DEVELOPMENT OF EFFICIENT OPERATING STRATEGIES UTILIZING COST INFORMATION FOR KOREAN REGIONAL PASSENGER RAILROAD SERVICE

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abstract : Several measures which can contribute substantially toward efficiency improvement of Korean regional passenger railroad operation were developed based on cost information for Korean National Railroad (KNR) and impacts of those were evaluated. Characteristics of the cost structure were analyzed based on the developed translog function. Based on the analysis, several measures to improve productivity were suggested. Inducing more traffic to railroad, abandonment of less-utilized lines, preferential service for long-distance travel, and lessening reliance on labor force with additional investment on infrastructure or automation were among those measures suggested. Issues in calibrating cost function and developing operation strategies were discussed.

1. INTRODUCTION

Korean National Railroad(KNR) operates 24 lines and has about 3,100 revenue kilometers. It carried 31,912 million passenger kilometer and 14,070 million ton-kilometers in 1994.

The share of railroad in total national transport has become fairly stable and the split between passenger and freight transport in KNR was also stablized. It can be said that railroad is carrying its fair sharen of traffic under the prevailing condition. However, it, as like any other public entities operating national railroads, faces strong pressures for efficiency improvement. It is heavily subsidized annually. It also faces prospect of changes in general business environment. More competition from competing modes and general movement toward deregulation are part of the changes that are much touted about. There is also some internal issues which should be addressed. New services, such as the anticipated introduction of the high speed rail service will surely have impact on the passenger service as well as freight transport on the existing lines. It has to pursue measures to improve its operating efficiency.

All these call for more efficient management and operation of the rail transport service. Many measures can be developed in this regard. Measures which can actually contribute to improve operation efficiency substantially should be employed in actual practice. Those measures should be critically based on the production structure and cost structure of KNR.

Some efficient operating strategies for regional rail passenger transport are developed in this paper toward that ends, and these are based on the actual cost structure of the KNR. Therefore these will allow decision makers to have fairly good picture of the impact of the actual implementation of these measurements in terms of operating cost. The cost structure of the KNR is addressed first. It is based on a variable cost function of the form of the translog function. It is calibrated for the passenger transport cost information for 1989-1993 time period. Separate cost functions can be developed for passenger and freight service, but passenger cost function is utilized in this paper under the assumption that the split between passenger and freight transport remains stable in KNR. Some important characteristics of the operating cost structure are discussed. Efficient operating strategies are developed based on the analysis of the cost structure. The approach taken in this paper has advantages over conventional approach based on rule-of-thumb or insight of small number of people by providing objective information of the impact of the measures to decision makers.

In the next section, prior research activities on the issue were reviewed along with initial introduction on the subject. Issues involved in developing a cost function and analyzing cost structure were discussed in section 3. Some of efficient strategies were developed in section 4 based on the analysis of the previous section. Finally, conclusion and further research direction were discussed.

2. LITERATURE REVIEW

Improving management efficiency of Korean regional rail service was one of the top issues in Korean transport policy. Therefore the list of research reports on the subject is long. They recommended varieties of measures ranging from very specific short-term measures to long-term measures of overall privatization of the currently government-operated Korean National Railroad. Most of the reports, however, resorted to the judgemental analysis method which lacks objective hard evidences for their conclusions. As noted by one of the report (KOTI, 1993), more objective studies in addition to the experts' judgement were called for to support policy recommendations whether they are short-term operating measures or long-term strategic measures. This research is one of the pioneering effort in that regard. It analyze cost structure of the operating agency and recommends operating strategies which will surely have positive impacts in cost reduction and cost efficiency.

In terms of analyzing cost structure and productivity structure of railroad operation, there is long lists of research papers. This paper benefits from those prior researches on the analysis of cost structure. It is almost impossible to go over all of them, instead only lists of those have direct relationship with this research are included.

