CHAPTER 7. CONCLUSIONS

This chapter summarizes the major findings of the current research. Some general conclusions are drawn based on the previous chapters and possible directions for future study are presented.

7.1 General Conclusions

The current research estimates efficiency and effectiveness scores, and productivity and sales force indexes for 44 selected railways over the period of 1995 to 2001 by different DEA approaches. Based on the detailed analysis results described in previous chapters, some important conclusions of the current research are summarized as follows.

1. Most railways in the world are facing decline situation.

Many rail systems in the world have been facing keen competition from such modes as highway and air carriers over the past few decades. Most railways have suffered a major decline in the market share and failed to adopt a strategy to improve the decline situation. The major reason for the decline situation can be attributed mostly to poor performance. Therefore, enhancing the technical efficiency and service effectiveness, as well as productivity and sales force has become an important issue for railway industry to remain competitive and sustainable in the transport market. If one could make a clear distinction among the measurements of efficiency, effectiveness, productivity, and sales force and also could scrutinize the sources of poor performance, then one would be able to propose useful guidelines to ameliorate the railway transport performance.

2. Accounting for environmental factors in the performance measurement is not a trivial task.

Based on the previous studies, the methods for measuring the efficiency or the productivity of railway systems can be generally classified into two categories: frontier and non-frontier methods. DEA and SFA are attributed to frontier methods, while index number and least squares are considered as non-frontier. Due to its advantages, frontier methods become widespread in the past two decades. DEA is a technique for assessing the relative efficiency or effectiveness of DMUs. This implies that researchers look for a homogeneous set where comparison makes sense. However, it is impossible to find out a completely homogeneous set. In many cases, the operating environments that DMUs experienced are not the same. One can always identify the differences between them. If one doesn’t take the effects of environment into account, the results will be biased. A relative efficient (effective) DMU may be operated efficiently (effectively) or simply enjoying favorable environment, whilst an inefficient (ineffective) DMU may be bad managed or simply be experiencing unfavorable environment.

3. The results will be biased if one ignores the influence of residual slacks.

In its conventional application, DEA has two drawbacks: without consideration of influence of input excesses and outputs slacks, and without taking statistical errors into account. Fried *et al*. (2002) have endeavored to address both of these drawbacks by developing a three-stage DEA model. However, there is no guarantee that such model can always completely eliminate the slacks. The measurement results will be biased if one ignores the influence of residual slacks. This research thus combines Fried's *et al*. (2002) three-stages approach with Sueyoshi's et al. (1999) slack-adjusted DEA model and term as four-stage DEA model. The proposed model incorporated environmental factors, statistical noise as well as input excesses and output slacks into the efficiency and effectiveness measurement. The empirical results shows that the efficiency and effectiveness scores measured from three-stage DEA model are somewhat overstated in comparison with those measured from four-stage DEA models. It is expected that the proposed four-stage model may enhance the DEA practicality.

4. Measuring sales force is necessary for transport industries.

In contrast to previous studies which concentrating measurement solely on the productivity, due to the non-storable characteristics of transportation industries, measuring sales force, which accounts for the degree of utilization of producers' service outputs, is also necessary. This research thus measures sales force by extending the concept of Malmquist Productivity Index. The research defines sales force as the sale capability of the firm and applies Färe's *et al*. (1994) technique to get the output-based Malmquist Sales-force Index. To our knowledge, it is the first application to the railway system. This technique is called FGNZ method in the current research. Similar to productivity measurement, this research also measures the sales force by adopting proposed four-stage method; which has taken environmental factors and statistical noise as well as slacks into account. The results show that both estimated values and meanings of MSI are quite different with MPI. The results also indicate that Malmquist Sales-force Index measured from proposed model is slightly less than those from FGNZ models. Consequently, again, this research confirms that the sales force index will be overstated if one ignores the environmental effects, statistical noise and slacks.

5. The strategies for improving efficiency.

Based on the empirical results, this research finally constructs some matrixes where each firm's performance can be properly allocated. As a result more appropriate strategies for enhancing the rail performance in different situations can be proposed, which include improving efficiency, effectiveness, productivity, and sales force. Since this research adopted input-oriented DEA model to evaluate efficiencies, thus the strategies for improving technical efficiency are curtailing inputs utilized, especially in staffs. Furthermore, the results show that the percentage of electrified lines and the ratio of passenger train kilometer to total train kilometer produced are the factors that influence the efficiency, as a consequence, enhancing electrification and passenger service produced could be the strategies for improvement. Certainly, reducing total loading and unloading time at stations would also be a good strategy, particularly for freight.

