A Study on the Third-Sector Urban Railway Efficiency in Japan

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Abstract: This paper applies network data envelopment model (network DEA) to analyze the efficiency of urban railways, vertically integrated structure consisting of such division as "Maintenance", "Operations", and "Sales". One of the advantages of network DEA is that it allows analyzing the efficiencies of each individual divisions as well as the efficiencies of an entire railway company. Ranking different management forms of urban railway business organization in order of productive efficiency [1], this paper describes the special company was the most efficient on average, followed by private companies, third-sector railways, then municipal railway companies. Turning to profitability efficiency[2], the third-sector companies were somewhat more efficient than the public and private railways across all divisions, but the significance level was low.

Key Words: *Urban railways, Third-Sector railways, Network DEA, Efficiency*

1. INTRODUCTION

The investment costs to build urban railways are so immense that private interests have shied away from entering this arena. Potential new entrants are further discouraged by the increasing losses currently being sustained by most municipal subways and other urban rail companies. Yet despite these unfortunate circumstances, urban railways are facing increased demands to upgrade passenger amenities and convenience, eliminate congestion on rail lines, and adopt more environmentally friendly practices and technologies that require the most efficient management policies and practices. Recently we have seen a growing number of urban railways built and operated by *third-sector* operators—a hybrid form of corporate organization financed by both public and private sector interests—but the third-sector operators have not

[1] Productive efficiency refers to efficiency with emphasis on production and technology.
[2] Profitability efficiency refers to efficiency with emphasis on earnings.

been immune from harsh economic realities and have experienced increasing losses.
Here we attempt to illuminate these issues by analyzing the performance of urban railway companies, focusing on the relative efficiencies of third-sector lines in comparison with other types of urban railway companies. The study will confirm (or disconfirm) our initial assumption that, in their ability to effectively utilize urban rail infrastructure and other factors, the third-sector railways occupy an intermediate position in performance: they are more efficient than municipal railways but less efficient than private railways. This paper also discusses policies and practices for enhancing the business efficiency of third-sector urban railways.

There are a number of procedures and methodologies for measuring and analyzing management efficiency[3], but here we employ data envelopment analysis (DEA). More specifically, we have applied a network DEA model. This approach is capable of assessing the efficiencies of the railway companies as a whole as well as the efficiencies of the divisions making up the companies.

2. CURRENT STATE AND CHALLENGES OF THE THIRD-SECTOR URBAN RAILWAYS

2.1 The Third-Sector Urban Railways

We define urban railways as companies performing the functions of a railway and operating rail cars on fixed rail guides or tracks for conveying passengers in urban areas with populations of 300,000 or more .

Note that the form of business organization referred to as *third sector* is not a legal designation, but rather a term of convenience used in official documents and now in society at large in Japan. If *third sector* refers to public-private business entities (hybrid public-private partnerships), there are nevertheless several levels of inclusiveness. Most broadly defined, third-sector companies are public-private (first sector and second sector) special corporations (*tokushu hojin*), chartered corporations (*ninka hojin*), commercial law corporations (*shoho hojin*), and civil law corporations (*minpo hojin*), all of which are jointly financed both by the public sector and private sector.

2.2 Current State and Challenges [4]

Most of the third-sector urban railways have been built and put into service at the behest of local governments. Although constrained by limited budgets, local governments often make the deployment of railways in their cities a top priority policy concern.

Projected income often turns out to be well below what was expected as a result of overly optimistic estimates of demand, so many of these railways face a bleak economic reality[5].

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[3] See for example the survey by Nakajima (2001).

[4] Our knowledge regarding the current state and issues faced by third-sector urban railways is also partly based on a mail survey that was conducted at 2004 in which questionnaires were sent to 35 third-sector urban railway operators (including Class 1, Class 2, and Class 3 licensed operators, as well as lines and facilities not yet completed. We received responses from 17 of the companies (one questionnaire was returned blank), for a response rate of 48.6%.

[5] Many of respondents said their demand was 'better than expected' or 'equivalent to plan,' but a majority of the respondents were companies that were doing well. To this extent, the survey results were somewhat biased.

Their business plans have had to be scaled back or revised downward, and some operators have had to admit that demand is far less than originally projected[6]. While the operators are doing everything in their own power to improve their bottom lines by increasing revenues and cutting costs, they should also contemplate restructuring to separate infrastructure from operations as the ultimate path to improved profitability.