Many papers on calibrating operating cost function for railroad firms can be found in U.S. literature. Most of the researches has something to do with rate setting for freight movement. Lee (1984) has studied cost structure of U.S. railroad for the period of 1980-1981. He calibrated a translog operating cost function and a generalized Leontief cost function, and reported the existence of the economies of scale in U.S. railroad industry. Caves *et al* (1980) calibrated a tranlog cost function using data from 1951-1974 period, and analyzed cost structure and productivity changes for U.S. railroad industry. Similar approach was adopted by McGeehan(1993) for the analysis of cost structure and production structure for Ireland. They all reported cross-elasticities between capital, labor, and power, and own-elasticity of input factors, effect of firm size and average line-haul distance on cost. Friedlaender and Spady (1971), however, reported that they could not identify scale economies in U.S. railroad industry.

For Korean environment, Suh and Lee(1994) and Suh and Lee(1996) adopted similar approach and calibrated translog functions for passenger and freight transport. This research adopt similar approach, but model specification has been improved and this paper attempts application of the model to actual practice.

3. ANALYSIS OF COST STRUCTURE

Analysis of cost structure of railroad operating agency is very important in many aspects. It can contribute to the knowledge of how the agency is operating, how the actual costs are incurring, what are the factors which contribute to the cost in general, and what is the most important factor in cost structure. These knowledge can help the decision makers in setting appropriate fare level, devising improved operating strategies for cost reduction, developing new marketing strategies, and developing long-term business plans, to name a few. The first step in the process of the cost structure analysis is to develop a theoretically sound cost function. The function should have appropriate functional form and be based on the complete data set. Therefore, model specification and identifying reliable data source are most important factors in developing a cost function and thus in cost structure analysis.

3.1 Operation Cost Function

Generally, variable cost function of railroad industry can be derived, using duality theory, from the production function which satisfies regularity condition as follows;

$$VC = f(Q,P,F,T) \tag{1}$$

where, VC : variable cost, P: factor cost , $P=(P_1, P_2, K , P_N)$, Q: outputs $Q=(Q_1,Q_2, K ,Q_M)$, F: fixed production factors, T: technical change

This cost function should be nondecreasing with regard to factor costs and outputs, monotonically increasing and concave with regard to factor costs, and also satisfy the condition of linear homogeneity.

Actual model specification should be flexible enough not to require a priori constraints and assumptions for cost structure. Translog function enjoys popularity in the literature, because it is flexible and can be transformed to represent more restrictive functional forms of Cobb-Douglas, or constant elasticity of substitution function.

Equation 1 can be represented by a translog function as follow;

$$\ln VC = \alpha_0 + \sum_i^m \alpha_i \ln Q_i + \alpha_F F + \sum_i^n \beta_i \ln P_i \tag{2}$$

$$+1/2\sum_{i}^{m}\sum_{j}^{m}\delta_{ij}\ln Q_i \ln Q_j + 1/2\delta_{FF}F^2$$
$$+1/2\sum_{i}^{n}\sum_{j}^{n}\gamma_{ij}\ln P_i \ln P_j + \sum_{i}^{m}\sum_{j}^{n}\rho_{ij}\ln Q_i \ln P_j$$
$$+\sum_{j}^{n}\rho_{Fj}F\ln P_j + \sum_{j}^{m}\rho_{Fj}F\ln Q_j$$

The equation 2 should satisfy the following symmetricity condition of equation 3 and condition of homogeneous of degree of one of equation 4

$$\delta_{ij} = \delta_{ji}; \gamma_{ij} = \gamma_{ji} \tag{3}$$

$$\sum_{i}^{n}\beta_i = 1,\ \sum_{j}^{n}\gamma_{ij} = 0,\ for\ (i = 1,K\ ,n),\ \sum_{j}^{n}\rho_{ij} = 0,\ \text{for } (i = 1,K\ ,m) \tag{4}$$

the equation 2 can be further refined by selecting appropriate input factors and outputs. Labor, power and capital are variable production factor, and thus, labor cost, power cost, and capital cost comprises variable cost factors. Transport demand in rtansported passenser-kilometer, and transport density in passenger-kilometer per kilometer of revenue are taken as outputs.

The Equation 2 can be further refined by selecting appropriate input factors and outputs. Labor, power and capital are variable production factors, and thus, labor cost, power cost, and capital cost comprises variable cost factors. Transport demand in transported passenger-kilometer, and transport density in passenger-kilometer per kilometer of revenue are taken as outputs.

Choice of demand related variables as outputs are fairly general considering railroad transport service. Berechman (1983) noted that size of infrastructure such as rolling stock operation distance can also be employed as output variable for total cost function development.

