HOW EFFICIENT ARE FERRIES IN PROVIDING PUBLIC TRANSPORT SERVICES? THE CASE OF NORWAY

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ABSTRACT

In this paper we provide a yardstick for measuring the performance of ferries involved in the Norwegian trunk road system. We establish a best practice frontier from which individual ferries are measured against. The potentials for efficiency improvements can then be derived giving the decision makers knowledge of the magnitude of efficiency gains that can be achieved if the current subsidy regime is changed. The approach we use for establishing the frontier is the Data Envelopment Analysis (DEA) which is known to tackle problems of this type appropriately and which is now popular in assessing the efficiency of public transport services. Further, we use rich data comprising about 82 ferries operating throughout the country. The data are from the account years 2003 – 2005 and includes as inputs; fuel, labour, capital and maintenance costs, and as output ferry kilometres per year.

Our results indicate that there is a large potential for efficiency improvements in the sector as whole. Further, we find that area of operation e.g. whether open sea or not has a significant impact on efficiency thus we warn the decision makers not to be indifferent concerning the area where services are provided when assessing performances of the ferry sector. Our findings if used appropriately could improve the ferry subsidy schemes which today are based on standard cost norms and that do not address special cost drivers such as area of operation and capacity of ferries.

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INTRODUCTION

The Norwegian trunk road system is supplemented by ferries due to long coastline with numerous islands and fjords. Ferries in the network operate very much like public transport; they provide scheduled transportation services. The services provided include transporting passengers, passenger vehicles and heavy vehicles across fjords, and there are costs associated with the provision of those services e.g. fuel and crew costs. Further, like all other forms of public transport, most of the ferries are run by private companies, but at a loss. The deficits are subsidised by the government and have risen rapidly in the recent years. Thus, the Norwegian government is constantly looking for ways to improve the efficiency of ferries as units of production.

One of the options currently being explored by the government to improve the efficiency of ferry services is a change of the subsidy regime from cost norms to tendering. The expectations are that the change possibly will lead to improved performances. However, to implement any new subsidy regime, an initial assessment of performance is needed. Such an assessment will aid in determining the potentials for efficiency improvement in the sector that could be gained as well as factors that determine those potentials.

In this paper we provide a yardstick for measuring the performance of ferries involved in the Norwegian trunk road system. We establish a best practice frontier from which individual ferries are measured against. We then address questions like (1) how efficient are ferries in providing services, (2) what are the determinants of inefficiency among ferries and, (3) have ferries prospered in delivering services in the recent years. Answers to these questions will provide valuable information worth consideration when evaluating a new subsidy regime for the ferry sector.

The approach we use for establishing the frontier is the Data Envelopment Analysis (DEA) which is known to tackle problems of this type appropriately and which is now popular in assessing the efficiency of public transport services as is evident in the numerous applied journals e.g., *Transportation, Transportation Reviews, Transportation Research Part A, Transport Economics and Policy and Socio-economic Planning Sciences*.

The literature on efficiency measurements in the transport sector using DEA is growing rapidly; see for instance, De Borger et al (2002) for some recent reviews on frontier studies of public transit performance. For the ferries services in particular, Førsund (1992) assessed the performances of ferries as production units. He found unrealized scale economies and found rationalization potentials of about 30 percent in total. Odeck and Bråthen (1997) studied ferry links as unit of production where ferries are the major production units. They found that a large potential for efficiency improvements in the sector as whole in the range 24 – 50 %, that tendered ferry links did not outperform non tendered ferry links and that the subsidizing authorities, whether central or regional do not seem to impact on the performance of ferry links. Thus, this study a further contribution to these studies where more recent data are used and the focus in on ferries as units of production. Newer in this study relative to that of Førsund (1992) and Odeck and Bråthen (1997) is that the data used are cleaner in the sense that the Public Roads Administration (NPRA) in 2000 introduced a new accounting system that registers all the appropriate operations data allowing a more robust assessment of efficiency services.