Based on our understanding of the current state and challenges faced by third-sector urban railways, we will analyze the efficiencies of urban railways focusing on corporate structure so we can better assess demand and effectiveness of company efforts to improve business performance.

3. Efficiency Analysis by Network DEA

3.1 Previous Studies of Railway Efficiency

In one previous study of railway efficiency, Nakashima et al. (1996) measured the total factor productivity (TFP) of the former Japan National Rail (JNR) broken out by activity, and showed the degree of contribution of each activity. Mizutani (1996) examined differences in efficiency for differently organized rail operators (private versus public operators). He found that the labor productivity of the private companies was higher than that of the public corporations, but Mizutani's study did not consider third-sector railways. Ooi (2006) compared third-sector railways with private railways in rural areas, and highlighted the advantages and disadvantages of each. A quantitative assessment of variable costs revealed no significant differences in the cost structures of the third-sector and private railway companies.

Oum and Yu (1994) conducted a DEA study of railway operations of 19 OECD countries, and found that the greater the subsidies the lower the productivity of the companies. Sueyoshi *et al*. (1997) examined the effects of privatizing the former Japan National Railways (JNR). Jitsuzumi and Nakamura (2006) used DEA to develop a scheme for calculating efficient subsidies for railway operators.

One can see from this brief survey that there have been a number studies of railway efficiency, but most of those dealing with third-sector railways have focused on the conversion of former JNR local services to third-sector companies, and very few studies have sought to assess the efficiency of third-sector urban railways.

3.2 Efficiency Analysis

3.2.1 Analysis Methods

In this work we use the data envelopment analysis (DEA) method to assess the efficiency of organizational units. DEA is linear programming technique that looks at the process of converting multiple inputs associated with the activities of *decision making units* (DMUs) into outputs, then measuring the relative efficiency of the conversion process according to a ratio scale[7].

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[6] The need for some railway operators to revise their demand forecast downward is attested from materials available from the rail operators and from plan revisions with which we are personally familiar.

[7] Tone (1993).

DEA first converts multiple inputs and multiple outputs into a single virtual input and virtual output, respectively. The relative efficiency of the DMU is then measured by the ratio scale, and an efficiency value for the unit (hereafter, *D-efficiency*) is determined by comparing its performance with the best performing units of the sample called the *efficiency frontier*. The advantages of DEA are that it yields a relative assessment of efficiency that is free of bias, it allows the scale of the DMUs to be factored into the assessment, and it permits comparison of relative efficiencies among the DMUs in the sample. Most importantly, DEA suggests ways that the inputs and outputs might be improved or changed to enhance the efficiency of the DMU. Note that this is not the same as estimating the production function itself.

We employ the DEA method in this study because the circumstances and conditions of urban railway companies vary tremendously—conditions along tracks, scale of business, degree of involvement by public interests, and so on. While it is difficult to measure the efficiency of such varied companies using a specific function, it is easy to do so using DEA[8].