Three additional variables are included in the cost function of this paper. A time series variable is added to represent the changes in technical level for the railroad transport. Average length of line-haul and one dummy variable are added to the list to further represent characteristics of outputs.

By taking these variables in the cost function specification, fixed production factors are implicitly incorporated. Traffic density can implicitly represent the fixed element by using revenue kilometer.

Final functional form of the cost function is as follow;

$$\begin{aligned}\ln\ \mathrm{VC} = {} & \alpha_0 + \alpha_T + \alpha_N + \alpha_M + \alpha_Y \ln \mathrm{Y} \\ & + \alpha_D \ln \mathrm{D} + \beta_L \ln \mathrm{p_L} + \beta_K \ln \mathrm{p_K} \\ & + \beta_F \ln \mathrm{p_F} + 1/2\delta_{YY} (\ln \mathrm{Y})^2 + 1/2\delta_{YD} \ln \mathrm{Y} \ln \mathrm{D} + 1/2\delta_{DD} (\ln \mathrm{D})^2 \\ & + 1/2\gamma_{LL} (\ln p_L)^2 + 1/2\gamma_{LK} \ln p_L \ln p_K + 1/2\gamma_{LF} \ln p_L \ln p_F \\ & + 1/2\gamma_{KK} (\ln p_K)^2 + 1/2\gamma_{KF} \ln p_K \ln p_F + 1/2\gamma_{FF} (\ln p_F)^2 \\ & + \rho_{LY} \ln p_L \ln Y + \rho_{LD} \ln p_L \ln D + \rho_{KY} \ln p_K \ln Y \\ & + \rho_{KD} \ln p_K \ln D + \rho_{FY} \ln p_F \ln Y + \rho_{FD} \ln p_F \ln D\end{aligned} \tag{5}$$

Where VC: variable cost, p_L, p_F, p_K: price index of labor, power, and capital, Y,D: demand and demand density, N: average line-haul distance, T: time-series variable for technical change, M: dummy variable which is set 1 for the case of revenue kilometer of less than 30 kilometer and demand density of higher than 100,000.

Equation 5 should meet the following condition for the homogeneity of degree of one.

$$\begin{aligned}\beta_L + \beta_K + \beta_F &= 1 \\ \gamma_{LL} + \gamma_{LK} + \gamma_{LF} &= 0 \\ \gamma_{KK} + \gamma_{LK} + \gamma_{KF} &= 0 \\ \gamma_{FF} + \gamma_{LF} + \gamma_{KF} &= 0 \\ \rho_{LY} + \rho_{KY} + \rho_{FY} &= 0 \\ \rho_{LD} + \rho_{KD} + \rho_{FD} &= 0\end{aligned} \tag{6}$$

Calibration of a translog function can be facilitated by including cost share functions in the process. Cost share equations for production factors can be derived from cost function following Shephard's lemma as follows;

$$\begin{aligned}S_L = \frac{\partial \ln C}{\partial \ln p_L} = {} & \beta_L + \gamma_{LL} \ln p_L + \gamma_{LF} \ln p_F \\ & + \gamma_{LK} \ln p_K + \rho_{LY} \ln Y + \rho_{LD} \ln D\end{aligned} \tag{7}$$

$$\begin{aligned}S_K = \frac{\partial \ln C}{\partial \ln p_K} = {} & \beta_K + \gamma_{KK} \ln p_K + \gamma_{LK} \ln p_L \\ & + \gamma_{KF} \ln p_F + \rho_{KY} \ln Y + \rho_{KD} \ln D\end{aligned}$$

$$S_F = \frac{\partial \ln C}{\partial \ln p_F} = \beta_F + \gamma_{FF} \ln p_F + \gamma_{LF} \ln p_F + \gamma_{KF} \ln p_K + \rho_{FY} \ln Y + \rho_{FD} \ln D$$

where S_L, S_K, S_F are cost shares of labor, power and capital.