The rest of this paper is organized as follows: Section 2 presents the analytical frameworks, while section 3 discusses and presents the data. In section 4, the analytic framework is applied and the results presented. Concluding remarks are offered in section 5.

METHODOLOGY – DEA

To address the issues of measuring performance of individual ferries raised in Section (1), we have employed a method known as Data Envelopment Analysis (DEA). DEA was introduced by Farell (1957) and extended by Charnes et al. (1978) and Färe et al. (1994, 1995). DEA uses nonparametric linear programming techniques to construct a “best practice” frontier from observed data on inputs and outputs. The best practice frontier is determined by those units (ferries) that provide a given level of services (outputs) with fewest resources (inputs). Equivalently, these ferries are those that produce the most services for a given level of resources. They thus constitute benchmarks from which the performance of other ferries can be measured. These benchmark ferries will receive scores of one in the analysis, meaning that they are 100% efficient, and the non-frontier ferries (the inefficient ones), will receive scores of less than one. One minus the score of the inefficient ferry gives the percentage by which the ferry operator needs to reduce their inputs in order to be on the best practice frontier.

DEA is regarded internationally as one of the most successful techniques of efficiency assessment proposed by researchers in management science/operations research. These successes are evident from extensive applications during the last decade and beyond. We have used this technique because of its advantages, such as: (i) efficiency is measured relative to the highest observed performance rather than against some average; (ii) it allows the simultaneous analysis of multiple outputs and multiple inputs; (iii) it does not require an explicit *a priori* determination of a production function; and (iv) it does not necessarily require information on prices.

Some weaknesses of DEA should also be mentioned, and include: (i) DEA is deterministic, and attributes all deviations from the frontier to inefficiencies; a frontier estimated by DEA is therefore likely to be sensitive to measurement errors, or other noise in the data; (ii) outliers may influence the results; and (iii) its efficiency scores are relative to the study sample; data from additional entities may thus affect the sample efficiency scores. Importantly, there are ways of dealing with these issues. While (i) above is still under research, to take account of stochastic factors in DEA models, one can form statistical regression and efficiency evaluation with DEA in a two-stage process [21]. Firstly, it involves determining factors associated with efficient and inefficient performances. Secondly, these factors are incorporated into a regression analysis as dummy variables. Concerning issue (ii), this problem can be minimized by excluding outliers in the analysis or including a larger sample. A larger sample increases the probability of having more outliers, thus making them more comparable. To deal with issue (iii), sensitivity analysis has been proposed as a way of evaluating data variation in DEA; Cooper et al. (1999).