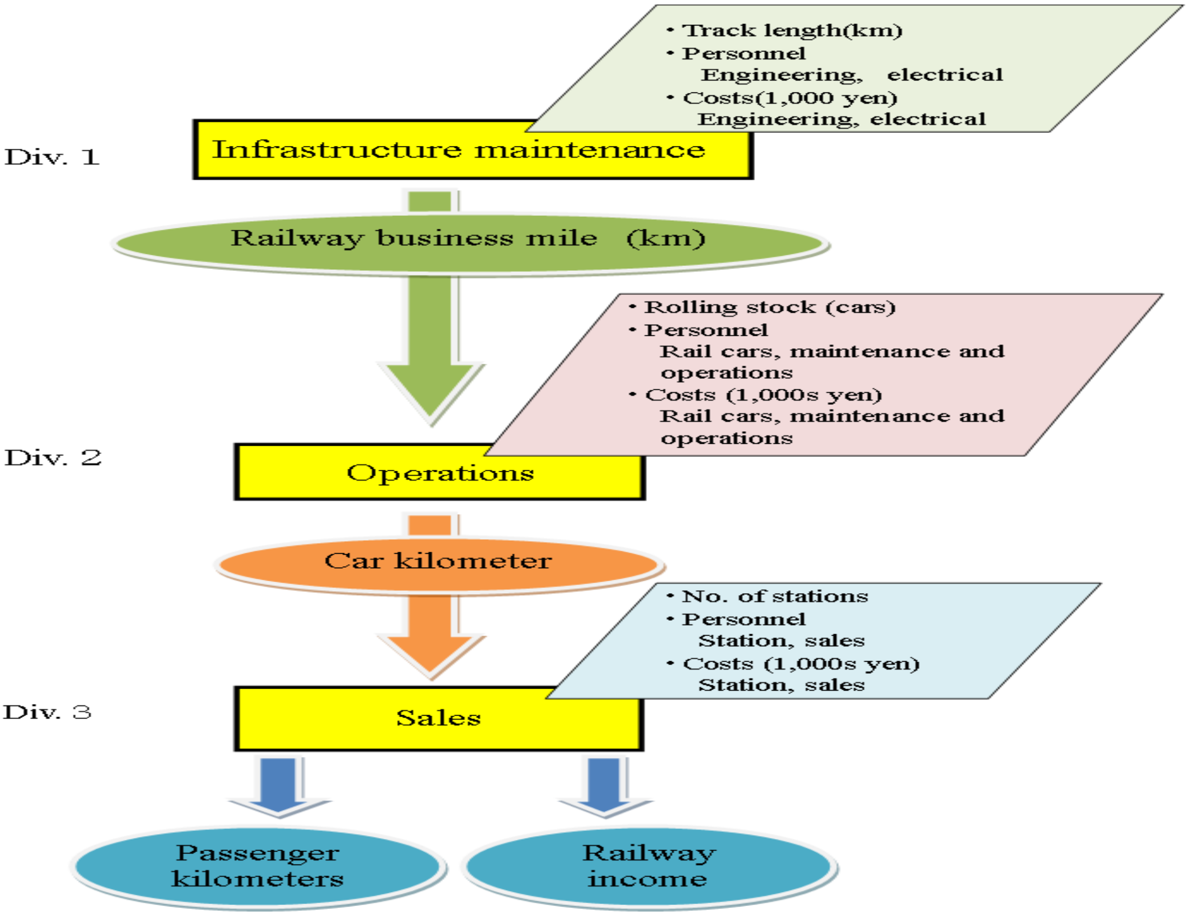

Figure 1 Analysis model

A number of DEA models have been developed[9], but the traditional DEA model does not consider the productive activities within the DMUs under analysis.

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[8] Nakajima (2001) described a side-by-side method for comparing DMU efficiency for specific functions that are difficult to set such as for external environmental factors like geographic conditions that readily affect the relative cost performance of railway companies.

[9] See for example Tone (1993) and Cooper, Seiford and Tone (2006).

Färe and Grosskopf (2000) proposed a new analytical approach called *network DEA* that does take the productive activities within DMUs into account. Network DEA thus represents a major improvement over traditional DEA, for it permits one to clearly model and measure the efficiency of the internal structures of DMUs, such as the divisions of urban railways. With this model we are able to (1) precisely handle the inputs and outputs of the divisions making up the DMUs, (2) consider the interrelationship between divisions in the DMUs, and (3) measure the performance of the DMUs by measuring the aggregate efficiencies of the component divisions.

While this kind of network DEA has yet to be applied to railway companies, it has been applied to such DMUs as electric power by Tsutsui and Tone (2007) and to broadcasting by Asai (2007). As one can see in Figure 1, urban railway companies are characterized by vertically integrated corporate structures, somewhat fixed facilities and labor, and economies of scale. So for the purposes of this analysis, we have adopted a "network DEA input-oriented variable returns to scale (VRS) free-link model". This model allows for input-oriented variable returns to scale (VRS) and free (discretionary) links [10] between divisions. For comparison, we simultaneously measured efficiencies using the variable returns to scale BCC (named after Banker, Charnes and Cooper) model for the traditional DEA.

3.2.2 Targets and Patterns of Analysis

As illustrated in Figure 1, urban railway companies consist of three divisions: the Maintenance and Infrastructure Division that maintains and manages track and electricity facilities (Division 1), the Operations Division that runs and takes care of rail cars (Division 2), and the Sales Division that deals with passengers at stations (Division 3). Here we model the productive activity of the vertically integrated railway companies (DMUs) consisting of these three divisions, and analyze their performance by network DEA.