3.2 Calibration of Cost Function

As like all other model calibration works, calibration of a translog cost function is critically dependent upon the availability of accurate data in its appropriate form. Data for five years, 1989-1993, were obtained from KNR's records of operating cost (KNR) and balance sheet(KNR), and some preliminary data reduction process was carried out because they were not directly applicable for the calibration. Detailed report on the data reduction process can be found in Suh and Lee(1994), but main impetus was to obtain all the data items in the cost function while securing enough degrees of freedom, because the cost function has many coefficients. Cross sectional data for twenty different lines and time series data for five years were pooled together to provide enough data points. Input price indecies to represent price change over time were utilized instead of input price per se. This is justifiable because number of employment, size of demand and revenue kilometer were fairly stable and did not show much differences for the time period considered. Price, rather than volume of input factors governed input factor price under this condition.

Table 1. Coefficients of Translog Cost Function for Passenger Transport

Coef.	Value	T-value	Coef.	Value	T-value
α_0	1.781	3.25	γ_{LL}	0.200	5.34
α_T	-0.009	-0.68	γ_{LK}	-0.157	-4.55
α_N	-0.137	-3.01	γ_{LF}	-0.034	-2.60
α_M	-2.373	-4.54	γ_{KK}	0.167	4.4
α_Y	1.402	6.17	γ_{KF}	-0.016	-1.38
α_D	-1.294	-4.50	γ_{FF}	0.043	2.54
β_L	1.061	19.04	ρ_{LY}	-0.039	-4.21
β_K	-0.088	-1.48	ρ_{LD}	0.002	0.19
β_F	0.030	1.87	ρ_{KY}	0.049	4.96
δ_{YY}	0.195	2.57	ρ_{KD}	-0.024	-1.82
δ_{YD}	-0.374	-3.37	ρ_{FY}	-0.010	-3.62
δ_{DD}	-0.725	4.05	ρ_{FD}	0.021	5.80

Systems of equations of Equation 5 and Equation 7 were calibrated utilizing seemingly unrelated regression of Zeller (1962). In the calibration process, one equation of Equation 7 was deleted to obtain a nonsingular variance-covariance matrix.

Table 1 how coefficient values of the translog function. As can be seen in the table, calibration results were satisfactory even though not all of the coefficients were statistically significant. Even the statistically not significant coefficients were retained in the cost function to maintain a translog functional form.

The calibrated translog function satisfies regularity conditions of concavity condition, positive cost share, monotonicity condition, and nondecreasing condition. Detailed proof of these condition can be found in Suh and Lee (1996). For the average condition, the calibrated translog function gives a familiar U-shaped cost function, as shown in Figure 1. Both average cost function and marginal cost function are show in the Figure 1. They have the form of typical cost functions.

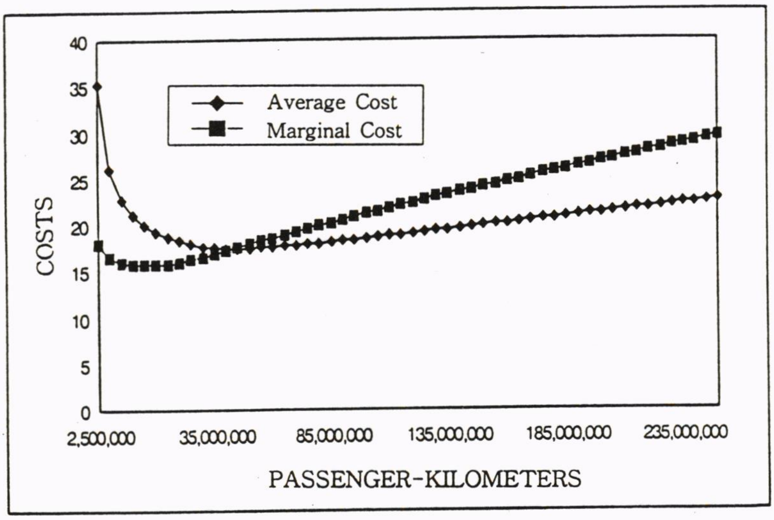

figure 1. The Operating Cost Function for Passenger Transport

3.3 Analysis of Cost Structure

The translog cost function can shed lights on the cost structure of the KNR operation. It can be critically utilized in developing various operation plans which are cost sensitive.