6. The strategies for improving effectiveness.

The results of empirical analysis indicate that the most of firms experience relatively ineffective. The gross income per capita and population are two exogenous factors, which affect the effectiveness. However, the manager of DMUs cannot control the factors, therefore, the strategies for improving service effectiveness is different from those for improving efficiency. In general, rescheduling the dispatch plans so as to meet the requirements of the market demand could be a good strategy. Certainly, improving service quality, raising punctual rate, providing discounts for commuters and group travelers, and marketing promotion so as to attract more passengers and freight demands could also be the good strategies.

7. The strategies for improving productivity.

The results of the productivity measurement also imply some policy implications. For those firms experienced productivity deterioration, enhancing efficiency and/or introducing innovative technologies could be a good strategy. More specifically, since the Malmquist Productivity Index can be decomposed into efficiency change and technical change, if the determinants of productivity deterioration can be attributed to technical change, then the policies for improving productivity levels are closely linked to technological advances. In such case, introduction of new modern train so as to raise operating speed, application of new technology in signaling and in train control system, and improvement in maintenance of train and tracks could be the good strategies.

8. The strategies for improving sales force.

For those firms experienced with sales force regression, enhancing effectiveness and/or introducing innovative sales technologies could be a good strategy. More specifically, since the Malmquist sales-force index could be decomposed into effectiveness change and sales technical change, if the determinants of sales force deterioration is attributed to technical change, improving effectiveness could be a wrong way. In such case, the policies for improving sales force levels are closely linked to technological advances. Introducing innovative marketing or sales technologies, such as introducing new dispatch management information system, replacing ticket counter by vending machine, booking ticket by Internet, cooperation with convenient stores and tourist agencies etc. could be the good strategies for improvement. In contrast, if the source of sales force deterioration is due to effectiveness regression, then the way for improvement is to enhance effectiveness, rather than efficiency.

9. The poor performance firms should learn from their benchmarks.

In general, the performance improvements may be achieved through learning processes, because today is an era of progress and competition is increasingly knowledge-based. Through learning process, firms can speed capability development by acquiring knowledge from others. Thus, the inefficient and/or ineffective firms should learn from those are efficient (effective). The current research has identified that NS, CFF, and JR are benchmarks of TRA; therefore, the performance improvements may be achieved if TRA is able to learn better productive technologies and sales routines from its benchmarks.

10. The contributions on efficiency and effectiveness measurement

There are two contributions of this research beyond Fried *et al*. (2002). First, in their paper, Fried *et al*. (2002) have taken slacks into account; however, there is no guarantee that such model can always completely eliminate the slacks. This research measures efficiency of 44 selected railways over seven years by considering environmental factors, statistical noises, and residual slacks. Second, since transportation firm produces non-storable outputs—transport service, therefore, concentrating measurement solely on the efficiency or effectiveness gives only a partial view of the performance evaluation problem. In contrast to previous studies, the current research distinguishes effectiveness measurement from the conventional efficiency measurement. The empirical results show that measuring both efficiency and effectiveness is more reasonable for transport industry.

11. The contributions on productivity and sales force indexes measurement.

There are two shortcomings in the FGNZ productivity measurement model. First, the

Malmquist productivity index is based on the ratios of Farrell's (1957) efficiency scores. When measuring radial efficiency, however, the full magnitude of inefficiency is not revealed if slacks were neglected. Another shortcoming is that environmental effects and statistical noise have not been taken into account. Thus, in contrast to previous studies, the contribution of this paper is that we incorporate environmental factors, statistical noise, and slacks into the productivity measurement model. Our results reveal that the Malmquist productivity index measured from the proposed model is somewhat less than those from conventional models. Thus, this research concludes that the productivity index will be overstated if one ignores the environmental effects, statistical noise and slacks.

7.2 Possible Extensions of the Research

This research proposed a four-stage DEA method to measure technical efficiency of railways and extended it to measure service effectiveness. Furthermore, the current research also extended the proposed four-stage DEA method to measure productivity growth index and sales force growth index. However, there are still a lot of research tasks, which may be extended in the future research. The current research finally attempts to list some possible extensions as follows.

