CHAPTER 1. INTRODUCTION

1.1 The Problem and Its Significance

Rail transport has long played an important role in economic development for a country. However, 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. Take China Railway (CR) as an example, the market share (ton-km) of CR freight has declined from 40.53 percent by 1990 to 32.54 percent in 1998 (Xie, *et al.*, 2002). Same situation has been occurred in Europe, as shown in Table 1-1, rail's share of the EU freight market declined from 32 percent in 1970 to 12 percent by 1999 (Lewis, *et al.*, 2001).

Table 1-1 Freight European Union Modal Split (%, ton-km)

Year	Rail	Truck	Waterways	Pipilines
1970	31.7	48.6	12.3	7.4
1980	24.9	57.4	9.8	7.9
1990	18.9	67.5	8.3	5.3
1994	14.9	71.3	7.7	5.6
1999	12.0	73.0	N/A	N/A

Source: Lewis *et al.* (2001)

One may argue that continuing growth in car ownership, road construction, and air traffic have provided competition on some of the longer trips, demand for rail services has consequently fallen in relative percentage. However, the major reason for the decline situation can be attributed mostly to inefficiency. As Fleming (1999) pointed out, truckers can deliver furniture from Lyon, France to Milan, Italy in eight hours, while railways need forty-eight hours. Therefore, enhancing the technical efficiency and service effectiveness, as well as productivity and sales force has become an important issue for this industry to remain competitive and sustainable under such a decline situation. To do so, one must identify and estimate the indexes of efficiency, effectiveness, productivity, and sales force, investigate the sources of poor performance, and propose guidance to direct the poorly performed rail systems toward a more healthy way.

The problem thus is how to measure the performance for rail system. As we all know that rail transport sector is a long-recognized element of the service economy. Is it suitable if one measure the performance of railways in the same manner as the common manufactory sector? For ordinary commodities, measures of technical efficiency (a transform of outputs from inputs) and technical effectiveness (a transform of consumptions from inputs) are essentially the same because the commodities, once produced, can be stockpiled for consumption. Nothing will be lost throughout the transformation from outputs to consumptions if one assumes that all the stockpiles are eventually sold out. For non-storable commodities, however, technical efficiency and technical effectiveness very often represent two distinct measurements. When the commodities are produced and a portion of them are not sold or consumed right away, the technical effectiveness, which considers the combined effect of both technical efficiency and sale effectiveness, would be less than the technical efficiency. In other words, evaluation of technical efficiency or technical effectiveness using a one-stage process for ordinary commodities cannot be directly applied to non-storable commodities. Furthermore, in the general management textbook, efficiency and effectiveness are two different criteria. Efficiency criterion seeks to achieve "more-for-less," that is, more ourputs and less inputs, while effectiveness criterion is determined by the distance between observed outputs and a set of desire goals. The goals, in a company, can always been defined as how many goods or serviecs have been sold. Therefore, for rail transport industry, due to services are perishable, the measurement of efficiency and effectiveness separately is not a trivial task.

Due to the decline situation, not only efficiency and effectiveness, but also productivity growth of rail industry becomes an important issue in resent years. Although many consider productivity and efficiency as synonymous, in fact, the two criteria are different. Figure 1-1 illustrates the distinction between technical efficiency and productivity. In this figure, the curve *f(x)* represents the technology or the production frontier, the slopes

