

## **Benchmarking the Operational Excellence of Dangerous Goods Transporters**

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### **Abstract**

Dangerous goods transportation sector in Turkey is not fully homogenous. While companies providing dangerous goods transportation to and from Europe already comply with The European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR) regulations, domestic companies which are mostly smaller in size do not hold any extended safety certification for management of their operations. In an effort to develop an economic trade off analysis to identify the possible benefits and drawbacks of ADR integration of Turkey and help dangerous goods transporters enhance productivity and operational efficiency, this study aims to examine the operational performance of a number of dangerous goods transportation companies in order to determine the relationships between ADR certification practices and firm performance. Using the examples of major dangerous goods transporters in Turkey, we use Data Envelopment Analysis (DEA) for measuring the operational and financial excellence of third party logistics service. The proposed DEA model not only helps dangerous goods transporters identify potential sources of inefficiency and provide useful benchmarks for the improvement of operational efficiency, but also provides an insight on the effects of quality and ADR certification on the operational excellence of companies providing dangerous goods transportation.

*Keywords:* Dangerous Goods Transportation, Data Envelopment Analysis, Certification.

### **1. Introduction**

Transportation of dangerous goods is a profitable business. Today 22 million tones of dangerous goods are transported annually through Turkey on the average, where class 3 represents 90% of the DG transported on Turkish roads [1]. Meanwhile, transport of dangerous goods includes substantial risks besides the opportunities it brings. Monetary and health damage related to accidents occur in transport of dangerous goods is 11% higher than transport of non-dangerous goods. Hence, safety arises as the first concern in all activities related to the transport of dangerous good. However it is important that the transport of dangerous goods continues to be a viable business sector such that transportation of dangerous goods keeps on being profitable and logistically effective business.

Transportation of dangerous goods is regulated to minimize the damage on persons, property or the environment. For road transport in Europe, the legal framework defined in the "The European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR)" is relevant. ADR has been revised and put into force in 2009 which governs the conditions for the international transport of dangerous goods within the 33 European ADR countries. It has been drawn up to improve safety in international road transport and to replace

the variety of national and local regulations in Europe, which are applicable to the international transport of dangerous goods, by a set of jointly-agreed conditions under which the international transport of dangerous goods is authorized within the borders of all ADR countries. These conditions have been drawn up to take into account all safety parameters (such as temperature, climate, topography, population density) involved in the national regulations to be replaced. It includes rigid safety standards for vehicles, safety training, and driver training for hazardous materials transporters.

Dangerous goods transportation sector in Turkey is not fully homogenous. While companies providing dangerous goods transportation to and from Europe already comply with The European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR) regulations, domestic companies which are mostly smaller in size do not hold any extended safety certification for management of their operations. Certification itself is a costly process but a company may enjoy many operational benefits from certification. Since certification requires a structured and documented system, good documentation can create more effective work instructions and control all aspects of the operational process, which leads to reduced costs and better control of operations [2]. Adopting a certification system may help companies to achieve enhanced employee productivity, systematization with good documents and data, better quality control, improved internal auditing, and clear managerial responsibility [3]. In the short term at least, it gives companies a competitive edge because of the positive impact the quality assurance system has on product/service quality, cost savings, reduced manufacturing lead time, access to markets, and overall efficiency of operations [4].

In an effort to develop an economic trade off analysis to identify the possible benefits and drawbacks of ADR integration of Turkey and help dangerous goods transporters enhance productivity and operational efficiency, this study aims to examine the operational performance of a number of dangerous goods transportation companies in order to determine the relationships between quality and ADR certification practices and operational performance. In setting the benchmark, we measure the operational efficiency of dangerous goods transporters by input/output ratios which can reflect the operational productivity of transportation companies. As a way of comparatively assessing the productivity of transportation firms with multiple inputs and outputs, we use a data envelopment analysis (DEA) which was successfully explored in measuring the operational efficiency in various sectors such as banks [5], hospitals [6], nursing homes [7], purchasing departments [8], cellular manufacturing [9], tourism [10], information technology investments [11], less-than-truckload (LTL) motor carriers [12] and international ports [13]. We then employ statistical analysis to investigate the relationship between efficiency scores and firms' certification status.