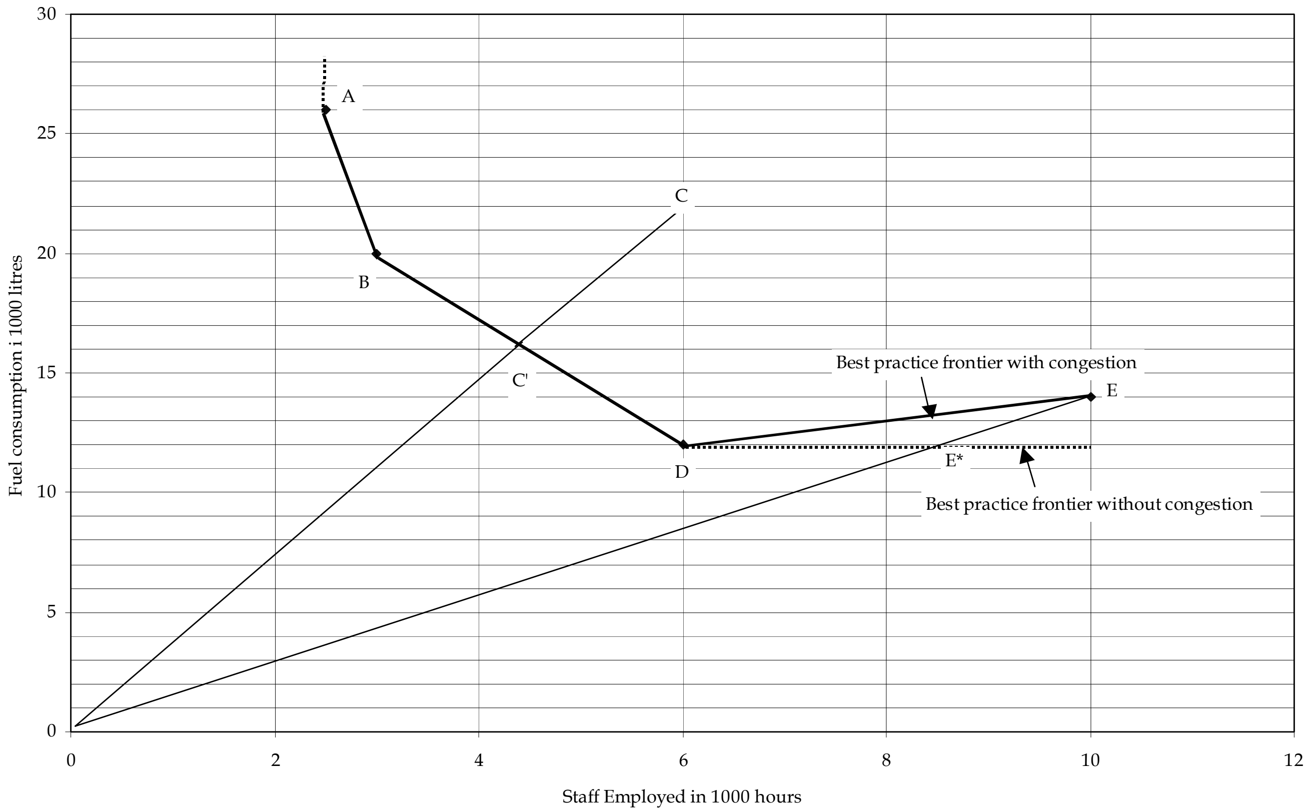

Figure 1: Illustrating DEA

To demonstrate the workings of DEA as applied in this paper, we provide an illustrative example in Fig. 1. It is assumed that the underlying production technology of a ferry can be described via the relationship between input usages (fuel consumption and staff employed etc), and transport services provided such as hours in operation. Fig. 1 is thus a two-dimensional version of such an analysis. The line segment A-E represents an isoquant, and designates the best combination of fuel consumption and staff employed that is required to produce a given level of transport services (hours in operation). Points A through E represent an individual ferry and their usage of fuel and labour (staff employed). It is assumed that all the ferries produce exactly the same type of output.

Consider ferry C, who uses more inputs (fuel and labour) than is required to produce its level of outputs. This loss in efficiency is measured as the ratio of best practice to observed inputs. In Fig.2, this ratio is found to be OC'/OC = 16/22 = 0.73. To find the input saving potential for ferry C, the score of 0.73 must be subtracted from 1. Hence, the input saving potential, the percentage by which the ferry would have to reduce inputs to achieve the best practice frontier, is 27%. Ferries A, B and D are all 100% efficient, i.e. they are on the frontier and thus cannot further reduce their inputs without reducing their outputs.

We have used the procedures outlined above to calculate efficiency for ferries. The linear programming method used to compute the distance to the best practice frontier, and the scale efficiencies, is based on the work of Färe, Grosskopf and Lovell [14], and hereafter referenced to as the FGL approach.

DATA

We use rich data comprising about 114 ferries operating throughout the country. The data are from the account years 2003 – 2005. The accounting data includes all expenses related to the running ferries such as wages and social costs, fuel, maintenance. However, capital cost may matter for the operation of a ferry. A proxy for capital cost used in this paper is the ferry capacity. This is the most appropriate proxy as was shown by Førsund, 1992. Available in the accounting system is also data on the annual distance covered by individual ferries, annual hours in operation and vintage year of ferries.