Average unit cost of passenger transport was analyzed to be 24.4Won/passenger-kilometer in 1993 which is identical with the reported average unit cost. Average cost has shown 10.4% annual increase from 16.4 Won to 24.4 from 1989 to 1993. On the average, labor cost accounted for about 54.4 %, capital cost 38.2 %, and power cost accounted for 7.4 % of the total cost. This proportion seemed stable over the analysis period.

Economies of scale of rail operation was analyzed according to the Equation 8 and more specifically to the Equation 9 for translog function. By assuming that infrastructure is fixed as it is, the Equation 8 and Equation 9 actually refers to the economies of density (Keller (1974). Positive value from the equation represents the economies of density, and correspond to the case in which average cost decreases with increasing travel demand.

$$ED = 1 - \left(\frac{\partial \ln C}{\partial \ln Y} + \frac{\partial \ln C}{\partial \ln D}\right) \tag{8}$$

$$\begin{aligned} ED = 1 - (&\alpha_Y + \alpha_D + \rho_{LY} \ln p_L + \rho_{LD} \ln p_L + \rho_{KY} \ln p_K + \rho_{KD} \ln p_K \\ &+ \rho_{FY} \ln p_F + \rho_{FD} \ln p_F + \delta_{YY} \ln Y + \delta_{YD} \ln Y + \delta_{DD} \ln D \end{aligned} \tag{9}$$

Results showed the value of 0.37 for 1993. This signifies the existence of the economies of density and means that if traffic density increases 1%, average cost for one passenger-kilometer will decrease 0.37%. Suh and Lee(1996) also utilized the results of other analysis method to confirm this finding.

Even the economies of density can not be retained over all possible values of density. Maximum traffic density can be calculated over which the economies of density no longer holds. That is the point where the elasticity of cost over product become one, and it is the critical traffic density over which average cost no longer can be reduced by increasing density. It can be calculated by equating the Equation 8 being 0. Maximum traffic density were identified in the range of 29,900-32,500 thousand-kilometer per revenue kilometer, and these figures are about three times higher than the actual realized traffic density of 9,300 to 10,600 thousand-kilometer.

Assuming traffic density and revenue scale are fixed, effect of average length of haul on the overall cost can be generally derived by taking a partial derivative of cost function with regard to average length of haul. In this paper, however, return to average length of haul can be directly read off from the coefficient of α_N, because average length of haul is included in the cost function. Usually, the return to average length of haul is a standing out feature in railroad industry. Obviously, cost of transporting one person over 400 kilometer will be different from that of transporting 400 persons over 1 kilometer. For Korean environment, the return to average length of haul was found to be -0.137. It means hat assuming density and revenue scale are fixed, average cost will decrease 0.137% when the average length of haul increase by one percent.

In translog cost function, elastisticity of substitution between two factor i, and j can be represented as follows according to Uzawa(1964);

$$\alpha_{ii} = \frac{\gamma_{ij} + S_i^2 - S_i}{S_i^2} \qquad \forall i = 1,\mathrm{K}\ ,3 \tag{10}$$

$$\alpha_{ij} = \frac{\gamma_{ij} + S_i S_j}{S_i S_j} \qquad \forall i,j = 1,\mathrm{K}\ ,3$$

Positive α_{ij} represents that two factors substitute and negative figures represents hat two factors do complement. Elasticities of substitution of 0.38, 0.23, and 0.12 were identified between capital-power, labor-capital, and labor-power pairs, respectively. This implies that when the price of labor or capital increases one percent, the use of capital and power will decrease 0.38 %. When the price of labor and capital increase by one percent, the use of capital and labor decrease 0.23 %. Also the use of power and labor will decrease 0.12 % when the price of labor and power increase by one percent.

Own-price elasticity of input factor represents the changes in the usage of the input factor with the price change of the factor. It is defined as

$$\varepsilon_{ii} = \alpha_{ii} S_i \qquad \forall i,j = 1,\mathrm{K}\ ,3 \tag{11}$$

Own-price elasticity of capital was -0.85. Those of power and labor were -0.32 and -0.08 respectively. This means that use of capital will be decrease by 0.85 % when the price of capital is increased by 1 %. Interpretation for other two factors are same. One thing of note is that the elasticity of labor is fairly low compared to the others.