Table 1 Analysis cases and inputs/outputs

	Inputs and outputs	Cases 1	Cases 2	Cases 3
Div.1	Track length(km)	○	○	○
	Personnel	○	○	○
	Costs	○	○	○
	railway businessmile(km)	●	●	●
Intermediate inputs	railway businessmile(km)			
Div.2	railway businessmile(km)	○	○	○
	Rolling stock	○	○	○
	Personnel	○	○	○
	Costs	○	○	○
	Car kilometer	●	●	●
Intermediate inputs	Car kilometer			
Div.3	Car kilometer	○	○	○
	No. of stations	○	○	○
	Personnel	○	○	○
	Costs	○	○	○
	Passenger kilometers	●	●	
	Railway income	●		●
Traditional DEA	Track length(km)	○	○	○
	Rolling stock	○	○	○
	No. of stations	○	○	○
	Personnel	○	○	○
	Costs	○	○	○
	Passenger kilometers	●	●	
	Railway income	●		●

Simplifying the internal structure of urban railways, the model assumes the following inputs and outputs for the three divisions. For the Maintenance and Infrastructure Division, the inputs are track length and the cost (excluding labor costs) associated with engineering work, electricity-

[10] Links are free not in the sense on independent divisions, but rather in the sense of ensuring continuity of links and the selection of optimal link values. This free link capability characterizes the advantages of the network model.

related maintenance, and the number of personnel, and the output is railway business kilometers. Next, for the Operations Division, the inputs are the number of rolling stock owned by the company, and the number of personnel, and the cost (excluding labor costs) associated with car maintenance and operations , and the output is car kilometers. Finally, for the Sales Division, the inputs are the number of the railway's stations and personnel, and the cost (excluding labor costs) associated with station and ticket sales at stations, and the outputs are passenger kilometers or railway income.

Starting with the set of 78 urban railway companies providing passenger service in Japan at the end of fiscal 2004, we eliminated one special small operator and two Class 2 rail license operators for a total of 75 urban railway companies (DMUs) to analyze. Broken out by form of business organization, the data of the 75 railway companies consisted of one special company, 12 municipal operators, 24 third-sector operators, and 38 private operators. In the DEA analysis, all 75 companies were evaluated at the same time without regard to their form of business organization. The single special company was treated as just one of the 75 companies and its relative efficiency was evaluated along with several other comparable companies.

The efficiency analysis was divided into three cases as shown in Table 1 [11]. Case 2 mostly evaluates productivity, Case 3 is primarily concerned with profitability, and Case 1 measures overall efficiency combining Cases 2 and 3.

The inputs and outputs for each case are listed in Table 1, and the input and output data are taken from the *2004 Annual of Railway Statistics* that is published annually by the Railway Bureau of the Ministry of Land, Infrastructure, Transport, and Tourism.

The input and output items for the different divisions reflected the nature of urban railway operations, and highly independent data for some of the items that could be obtained. Outputs of the Sales Division were passenger kilometers for Case 2, railroad income for Case 3, and both passenger kilometers and railroad income for Case 1. One might assume there is a high correlation between these two items (passenger kilometers and railroad income), but there could be a disparity due to differences in the way fares are set. One of the key advantages of the DEA model is its ability to analyze multiple output cases.

3.3 Analysis Results

3.3.1 Overall Assessment and Division-Specific Assessment

Analysis results for Case 1 are presented in Table 2. Network DEA was used to measure separate D-efficiencies for overall DMUs (the railway companies), the Infrastructure Maintenance Divisions (Div. 1), Operations Divisions (Div. 2), and Sales Divisions (Div. 3). In order to investigate the different D-efficiency scores broken out by form of business and division, each group was totaled to find average values and average rankings (the higher the D-efficiency, the larger the ranking).

The Kruskal-Wallis test was then applied to determine if there were significant differences in

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[11] Efficiency is usually measured in terms productivity, but given the challenges facing urban railways in achieving profitability, here we analyze efficiency in terms of profitability assuming railway income as the output.