1. Extending the four-stage DEA method to other modes, industries, and macro level.

This research measures the performance of railway transport. As mentioned earlier, it is expected that the proposed four-stage method may enhance the DEA practicality, therefore, the future researches may enhance the application to other transportation modes, such as transit, air and highway carriers. Furthermore, DEA method can be applied not only on firm level, industry level, but also on macro level. For example, in their classical paper, Färe *et al.* (1994) adopted DEA-like linear programming method to measure productivity growth in 17 OECD countries over the period 1979-1988. However, they do not take environmental factors, statistical noises, and residual slacks into account. Consequently, one possible avenue of future research could be to apply the proposed four-stage DEA method to obtain more rational performance measurement for macro level.

2. Some operating differences could be considered in the future research.

This research selected percentage of electrified lines, ratio of passenger train kilometers to total train kilometers as internal characteristics, and gross income per capita, population as environmental factors. For simplicity, this research has not accounted for some operating differences, such as network characteristics and regulatory differences. Based on the underlying knowledge, the efficiency and/or effectiveness could be influenced by these two factors; therefore, these factors and some other possible affecting factors could be considered in the future research in order to make measured results more rational.

3. Extending to cost, revenue, and profit efficiencies.

The rail transport firms are long-recognized service industry. Cost minimization behavior may be an appropriate assumption no matter it is public or private. Therefore, the cost efficiency measurement may be a possible way for future research if input factors price information is available. In addition, revenue maximization is also an appropriate behavioral assumption for rail industry. Corresponding to effectiveness, the allocative efficiency in consumption mix selection thus could be accounted for in the future research if price information of unit consumption is available. Furthermore, combining cost minimization and revenue maximization implies profit maximization. However, very little attentions have been paid on profit efficiency by using DEA method in previous studies, especially with consideration of environmental factors, statistical noises, and residual slacks in profit efficiency measurement. This could be a possible extension of future research.

4. Measure efficiency and/or effectiveness by considering congestion.

Throughout this research, both the efficiency and the effectiveness measurements have been ignored in evaluating the effects of congestion. That is, this research implicitly assumes strong disposability in inputs and outputs, or in other words, the research assumes that a firm can always freely dispose unwanted inputs and outputs. In many cases, however, the excess input factors use may due to constraints, which are not under control of the manager of DMUs. For instance, a reduction in employee may be prevented by labor unions, or some inputs are controlled by government. For transport industries, some externalities such as air pollution, noise, and accident may be defined as unwanted outputs, which were produced accompany with desirable outputs. In literature, input congestion was defined as: whenever increasing one or more inputs decreases some outputs without improving other inputs or outputs, or conversely, whenever decreasing some inputs increases some outputs without worsening other inputs or outputs (Cooper *et al.* (2001)). It is of interest to measure efficiency and effectiveness when congestion is present. Therefore, one possible avenue of future research could be to measure performance of rail transport by considering effects of input congestion, such as labor, and output congestion, such as accident.

5. Relax some assumptions.

In this research, passenger train kilometer and freight train kilometer were selected as two outputs, which implies that, take passenger service as an example, both the average number of cars per train and the average number of seats per car are same in different company and different train set, respectively. This may be a strong assumption and in fact is not the case. The reason for making this assumption is due to the data not available. Therefore, in order to measure the performance more precisely, it is more rational to select seat kilometer as a passenger service output in the future research if the data difficulties can be overcame.

6. Compared with parametric distance function method.

Efficiency and Malmquist productivity indexes are generally estimated using non-parametric frontier approaches. In fact, it can also be estimated by using parametric stochastic frontier approaches. However, little attentions have been paid on parametric methods in the previous studies, especially for productivity measurement. This is partly because the parametric Malmquist productivity indexes cannot be decomposed into changes in efficiency and changes in technology. Recently, it was shown that a Malmquist productivity index could be estimated and decomposed in the same manner as in Färe *et al*. (1994) using distance function ratios. It is of interest to compare results estimated based on DEA non-parametric technique with those from parametric frontier method. In addition, since the sales force index is different from productivity index, especially for transport industries, therefore, measuring both productivity and sales force growth by using parametric distance function method could be another possible extension in the future research.