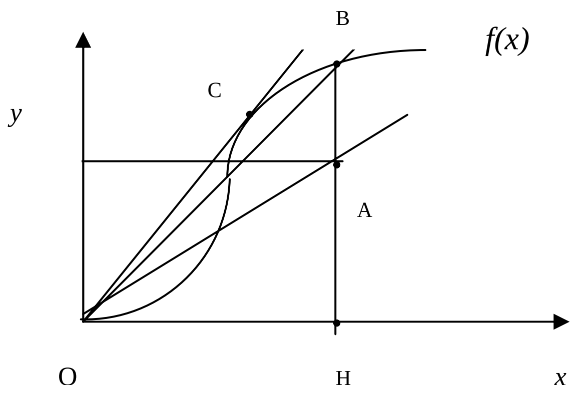

Fig. 1-1 Productivity and Technical Efficiency

of ray OA, OB, OC, provide the measures of prodictivity of A, B, C, respectively. The output-oriented efficiency is defined as the ratio of observed output to maximum feasible output. In figure 1-1, obviously, the efficiency of firm A is AH/BH, and which is technically inefficient. If the firm A were to move to point B, which is technically efficient, the slope of the ray would be greater, implying higher productivity at point B. However, comparing with firm B, the slope of the ray OC would be even greater, implying that firm C is the maximum possible productivity though both firm B and frim C are technically efficient. In other words, firm C is the point of optimal scale, operation at any other point on the production frontier results in lower productivity (Coelli *et al*. 1998).

Because the productivity and efficiency are different criterion, therefore, in addition to the efficiency and effectiveness evaluation, measuring productivity is essentially needed for estimating performance of the firms. The other reason for productivity measurement is that it can be decomposed into two components, technical change (TC) and efficiency change (EC), from the measurement and decomposition, one can easily distinguish the productivity growth (or regress) of a firm due to TC or EC and thus can give the strategies in the right way.

Similar to aforementioned efficiency and effectiveness measurement, the productivity index and sales force index are different criterion. The former defines the force of production, while the later defines the force of sale. In order to find out the determinants of decline situation, this research measures the performance by adopting four indexes, technical efficiency, service effectiveness, productivity index, and sales force index, for the railway systems.

1.2 Motivation and Purposes for the Research

To evaluate the performance of transportation firms or industry, Fielding *et al*. (1985) introduced a conceptual framework, in which they proposed to measure cost-efficiency, service-effectiveness and cost-effectiveness by indexing the ratios of appropriate factors drawn from output/input, consumption/output and consumption/input, respectively. However, previous studies related to railway performance evaluation mainly focused on the cost efficiency (in fact, if the price information is unavailable, it is appropriate to call technical efficiency, rather than cost efficiency) and cost effectiveness. Little has been devoted to service effectiveness. On the other hand, yet some papers analyzed the productivity of railways, none of them paid attention to sales force measurement. The shortcomings in the previous studies can be summarized as follows:

1. When measuring performance, the previous studies do not take the non-storable characteristics of transportation industry into account, they usually measured only technical efficiency and/or productivity, quite few attentions have been paid to effectiveness or sales force analysis.
2. Improperly choose the outputs and input factors, as aforementioned, consumption is different from outputs in transportation industries. However, instead of output data,

previous studies usually selected consumption data as outputs when measuring technical efficiency.

3. When measuring the efficiency, though some researchers have considered slacks, unfortunely, there is no guarantee that such considerations can always completely eliminate the slacks.
4. When estimating the productivity, previous studies did not take environmental factors, statistical noise, and slacks into account.
5. The previous studies paid attention only to productivity measurement; none has devoted to the analysis of sales force.

This research attempts to estimate technical efficiency, service effectiveness, productivity and sales force for some selected worldwide rail systems (called decision making units; DMUs) by employing data envelopment analysis (DEA) and stochastic frontier analysis (SFA). Extending the Fried's *et al*. (2002) three-stage measurement procedure, a four-stage analysis is proposed and then applied to railways performance evaluation. In the efficiency measurement, this research uses input-orientation DEA models (measuring the maximum possible proportional reduction in all inputs, keeping all outputs fixed) by selecting number of employees per kilometer of lines, number of passenger cars per kilometer of lines, and number of freight cars per kilometer of lines as inputs, and passenger train-kilometer per kilometer of lines, and freight train-kilometer per kilometer of lines as outputs. The research also measures effectiveness by adopting output-orientation DEA models (measuring the maximum possible proportional expansion in all outputs while all inputs remaining unchanged) and selecting passenger train-kilometer and freight train-kilometer as inputs and passenger-kilometer and ton-kilometer as outputs. The more detail analytical framework can be found in chapter three.