D-efficiency in each group, and significance levels of 1% and 5% were noted. The Kruskal-Wallis test is a procedure for performing rank sum tests on three or more groups. Although there are four forms of corporate organization in our sample (special company, municipal, third-sector, and private railways), there is only one special company. Since there is nothing to compare it against, we performed the significance rank sum testing on the other three groups: municipal, third-sector, and private railways.

Table 2 Case 1 D-efficiencies

		Special company	Municipal	Third-sector	Private	Significance level
	Sample No.	1	12	24	38	
Overall	Average D values	0.854	0.587	0.586	0.623	
	Average rankings		38.000	35.313	38.724	
	Average ranking order		2	3	1	
Div.1	Average D values	0.409	0.263	0.317	0.389	
	Average rankings		29.125	37.688	40.026	
	Average ranking order		3	2	1	
Div.2	Average D values	0.931	0.571	0.650	0.647	
	Average rankings		33.125	38.917	37.987	
	Average ranking order		3	1	2	
Div.3	Average D values	1.000	0.803	0.646	0.724	
	Average rankings		46.000	30.875	39.000	
	Average ranking order		1	3	2	
Traditional DEA	Average D values	1.000	0.813	0.789	0.791	
	Average rankings		39.250	37.125	37.184	
	Average ranking order		1	3	2	

* Significance column shows Kruskal-Wallis test results
** 1% significance, * 5% significance

For Case 1 (productivity and profitability), the special company had higher D-efficiencies overall and for all divisions compared to the other forms of business. In the average ranking for overall companies for the other three types of businesses, the private railways were most efficient followed by the municipal and third-sector operators. Comparing Infrastructure Maintenance Divisions, the private railway companies were most efficient, followed by third-sector and municipal operators. The order of efficiency for Operations Divisions was third-sector, private,

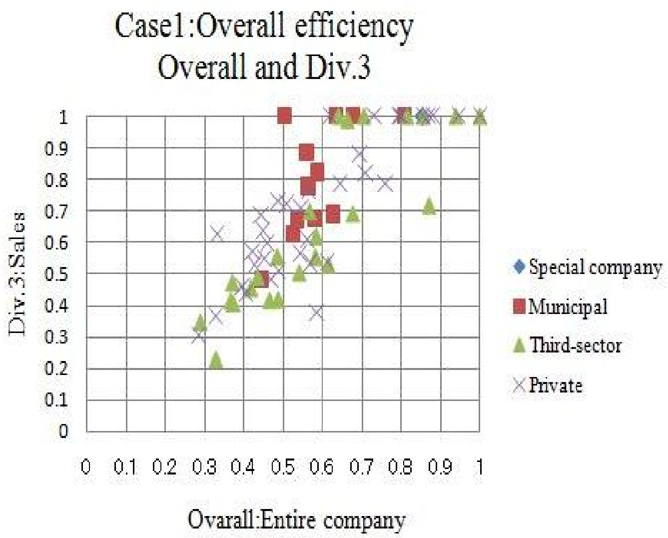

Figure 2 Case 1 D-efficiency scatter diagram

and municipal; and the ranking order for Sales Divisions was municipal, private, third-sector railways. Note, however, that the significance levels revealed by the Kruskal-Wallis rank sum test were fairly low.

D-efficiency average rankings for the Infrastructure Maintenance and Operations Divisions of the third-sector railways were equivalent or better than the other forms of business. Figure 2 shows a scatter diagram of overall and Sales Division D-efficiencies for all the companies, and it's apparent that the efficiencies for overall companies and Sales Divisions are poor.

Table 3 Case 2 D-efficiencies

		Special company	Municipal	Third-sector	Private	Significance level
	Sample No.	1	12	24	38	
Overall	Average D values	0.854	0.376	0.480	0.575	
	Average rankings		23.833	34.167	43.921	*
	Average ranking order		3	2	1	
Div.1	Average D values	0.409	0.222	0.310	0.387	
	Average rankings		24.833	37.708	41.368	
	Average ranking order		3	2	1	
Div.2	Average D values	0.931	0.380	0.489	0.608	
	Average rankings		24.750	32.917	44.421	* *
	Average ranking order		3	2	1	
Div.3	Average D values	1.000	0.463	0.567	0.636	
	Average rankings		23.500	36.833	42.342	*
	Average ranking order		3	2	1	
Traditional DEA	Average D values	1.000	0.486	0.663	0.717	
	Average rankings		18.417	37.813	43.329	* *
	Average ranking order		3	2	1	

* Significance column shows Kruskal-Wallis test results
** 1% significance, * 5% significance

Turning to Case 2 (productivity), again we found that the special company had higher D-efficiencies overall and for all divisions compared to the other forms of business. In the average ranking for the other three types of businesses, the order of efficiency was the same across the board for overall companies, Infrastructure Maintenance Divisions, Operations Divisions, and Sales Divisions: the private companies were most efficient, followed in order by the third-sector and municipal railways.