Given the data available the inputs were chosen to comprise wages, fuel, maintenance costs and capital as measured by capacity. The outputs were chosen to be annual distance covered and hours in operation. Thus we have four inputs and two outputs. A summary of the variables used are shown in Table 1. Note that vintage year is shown in the table although it is not used as input or output in the efficiency estimations. It impact on efficiency will however be measured in a second-stage analysis where the efficiency scores are regressed on age or vintage year of ferries.

Table 1: Summary Values of Variables, per year

	Fuel	Maintenance	Wages	Hours in Operation	Distance in Km	Capacity (PB)	Vintage
2003							
Total	191588826	128644226	643367850	409413	4806606	4142	162430
Average	2336449	1568832	7845949	4993	58617	51	1981
Stand.dev	1552879	723829	3267405	1770	28455	28	11
Max.	9834000	3990221	15097286	7920	163336	124	2002
Min.	159796	4084	532266	254	2633	9	1962
2004							
Total	174924943	113560853	618018920	404460	4813920	4142	162430
Average	2133231	1384888	7536816	4932	58706	51	1981
Stand.dev	1344425	661412	3126598	1695	28066	28	11
Max.	7505000	3583258	14715000	7899	157159	124	2002
Min.	244156	0	797000	100	1200	9	1962
2005							
Total	240596791	128918510	654334055	398054	4761413	4142	162430
Average	2934107	1572177	7979684	4854	58066	51	1981
Stand.dev	2001761	803563	3560552	1999	30829	28	11
Max.	11805000	3727382	15378321	8539	157577	124	2002
Min.	15732	40	85558	36	393	9	1962

One important thing that can be noted from Table 1 is that while there has been little variation in variables from one year to the other, the variation of variables among ferries is quite large meaning that some are very small while others are very large. The number of ferries in the analysis is 82 and represents about 60 percent of total excluding capital costs.

RESULTS

Before presenting our results, it is worth considering whether ferries should be evaluated from input minimizing, output maximizing, or from both points of view. Since ferries are generally subsidized, and hence, route frequency predetermined, input minimization should be the appropriate measure from a policy point of view.

Tables 2 presents the summary result on average, ferries had input saving efficiency scores of between 0.76, 0.78 and 0.74 in 2003, 2004 and 2005 respectively. These results suggest the presence of inefficiency in the Norwegian bus industry. An average ferry could thus have reduced its inputs by an average of 22- 26% and still have produced the same level of outputs as the best practice ferry. The standard deviations reveal that there is in fact a wide variation inefficiency scores where some ferries score as low as 0.2 while others score 1.0. This implies that the distribution of scores needs to be examined further.

Table 2: Summary results

	2003	2004	2005
Average	0.76	0.78	0.74
Stand.dev	0.21	0.20	0.19
Max.	1.00	1.00	1.00
Min.	0.20	0.43	0.37

In Figure 2, the distributions of efficiency scores are shown categorized by size of ferries as measured by their capacities. The question readily asked is whether larger (smaller) ferries perform better than smaller (larger) ones. Some interesting observations emerge from Figure 2. While the inefficient ferries comprise both large and smaller ferries, the efficient ones comprise mostly of larger ferries. Note that the number of very small ferries is much smaller than the larger ones. However, a possible explanation for the observations above is that there are still some to small ferries relative to engine power and the waters they operate in. In fact a closer analysis reveals that the very small ferries are older than the average vessel park.