In general, based on the aforementioned, the purposes of this research are:

1. to measure the efficiency and effectiveness for some selected railways;
2. to test the returns to scale, that is, which is more suitable for railway industry between CRS and VRS;
3. to find out the environmental factors which influence the efficiency and effectiveness of railways;
4. to find out the determinants which affect the amount of slacks;
5. to re-measure the efficiency and effectiveness by considering environmental factors, statistical noise, and slacks;
6. to measure the productivity and sales force;
7. to find out the determinants of productivity and sales force growth (or regress);
8. to re-measure the productivity and sales force with consideration of

environmental factors, statistical noise, and slacks.

1.3 Methodology

In the modern neoclassical production economics, the possibility that producers might operate inefficiently is typically ignored. It is assumed that the producer always allocates resources successfully so as to maximize its production and minimize its cost. In practice, however, due to some controllable and uncontrollable factors, the firm usually produce in an inefficient manner. Recently, an increasing number of economists aware that the problem of measuring the productive efficiency of an industry or a firm is important to both theorist and operator. Many measuring methods thus have been developed. Farrell (1957) was the first to develop a method for estimating efficient (rather than average) production function from observed set of input and output data. Inspirated by Koopmans (1951) and Debreu (1951), he also showed how to define cost efficiency and how to decompose it into technical and allocative components. Farrell's (1957) concept eventually influenced the development of Data Envelopment Analysis (DEA); which was firstly introduced by Charnes, Cooper and Rohdes (1978, CCR). They developed a mathematical programming technique for evaluating the performance of dicision making units (DMUs) and coined as DEA. Nowadays, DEA is becoming increasingly widespread in the field of efficiency measurement for three reasons. First, DEA is capable of addressing multiple inputs and multiple outputs problems with minimized restriction. Second, it is a non-parametric approach and therefore does not require any assumptions about the functional form. Third, it does not require the assumption of cost minimization and revenue maximization, and does not require price information. Although DEA was firstly developed for evaluation of Program Follow-Through in U.S. education, at present, it become widely-used for many application fields, including public and private sectors, profit-oriented and non-profit-oriented units, for example, measuring efficiency on banks (Barr *et al.*, 1993; Berg *et al.*, 1993; Sathye, 2003), on education (Grosskopf *et al.*, 1999), on hospital (Chilingerian, 1994; Harris II *et al*. 2000), on farming (Thompson, 1990; Thompson *et al.*, 1994), on police force (Thanassoulis, 1995; Drake and Simper, 2003), on electric utilities (Goto and Tsutsui, 1998; Athanassopoulos et al., 1999), on telecommunications (Sueyoshi, 1997; Sueyoshi, 1998; Athanassopoulos and Giokas, 1998), on Semiconductor companies (Kozmetsky and Yue, 1998), on agriculture cooperatives (Sueyoshi, 1999; Sueyoshi *et al*. 2001). For more details regarding the empirical studies, one can refer to Seiford (1996), who lists over 700 publised journal articles. In measuring efficiency of transportation industries, Førsund and Hernaes (1994) employed the DEA method to analyze the efficiency of ferry transport in Norway.

Parker (1999) adopted the DEA to measure the performance of British Airport Authority before and after privatization. Chapin and Schmidt (1999) used the DEA approach to measure the efficiency of US Class I railroad companies. Cowie (1999) also applied the DEA method to compare the efficiency of Swiss public and private railways. Lan and Lin (2003) further compared the difference of technical efficiency and service effectiveness for 76 worldwide railway systems.