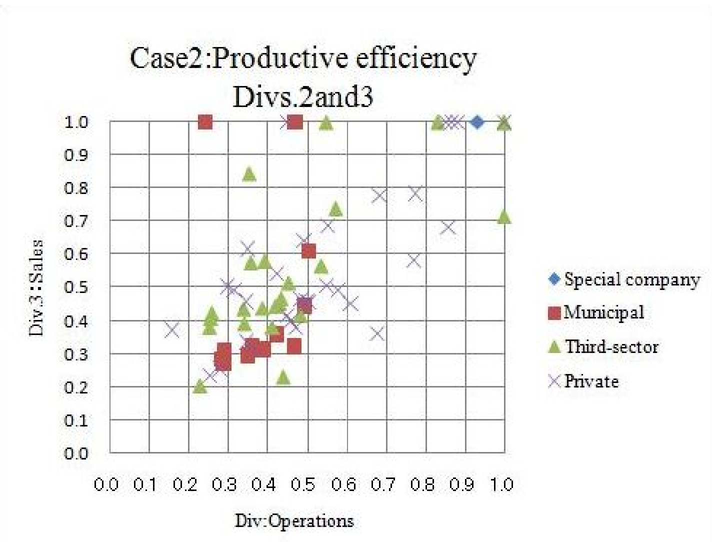

Figure 3 Case 2 D-efficiency scatter diagram

Here the significance level measured by the Kruskal-Wallis rank sum test can be considered fairly high. Figure 3 shows a scatter diagram of D-efficiencies for Operations and Sales Divisions of all companies, and one can see that in terms of productive efficiency, the third-sector companies fall approximately midway between the private and the municipal railways.

For Case 3 (profitability), again the special company had higher D-efficiencies overall and of all divisions compared to the other types of railway organization. In the average ranking of overall companies for the other three forms of businesses, the municipal railways were most efficient, followed by the third-sector then the private railways. Assessing the Infrastructure Maintenance Divisions, the third-sector companies had the best performance, followed by the private then the municipal railways. The order of ranking for the Operations Divisions was third-sector, private, then municipal; and the ranking order for Sales Divisions was municipal, private, and third-sector railways. If we count depreciation costs into

Table 4 Case 3 D-efficiencies

		Special	Municipal	Third-sector	Private	Significance
	Sample No.	1	12	24	38	
Overall	Average D values	0.854	0.569	0.576	0.576	
	Average rankings		41.750	37.542	36.132	
	Average ranking order		1	2	3	
Div.1	Average D values	0.409	0.246	0.317	0.363	
	Average rankings	19.000	30.583	39.271	38.566	
	Average ranking order		3	1	2	
Div.2	Average D values	0.931	0.547	0.650	0.592	
	Average rankings		34.500	42.125	35.526	
	Average ranking order		3	1	2	
Div.3	Average D values	1.000	0.794	0.618	0.677	
	Average rankings		48.417	31.792	37.658	
	Average ranking order		1	3	2	
Traditional DEA	Average D values	1.000	0.810	0.779	0.757	
	Average rankings		41.458	38.500	35.618	
	Average ranking order		1	2	3	