## **2. Method**

DEA is a non-parametric technique for measuring relative efficiency among similar organizations by evaluating the maximum potential output for a given set of inputs. DEA is a useful tool for benchmarking by identifying relatively efficient companies among a group of given firms by easily accommodating both multiple inputs and multiple outputs without prior aggregation. DEA is a special application of linear programming (LP) based on the frontier methodology of Farrell [14], advanced by Charnes *et al.* [15]. There are numerous variations of DEA models for different analyses since then. A general description of the model may be found in several studies ([16] and [17]), and a detailed explanation is given in [18] and [19].

## 2.1. The model input and output measures

The assessment of operational efficiency using DEA begins with the selection of appropriate input and output measures that can be aggregated into a composite index of overall performance standards. Although any resources used by DMU should be included as input, and operating expenses can be considered as the major input for a performance evaluation system, lack of cost data due to confidentiality issues prevent us to include it in the analysis. Considering the labor intensive nature of logistics industry we selected four different metrics as inputs mainly due to data availability. These are number of employees, number of drivers, and number of vehicles separated as number of trucks and tanks/containers. Number of employees consists of managers, dispatchers, order pickers, and cargo handlers, among others, on either a part-time or full-time basis.

Number of vehicles is viewed as a resource for dangerous goods transporters, because the utilization of a transporter's capacity can increase the efficiency in filling the needs of their customers. On the output side, the overall performance of a transportation company is measured by operating income that best reflects the operational efficiency. Other well-known financial ratios such as profit margin and return-on investment were not considered relevant, because a less profitable firm may be more efficient in utilizing its personnel and equipment than the more profitable firm. For example, a favorable change in fuel price and tax rate can increase profitability, but not necessarily the operational efficiency. In fact, profit measure is not considered as a good indicator of how efficiently resources were used to provide customer services [20].

## 2.2. Data Collection

Data is obtained from a survey conducted by International Transporters Association (UND) over road transportation companies operating in Turkey and EU. Web based questionnaires are filled out by a group of undergraduate students during visits to companies taking part in the survey. Target respondents were general managers or logistics managers of the companies. Interviews are targeted to cover the complete list of companies registered under UND. Out of a total of 386 questionnaires returned, 115 belong to companies providing dangerous goods transportation services. 43 of collected questionnaires are not usable because of missing or inconsistent data and incompleteness. The profiles of the remaining 71 respondent companies and their characteristics are displayed in Table 1.

Revenue (TRY)	Number	%	Number of employees	Number	%
< 2.5 M	24	34%	< 50	59	83%
2.5-5 M	19	27%	50-100	7	10%
5-7.5 M	12	17%	100-150	2	3%
7.5-10 M	5	7%	150-200	0	0%
10-12.5 M	3	4%	200-250	0	0%
12.5-15 M	1	1%	> 250	3	4%
>15 M	7	10%	Number of drivers	Number	%
Vehicles	Number	%	< 50	61	86%
< 100	60	85%	50-100	5	7%
100-200	6	8%	100-150	3	4%
200-300	4	6%	150-200	2	3%
300-400	1	1%	> 200	0	0%

Table 1-Profile of the respondent companies (n =71)

### 2.3. Analysis

DEA provides an evaluation of operational efficiency either input or output oriented. With input-oriented DEA, the linear programming model is configured so as to determine how much the input use could be contracted if used efficiently in order to achieve the same output level. Alternatively, the purpose of an output model is to evaluate by how much output quantity can be increased without changing the input quantities. We employ input oriented CCR-DEA model to evaluate the relative efficiency of different logistics companies. CCR-DEA model employs a set of normalizing constraints that reflects the condition that the virtual output to virtual input ratio of every company must be less than or equal to unity. The mathematical programming problem may thus be stated as:

$$\begin{aligned}
 & \text{Max } \theta_0 = \sum_r u_r y_{r0} \\
 & \text{s.t.} \\
 & \sum_i v_i x_{i0} = 1 \\
 & \sum_r u_r y_{rj} - \sum_i v_i x_{ij} \leq 0 \quad \forall j \\
 & u_r, v_i \geq 0 \quad \forall i, r
 \end{aligned} \tag{1}$$

We identify annual operating income as the primary output and four different inputs, as number of employees, number of drivers, and number of trucks and trailer/tanks to assess efficiency regarding performance measures that could be interpreted as inputs of main logistics operations.