The other branch of frontier method, Stochastic Frontier Analysis (SFA), is a parametric approach and is also the exertion of Farrell's (1957) work. The methods developed by Aigner and Chu (1968), Afriat (1972) and Richmond (1974) directly contribute to the development of SFA, though their's models were attributed to deterministic production frontier. SFA was originally developed by Aigner, Lovell and Schmidt (ALS, 1977), and Meeusen and van den Broeck (MB, 1977) almost simultaneously. Both of which were developed in a production frontier context and shared the composed error structure. The first error term is designed to capture the effects of statistical noise and the second error term is intended to capture the effects of technical inefficiency. After the SFA was proposed, however, it is not possible to estimate individual technical inefficiency until Jondrow *et al*. (1982), who proposed the method to estimate the technical inefficiency of each producer in the sample. Though early developed SFA was based on production context, it can be easily convert to a cost frontier model by changing the sign of inefficinecy error term u_i from minus to plus. Since the initial studies by ALS (1977) and MB (1977), the use of SFA is becoming increasingly widespread for a variety of empirical studies. Many articles have appeared in the literature. For example, Mester (1993, 1997) adopted stochastic cost frontier approach to investigate efficiency on U.S. savings and loan industry (1993) and on U.S. banks (1997). Sueyoshi (1994) applied stochastic frontier production model to measure performance of public telecommunications in 24 OECD countries. Ahmad and Bravo-Ureta (1996) measured technical efficiency for dairy farms by using stochastic production frontier method. Resti (1997) evaluated the cost-efficiency of Italian banking system by using parametric and non-parametric techniques. DeYoung and Hasan (1998) used a econometric profit frontier to measure the performance of commercial banks. In the application in transport industries, Liu (1995) applied the translog production frontier to compare the performance of public and private British port. McMullen and Lee (1999) adopted SFA to compare the cost efficiencies in the US motor carrier industry before and after deregulation. Cantos and Maudos (2000) estimated productivity, efficiency and technical change for 15 European railways by using the SFA approach. Cantos and Maudos (2001) also employed SFA to estimate both cost efficiency and revenue efficiency for 16 European railways. Lan and Lin (2002) compared the efficiency of 85 selected railways by using both DEA and SFA.

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 the residual slacks. In this paper, we thus combine 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 will incorporate the environmental effects, statistical noise as well as the adjustments of input excesses and output slacks into the efficiency and effectiveness measurement.

Similar to efficiency measurement, there are two shortcomings in the conventional productivity measurement model. First, the Malmquist productivity index is based on the ratios of Farrell's (1957) radial efficiency scores. When measuring radial efficiency, however, the full magnitude of inefficiency and ineffectiveness are not revealed if slacks were neglected. Another shortcoming is that such measurement does not take the environmental effects and statistical noises into account. Thus, in contrast to previous studies, the contribution of this research is to propose the method which incorporates environmental factors and statistical noise, as well as slacks into the productivity measurement and further extends to sales force measurement model.

1.4 Organization of the Research

This research is composed of seven chapters. Chapter one describes the research motivation and purposes. Two principle methods, DEA and SFA, adopted in this research have been briftly described. Chapter two reviews the previous studies on efficiency and productivity measurement. Basically, there are two categories: frontier methods and non-frontier methods in the literatures. Each of them can be further classified into parameter and non-parameter sub-categories. Some theoretical studies of four methods and empirical applications in transport industries, especially in rail industry are briefly summarized and critiqued.

Chapter three describes the methodologies and a framework for this research, including Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA). Both of them are described in detail. This research proposed a four-stage DEA model, which incorporates the environmental factors, statistical noise as well as input excesses and output slacks into the efficiency and effectiveness measurement.

Chapter four deals with the empirical application of the proposed approach on the measurements of efficiency and effectiveness for rail transport industry. The complete panel data set contains 44 railways and covers seven years (1995-2001), so there is a total of 308 observations. The results estimated from the proposed approach are compared with those from the conventional DEA models, and from the three-stage DEA method. Chapter five presents a case study on productivity index and sales force index measurements for railways with application of both conventional and proposed approaches. The results are indicated and discussed, and some major findings are thus presented.

In chapter six, the performance matrix has been constructed, in which each firm's performance can be properly allocated. Appropriate strategies for enhancing the rail performance in different sub-matrixes are then addressed. Some policy implications also presented. The final chapter summarizes the general findings in this research and proposes possible extentions for future research.