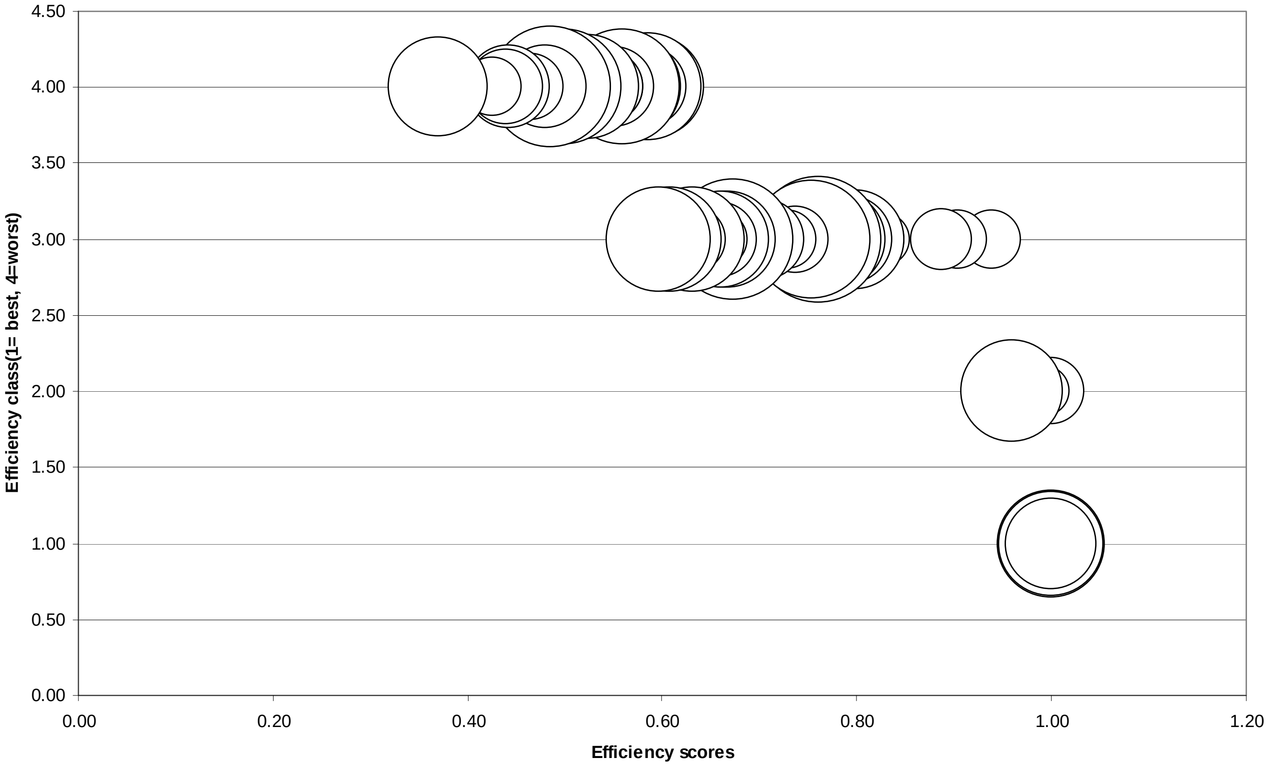

Figure 2: Distribution of efficiency scores

Next, we examined the extent to which efficiencies are influenced by the type of waters in which they operate type of ferry and the vintage year. The type of waters are classified as either open sea or fjord; type of ferries are classified as ferries with open end at both sides or only on one end meaning that those open at one end must turn every time they anchor. A Tobit-regression was run against these variables with efficiency scores as the independent variable. Note that for water and ferry type the variables were dummies. Table 3 replicates the results.

Table 3: Tobit-regression results

Innefficiency Tobit-regression		
	Beta	*t-values*
Constant	0.097	0.032
Waters	0.017	0.012
Ferry type	0.000	0.000
Vintage	0.046	0.009

The results in Table 3 shows that waters in which ferry operate matters for efficiency to the extent that ferries operating in rough waters i.e., open sea are less efficient than those operating within fjords. This is expected as rough waters imply more fuel consumption. Second, double open ended ferries are more efficient than one open ended ferries and the explanation again is the fuel consumption need while turning. And finally, vintage year although not significant at 5% level seems to have an impact on efficiency of ferries. A most likely explanation again is that newer ferries are more fuel efficient than older ones.

CONCLUDING REMARKS

The results so far indicate substantial variation in efficiency across ferries. The potentials for increasing input saving efficiency is on average at about 25 percent. The differences in efficiencies scores across ferries are explained by size as measured by ferry capacity, vintage and waters in which ferries operate.