### 3. Findings

As indicated earlier, in the first stage we analyze the relative efficiencies of the 71 companies by data envelopment analysis. The average efficiency score of the companies providing dangerous goods transportation is calculated around 46.2% with the standard deviation of 0.26. The minimum efficiency score was found around 2%. Among 71 companies, six were found relatively efficient with efficiency score of 1. The efficient units have also zero slacks for each input and output in the model. In the solution of the model, two companies have the efficiency score of greater than 90% while six companies have the scores of varying between 65% and 80%. The remaining 77.5 % companies were found to have efficiency measures smaller than 60%. Some of the inefficient units have positive slacks for one or more than one inputs.

As DEA methodology provides the targets for the each inefficient unit to render an efficient one, it can be suggested to the companies target values for the inputs they used and/or target values for the output they achieved. For illustration, Table 2 indicates how Company 42 could render efficiency. This table presents the actual the inputs and the output used in the analysis for measuring the operational efficiency of Company 42 as well as the target levels for each input and the output, calculated based on the reference sets of the company. The last column presents the rate of possible reduction in input levels and the rate of possible increase in the output level. In other words, if the number of employees, drivers, towing vehicle and trailer would be reduced by 21.3%, 21.3%, 54.7% and 27.9%, respectively while input was kept at the original level for Company 42 to be fully efficient.

Input (I) / Output (O)	Current Level	Target level	Difference	Change (%)
Number of employees (I <sub>1</sub> )	12	9.45	2.55	21.3
Number of drivers (I <sub>2</sub> )	10	7.87	2.13	21.3
Number of towing vehicle (I <sub>3</sub> )	15	6.8	8.2	54.7
Number of trailer (I <sub>4</sub> )	22	15.85	6.15	27.9
Annual income (O)	3502648	3502648	0	0

*Table 2. Targets for Company 42 for rendering to be efficient*

To determine the impact of the certification on the overall performance of the third party logistic firms, the companies are classified in two groups: the one holding a quality certificate (Group 1) and the one not having any quality certification (Group 2). The statistics have shown that only 11.3% of the companies have the quality certificate. Then, t-test is conducted on the efficiency scores to reveal the differences between the companies classified with regard to the availability of the certificate. As illustrated in Table 3, the results of the t –test revealed that the mean score for the companies having the certificate is higher than the score for the ones without certificate. There is a statistically highly significant difference between the two groups.

	N	Mean	S.D.
Group 1	8	0.71	0.26
Group 2	63	0.43	0.25
t: 2.987; p: 0.004			

*Table 3. Mean comparison in efficiency with regard to quality certificate*

On the other hand, in order to analyze the effect of ADR certification on companies' efficiencies, sample set has been classified into three groups. First group includes the companies with 51% to 100% of the drivers having ADR certification (Group A). Second group is constituted by companies with a driver ADR certification rate of 0.5 or less (Group B). Companies not employing any driver with ADR certification are classified in last group (Group C). Group A constitutes 12.7% of the all companies, where 45.1% of companies are included in Group B. On the other hand, 42.3% the companies analyzed in the study have no ADR certified drivers. We conduct one way analysis of variance test to compare the efficiencies of three groups for determining whether they differ significantly. Table 4 illustrates the mean comparison across the companies with regard to ADR certification. The analysis shows that there is not a statistically significant mean difference in operational efficiency among the groups at 5 percent significance level.

	N	Mean	S.D.
Group A	9	0.605	0.235
Group B	32	0.413	0.247
Group C	30	0.471	0.277
F: 1.970; p: 0.147			

Table 4. Mean comparison in efficiency with regard to ADR certificate

## 5. Conclusions

In this paper, we use data envelopment analysis (DEA) to evaluate operational efficiencies of a set of 71 dangerous goods transporters and investigate the impact of quality and ADR certification on operational efficiency. We found that even though there is a remarkable difference in operation efficiency scores between companies which hold a quality certificate and the one that do not, we haven't observed any significant correlation, either positive or negative, between operational efficiency and ADR certification.

The proposed DEA model not only helps dangerous goods transporters identify potential sources of inefficiency and provide useful benchmarks for the improvement of operational efficiency, but also provides an insight on the effects of quality and ADR certification on the operational excellence of companies providing dangerous goods transportation.

This study suffers from several limitations. First, measures used as inputs and outputs in the study can be extended to cover operational expenditures, quality indicators and capacity utilization rates for a more comprehensive analysis. Second, the sample of respondents is only gathered from companies located in a relatively small geographic region. Even though most transportation companies in Turkey are clustered in selected region, the study results could be different if the data collected other regions. In order to provide more insights with respect to the findings of this study, further qualitative research might be done to investigate and contrast the operational differences in organizations.

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