeds the available capacity. If the forecasted demand is less than available capacity, the company cannot subcontract the idle (unused) capacity.

4. Any potential revenue reflecting effective demand for capacity which is not planned either by the company's vehicles or the leased vehicles is lost.

5. The company has two types of costs due to errors in forecasting:

   a. Error due to under estimation, and
   b. Error due to over estimation.

4.1 Notations

A = Actual cost with available forecast;
P = Cost with perfect forecast;
A-P = LCF = Loss cost function;
C = Cost per unit capacity of company vehicle;
L = Cost per unit capacity of leased vehicle;
R = Revenue per unit of capacity subcontracted out;
S = Loss of revenue per unit capacity not planned for;

During period "t" let

X_t = Available capacity owned by the company.
F_t = Forecast of demand.
D_t = Actual demand.

5.0 Loss Cost Functions

Normally the company may face any of the following six cases where the forecast error in terms of dollar value will be estimated.

5.1 Case 1: ($D_t \leq F_t \leq X_t$)

The Actual Demand is less than or equal to the forecasted demand which in turn is less than or equal to the available capacity owned by the company. In this case the company is not going to lease extra trucks because both the actual demand and the forecasted demand are less than the capacity owned by the company. In this case, we have

$$A = CD_t - R(X_t - F_t)$$

$$P = CD_t - R(X_t - D_t)$$

$$LCF = A - P = R(F_t - D_t) \qquad (1)$$

5.2 Case 2: ($F_t \leq D_t \leq X_t$)

The forecast is less than the actual demand and the actual demand is less than the capacity owned by the company. Thus, leasing from outside is not required. The loss cost function is determined by the difference between A and P. Note that revenue is lost due to shortfall in capacity equal to ($D_t - F_t$).

$$A = CF_t + S(D_t - F_t) - R(X_t - F_t)$$

$$P = CD_t - R(X_t - D_t)$$

Loss Cost Function = A - P.

$$LCF = (D_t - F_t)\ (S-C-R) \qquad (2)$$

5.3 Case 3: ($F_t \leq X_t \leq D_t$)

The forecast is less than the capacity owned by the company and the capacity is less than the actual demand. In this case there is a shortage of capacity equal to ($D_t - F_t$). Thus the loss cost function is determined as follows:

$$A = CF_t + S(D_t - F_t) - R(X_t - F_t)$$

$$P = CX_t + L(D_t - X_t)$$

$$LCF = A - P = S(D_t - F_t) - (R+C)(X_t - F_t) \qquad (3)$$

5.4 Case 4: ($F_t \geq X_t \geq D_t$)

The forecast is greater than the capacity owned by the company and the capacity is greater than demand. The company faces the extra cost of leasing trucks to meet the demand. The loss cost function is determined by:

$$A = CX_t + L(F_t - X_t)$$

$$P = CD_t - R(X_t - D_t)$$

$$LCF = A - P = (C+R)(X_t - D_t) + L(F_t - X_t) \qquad (4)$$

5.5 Case 5: ($F_t \geq D_t \geq X_t$)

The forecast is greater than the actual demand and the actual demand is greater than the capacity owned by the company. In determining the actual cost of forecast in this case, the cost of leasing from other companies must be considered: Hence we get

$$A = CX_t + L(F_t - X_t)$$

$$P = CX_t + L(D_t - X_t)$$

$$LCF = A - P = L(F_t - D_t) \qquad (5)$$

5.6 Case 6: ($D_t \geq F_t \geq C_t$)

The actual demand is greater than the forecast and the forecast is greater than the capacity owned by the company. Hence ($F_t - X_t$) will be the capacity obtained from the outside and ($D_t - F_t$) will not be met. In this case we get:

$$A = CX_t + L(F_t - X_t) + S(D_t - F_t)$$

$$P = CX_t + L(D_t - X_t)$$

$$\text{Lost Cost Function} = A - P = (S-L)(D_t - F_t) \qquad (6)$$

It should be noted that the six cases were derived on the basis of different assumptions which were stated with respect to each case. There may however be special circumstances which necessitate a slight modification of the loss-cost function to match the special case (see for example, Mahmoud 1982, Mahmoud and Goyal, 1984).

6.0 Conclusion

There is a managerial need for a meaningful accuracy measure to evaluate different forecasting techniques utilized by the transportation industry. In order that accuracy measure be used effectively it should be expressed in terms of monitary units. The loss-cost functions presented above measure the opportunity cost of an inaccurate prediction and meet these requirements. In delineating the approach above we have developed six different loss-cost functions applicable to the rail and trucking industries. Empirical testing to investigate the use of these functions by managers is desirable. These functions do not replace the accuracy measures presented by Makridakis et al., 1983. In the initial stages one needs to have a method to select the best possible model from among many possible others. The residual analysis procedures of Makridakis et al. as well as Box and Jenkins methods are still needed in the initial model selection stages. Once a model has been selected and implemented accuracy analysis can be conducted by using our loss-cost functions to compare the selected forecast system with alternative forecasts. The intention is to examine forecasting practices in the rail, trucking, and air transportation industries in detail in order to test these loss-cost functions empirically. In the process we hope to be able to improve the models suggested above and perhaps develop more relevant models. We believe that this research will take us a long way to meeting the needs for loss-cost functions that can measure the accuracy of forecasts used by the different sectors of the transportation industry.

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