* Significance column shows Kruskal-Wallis test results

** 1% significance, * 5% significance

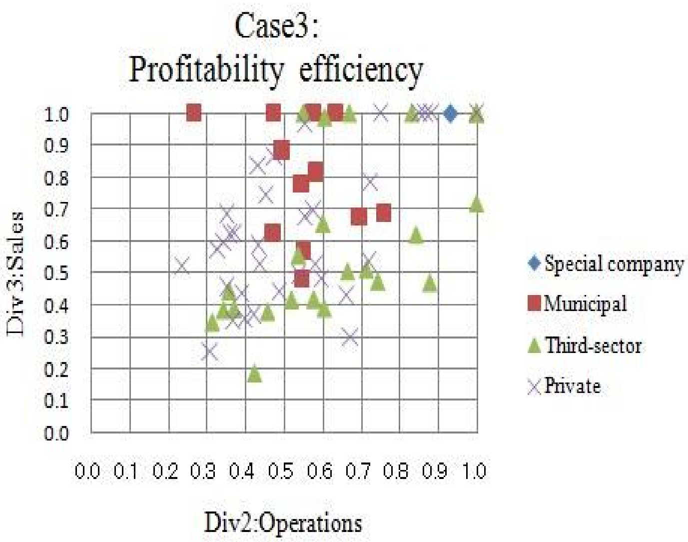

Figure 4 Case 3 D-efficiency scatter diagram

operating expenses, the municipal railways would probably have significantly lower D-efficiencies than the third-sector railways. Note too that the fares of the municipal lines are higher than those of the private companies, so we would expect the D-efficiencies of the municipal lines to be higher than the private lines.

The Infrastructure Maintenance and Operations Divisions of the third-sector companies were more efficient than the other types of railways, but the Sales Divisions of third-sector companies were found to be relatively inefficient. This is apparent from the scatter diagram of D-efficiencies of the Operations and Sales Divisions of all the companies presented in Figure 4. The third-sector companies have implemented cost-cutting measures, but their Sales Divisions clearly need to do more to boost demand. We would note, however, that the significance levels revealed by the Kruskal-Wallis rank sum test were low.

Table 5 shows a summary overview of the average ranking and D-efficiencies for Cases 2 and 3 broken out by the forms of corporate organization. Considering their history and how they were established, we would hypothesize that the third-sector railways would fall somewhere in the middle between the municipal and private line in terms of efficiency, and indeed the productive efficiency (Case 2) did closely match our assumptions for the overall companies and all the divisions. The high level of significance revealed by the Kruskal-Wallis rank sum test corroborates our assumption.

Table 5 Average rankings for different railway organization types

		Municipal	Third-sector	Private
case2	Overall	3	2	1
	Div.1	3	2	1
	Div.2	3	2	1
	Div.3	3	2	1
case3	Overall	1	2	3
	Div.1	3	1	2
	Div.2	3	1	2
	Div.3	1	3	2

In terms of profitability efficiency (Case 3), the Infrastructure Maintenance and Operations Divisions of the third-sector lines were most efficient, but the Sales Divisions were least efficient at the third-sector companies and most efficient at the municipal rail. This latter finding contradicts our hypothesis, but the significance found by the Kruskal-Wallis rank sum test was low.

3.3.2 Comparison of Network DEA and Traditional DEA Models

Highlighting the differences between the network DEA and the traditional DEA models, we included the D-efficiencies derived by the BCC model (traditional DEA) for the three cases shown earlier at the bottom of Table 2 to Table 4. One can see that the traditional model yielded higher D-efficiencies for overall companies than the network DEA. This is attributed to an inherent tendency of the traditional model and the fact that analysis by network DEA comes closer to actual efficiency[12].

3.3.3 Assessment of Companies That Separate Infrastructure and Operations

As noted earlier in discussing the current state and challenges facing third-sector railways, one promising approach for improving the business performance of urban railways is to separate infrastructure from operations. Indeed, some railway companies are already moving away

[12] See for example Tsutsui and Tone (2007).

from the traditional centralized corporate structure to separate their infrastructures from their operations and sales.

The author conducted a trial to explore the potential usefulness of the network DEA model for evaluating the effects that separation of infrastructure from operations might have on the efficiency of urban railway companies. For the trial analysis, the author added two Class 2 rail operators (operation providers) to the sample of 75 railway companies for a total of 77 companies that were analyzed in the same way. Only two companies is really too few for any definite conclusions, but provisional findings for Case 1 (productivity and profitability efficiency) are shown in Table 6 (the sample includes two Class 2 rail operators plus 75 companies shown earlier in Table 2 for a total of 77 companies).