4. DEVELOPMENT OF OPERATING STRATEGIES

Salient features among the characteristics of cost structure can be summarized as follows;

- The economies of density and return to average length of haul were identified.
- Positive elasticities of substitution were identified between labor-power, labor-

capital, and capital-power pairs.

- Labor cost has lion's share of total cost, and is a major input factor for operation cost.
- Own-price elasticities of input factors were identified to be less than one.

Based on the analysis of cost structure of the KNR, some efficient operating strategies can be developed. Considering the fact that economies of density does exist in KNR's operation, and currently achieved operation density is about one-third of the maximum density, overall average cost can be reduced by inducing more traffics to railroad. In this regard, KNR's aggressive marketing strategies to increase railroad patronage will be very desirable.

Another approach which can be developed based on the economies of density is abandonment of less-utilized lines. This can be directly deduced from the economies of density. This measure, however, warrants more scrutiny regarding implementability because of equity concerns. Also long-distance traffic should be encouraged to use railroad. They will contribute toward to the efficient operation of regional railroad considering positive return to average length of haul identified in the cost structure. Preferential fare and service strategies for long-distance traffic are desirable. Effects of combined increase of traffic demand and line haul length of demand will be greater than the sum of separate effects. Longer lines showed better cost figures, therefore, it will be also desirable to employ a fare systems which can differentiate length of lines.

Rearrangement of input factors are also possible to improve operation efficiency. One single most important item is to reduce the reliance on labor. This can be achieved considering the positive elasticities of substitution. One can substitute labor for other more efficient input factors such as capital. In this case, it means more investment on infrastructure, or automation.

Five explicit operating strategies which will contribute toward to the improved operation efficiency of Korean regional passenger transport were proposed based on explicit analysis of the cost structure of the railroad operation. This effort is different from the existing efforts which have been mainly based on the conventional wisdom or insight of small number of experts. By taking the approach proposed by this paper, impacts of the operation strategies can be objectively identified. The endeavor is not included in this paper, but should be treated with high priorities in subsequent researches.

More operational strategies can be developed based on the analysis. There is no doubt that by taking these strategies, overall efficiency of the operation can be improved. Fare increase or government subsidy can be kept in their minimum. Management efficiency can be more easily attainable. Actual implementation of these proposed strategies, however, should be scrutinized by exercising other policy factors too.

5. CONCLUSION

5.1 Conclusion

An operation cost function was calibrated based on the actual cost data for the period of 1989 to 1993 utilizing a translog function for Korean regional passenger transport. Validity of the cost function was scrutinized and the function was found to be reliable and easy to use. Cost structure of regional railroad operation was analyzed utilizing the developed translog function. The economies of density and return to average length of haul were identified. Positive elasticities of substitution were identified between labor-power, labor-capital, and capital-power pairs. Labor cost has lion's share of total cost, and is a major input factor for operation cost. Own-price elasticities of input factors were identified to be less than one.

Based on the analysis of cost structure of the KNR, some efficient operating strategies were proposed. The existence of the economies of density justifies the effort in inducing more traffic to railroad, and eventual increase of traffic density. It will contribute to the reduced average cost. Therefore the necessity of marketing efforts was implied. Abandonment of less-utilized lines should be also considered as a serious alternative. Positive return to average length of haul identified in the cost structure requires that long-distance traffic should be encouraged to use railroad. Preferential fare and service strategies for long-distance traffic were proposed. Considering the fact that there exists positive elasticities of substitution between input factors, efforts to reduce reliance on labor, for example by substituting it with more automation, was proposed as a very important measure for operation efficiency improvement.

5.2 Further Research Direction

Explicit size of the impacts of the proposed strategies were not calculated in this paper, but should be treated with high priorities in subsequent researches. Currently KNR operates four different passenger services. Natural extension of the effort will be to include the service classes as variable in the function.

In the approach taken, the split between passenger and freight was assumed given. But line capacity of rail is fixed and passenger and freight service can be considered competing for the use of the scarce resource. Operating cost function which has both passenger and freight transport in it can play important role in efficiently allocating the resource.

Developed operation cost function can be also critically utilized in analyzing feasibility of railroad investment. Actual application in this regard, and improvement achieved in the overall process might be also very interesting. Also non-economical impacts of the proposed strategies should be studied.

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