The findings from our study have policy implications for decision makers, particularly in terms of encouraging more efficiency in the Norwegian bus industryferry sector. Since all Norwegian ferries in our observation set operators are subsidized, a key aim should be to reduce government spending. Communicating the results of our DEA analyses to the bus companiesferry operator and subsidizers, management would identify key factors and conditions (variables) they could better manage in the future. Such factors could also be included in a second round of DEA assessments. However, the study team's first task would be to ensure that our results are accepted by the industry. For the approach to be fully accepted, the study team's task involves finding viable explanations for all major variations in performance. An effective approach here is to inspect the key characteristics of each frontier ferrycompany and compare them to those of the inefficient ones.companies. The managers of inefficient ferriescompanies may then learn from the frontier ferriescompanies and, more importantly seek causes for their own inefficiencies. The central authority will then be able isolate those companies that use public funds inefficiently from those that perform more efficiently. Additional administrative attention should thus be paid to the former group of companies.

One way of improving the potential of the inefficient ferries companies would be to survey them, while considering the following:

- (a) Confront the companies running the ferries with the DEA results and ask them to identify and discuss any factors that might have contributed to the poor results, and prevented them from achieving higher efficiency ratings.

- Each inefficient company should be given a detailed qualitative comparison with the efficient reference companies of greatest relevance. In our case, this implies that the inefficient companies must be compared to reference companies operating under similar conditions, e.g., in the same waters and of the same vintageregion.

- (c) "Special" factors that have not been incorporated into the DEA model should be identified and included in a second round assessment. In our case, this involved formulating regional constraints into the DEA model.

The additional benefit of our study is that it be used to improve the current ferry subsidy system which is based on standard cost norms that do to take into account the above factors found to impact on efficiency.

REFERENCES

Aigner, D.J and S.F. Chu (1968), "On estimating the industry production function", *American Economic Review* 58, 826-839

Banker, R. D., A. Charnes and W.W Cooper (1984), "Some models for estimating technical and scale efficiencies in Data envelopment analysis", *Management Science* 30/9, 1078-1092.

Battese, G.E., and Coelli, T.J., (1988), "Prediction of firm-level technical efficiencies with a generalised frontier Production function and panel data", *Journal of Econometrics* **38**, 387 -399

Berg, S.A., F.R. Førsund and E.S. Jansen (1991), "Technical efficiency of Norwegian banks: The non-parametric approach to efficiency measurements", *Journal of Productivity Analysis* **2**, 127 –142

Bjurek, H., and L. Hjalmarsson (1995), "Productivity in multiple output public services: A quadratic frontier function and Malmquist index approach." *Journal of Public Economics* **56**, 447-460

Brocket, P., L., and Golany, B., 1996, "Using rank statistics for determining programmatic efficiency differences in data envelopment analysis", *Management science* 42(3), 466-572

Cowie, J., Asenova, D., 1999, „Organization form, Scale Effects and efficiency in the British bus Industry", *Transportation* 26, 231-248.

Cowie, J., (2002), "Acquisition, efficiency and scale economies: analysis of the British bus industry" *Transport Reviews*, 22(2): 147 - 157

Chang, K.P., and Kao, P.H., 1992, "The relative efficiency of public versus private municipal bus firms: An application of data envelopment analysis", *Journal of Productivity analysis*, **3**, 67 –84.

Charnes, A., W.W. Cooper and E. Rhodes (1978), "Measuring the efficiency of decision making units", *European Journal of Operational Research* **2** (November), 429-444.

Charnes, A., Cooper, W.W., Rhodes, E., 1981, "Evaluating program and managerial efficiency: application of data envelopment to program follow-through",

Management Science 27**:** 429 – 444.

Coelli, T. J., (1995), "Recent developments in frontier modelling and efficiency measurement", *Australian Journal of Agricultural Economics* **39**,219 –245

Coelli, T.J. (1996), A guide to FRONTIER version 4.1: a computer program for stochastic frontier production and cost function estimation. Department of Econometrics, University of New England, Armidale, Australia.