Table 6 Comparison of D-efficiencies including Class 2 rail operators

		Class-1 rail operators				Class-2 rail operators	Significance level
		Special company	Municipal	Third-sector	Private		
	Sample No.	1	12	24	38	2	
Overall	Average D values	0.854	0.587	0.586	0.623		
75	Average rankings		38.000	35.313	38.724		
	Average ranking order		2	3	1		
Overall	Average D values	0.862	0.581	0.694	0.745	1.000	
77	Average rankings		19.917	36.396	43.908	72.500	**
	Average ranking order		4	3	2	1	
Div.1	Average D values	0.409	0.263	0.317	0.389		
75	Average rankings		29.125	37.688	40.026		
	Average ranking order		3	2	1		
Div.1	Average D values	0.273	0.256	0.345	0.548	1.000	
77	Average rankings		25.250	28.583	47.316	69.500	**
	Average ranking order		4	3	2	1	
Div.2	Average D values	0.931	0.571	0.650	0.647		
75	Average rankings		33.125	38.917	37.987		
	Average ranking order		3	1	2		
Div.2	Average D values	1.000	0.540	0.790	0.766	1.000	
77	Average rankings		19.167	43.208	40.289	64.000	**
	Average ranking order		4	2	3	1	
Div.3	Average D values	1.000	0.803	0.646	0.724		
75	Average rankings		46.000	30.875	39.000		
	Average ranking order		1	3	2		
Div.3	Average D values	1.000	0.839	0.754	0.829	1.000	
77	Average rankings		40.750	33.042	40.184	58.500	
	Average ranking order		2	4	3	1	
Traditional DEA	Average D values	1.000	0.813	0.789	0.791		
	Average rankings		39.250	37.125	37.184		
75	Average ranking order		1	3	2		
Traditional DEA	Average D values	1.000	0.804	0.725	0.770	1.000	
	Average rankings		41.333	34.625	38.605	66.000	
77	Average ranking order		2	4	3	1	

* Significance column shows Kruskal-Wallis test results

** 1% significance, * 5% significance

It is immediately apparent that the D-efficiencies for the two Class 2 operators are better than those of the Class 1 operators for the companies as a whole and for all constituent divisions. Infrastructure access charges are statistically included in operating costs.

It would be interesting to analyze how the efficiency of railway companies is affected by separating infrastructure from operations, but ideally this would require (1) aggregate data for the now divided infrastructure and operations components of railway companies that were formerly consolidated, (2) data for the consolidated railway companies before they were split up, and (3) aggregate data for railway infrastructure and operations companies that had never been consolidated. Given the scarcity or unavailability of this data, this paper was unable to include the effects of separating infrastructure from operations in the present analysis.

4. Conclusions

Third-sector urban railways have generally been built at the behest of local governments, and many have found that demand is far less than projected. As a result, many third-sector operators are currently doing everything in their own power to improve their bottom lines by increasing revenues and cutting costs by holding down labor costs and outsourcing wherever possible. In situations where it is possible to separate infrastructure from operations, third-sector urban railways could markedly enhance their effectiveness by assuming the operations and sales parts of the company while spinning off the infrastructure part, and indeed we are beginning to see some urban railways that have split up in just this fashion.

Network DEA revealed that the special company had higher D-efficiencies overall and for all divisions compared to the other forms of railway organization. We hypothesized that the third-sector railways would fall somewhere between the municipal and private operators in terms of productivity efficiency, and the analysis for the companies as a whole and the separate divisions corroborated that this is the case. Turning to profitability efficiency, no great significance was found for the companies as a whole or the separate divisions based on type of business organization, but the efficiencies of the third-sector railways were better in some cases and worse in one case than those of the private and municipal railways. The third-sector companies were the most efficient in the Infrastructure Maintenance and Operations Divisions as a result of cost-cutting and other measures, but were least efficient in the Sales Divisions as a result of languishing demand. The Sales Divisions of the municipal railways exhibited greater profitability efficiency than the private and third-sector companies, which are attributed to the fact that depreciation costs were not included in the analysis and the fact that municipal railway tend to charge higher fares.

The network DEA model used in this study is better able to assess efficiencies reflecting the tasks performed by different divisions of the urban railway companies, and thus comes closer to analyzing actual efficiencies than the traditional DEA model. Building on the analytical work reported in this study, the author plans to enhance the robustness of the analysis by optimizing the inputs and outputs, and construct a model that includes construction divisions of railways to assess the effects of separating infrastructure from operations.

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