Coelli, E.G., D.S.P. Rao and G. E. Battese (1998), *An Introduction to Efficiency and Productivity Analysis*, Kluwer Academic Publishers, Boston/Dordretch/London.

Dalen and Gomez-Lobo (2003), "Yardsticks on the road: Regulatory contracts and cost efficiency in the Norwegian bus industry", *Transportation 30(4): 371 - 386*

De Borger, B., and Kerstens K., 2000, The performance of Bus-transit operators, (chapter 36) in David A. Hensher & Kenneth J. Button (ed.): *Handbook of Transport Modeling*, Pergamon. Amsterdam.

De Borger, B., Kerstens, K., and Costa A., 2002. “Public transit performance: what does one learn from frontier studies?”, Transport Reviews 22(1), 1-38

Førsund, F., (1992), “A comparison of parametric and non-parametric efficiency measures: The case of Norwegian ferries” *Journal of Productivity Analysis* **3**: 24-45

Färe, R., Grosskopf, S., and Lovell, C., 1985. *The measurement of efficiency of production*. Kluwer Nijhoff Publishing. Boston.

Färe, R., Grosskopf, S., and Lovell, C., 1994. *Production frontiers*. Cambridge University Press. New York

Grifell-Tatjé and C. A. K.Lovell (1995), “A note on the Malmquist Productivity Index”, *Economic Letters* 47, 169-175

Grosskopf S., (2003), “Some remarks on productivity indexes” *Journal of Productivity Analysis* **20**, 459-74

Jondrow, J., Lovell, C.A.K., Materov, I.S., and Schmidt P.(1982), “On the estimation of technical inefficiency in the stochastic frontier production model”, Journal of Econometrics, **19,** 233- 238.

Jørgensen, F., Pedersen, P., Volden, F., 1997, “Estimating the inefficiency in the Norwegian bus Industry from Stochastic cost frontier models”, Transportation 24, 421-433.

Kerstens, K., 1996, “Technical efficiency measurement and explanation of French urban transit companies”, Transportation *Research Part A*, 30, 431-452.

Lovell, C. A. K., (2003), “The decomposition of Malmquist productivity indexes”, *Journal of Productivity Analysis* **20,** 437-58

Meeusen, W., and J. van de Broeck (1977), “Efficiency estimation from Cobb-Douglas production functions with composite error”, International *Economic Review 18*, 435-444

Odeck, J., (2000), “Assessing the relative efficiency and productivity growth of vehicle inspection services: An application of DEA and Malmquist indices” *European Journal of Operational Research* **126**, 501-514.

Odeck, J., and Alkadi, A. (2001) “Evaluating efficiency in the Norwegian bus industry using Data Envelopment Analysis” Transportation 28, 211-232.

Odeck, J., (2006). **“**Congestion, ownership, region of operation, and scale: Their impact on bus operator performance in Norway**”** *Socio-Economic Planning Sciences* 40(1), 52-69

Puncher, J., 1988. Urban public transport subsidies in Western Europe and North America. *Transportation Quarterly*, 42: 377-402

Perry, J., Babitsky, T., and Gregersen H., 1988, “Organizational form and performance in urban mass transit” *Transport Reviews*, 8: 125-143

Ruggiero, J. and D.F. Vitaliano(1999), “Assessing the efficiency of Public Schools Using Data Envelopment Analysis and Frontier Regression,” *Contemporary Economic Policy*, Vol.17, No. 3 July, 321-331

Seiford, L M, (1996), “Data Envelopment Analysis: The Evolution of the state of the art (1978-1995*),” Journal of Productivity Analysis* ***7:*** *99-137*

Talvitie, A. P., Obeng, K., 1991, “Productivity and Performance” *Transportation Planning and Technology* 15, November 2/4, 169 – 176.

Viton, P. A., 1997, “Technical efficiency in multi-mode bus transit: A production frontier analysis” *Transportation Research Part B.* Vol. 31, No 1, 23 –39.